ADVERTISED PLAN

Barwon Water Regional Renewable Organics Network

Air Human Health Risk Assessment

Barwon Water

01 November 2024

→ The Power of Commitment

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The Power of Commitment

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1. Introduction

1.1 Background

Barwon Water (BW) has engaged GHD Pty Ltd to prepare a Development Licence Application (DLA) for its proposed Regional Renewable Organics Network (RRON). This Air Human Health Risk Assessment (HHRA) has been prepared to support the DLA.

The RRON will be located at BW's Black Rock Water Reclamation Plant (WRP) located at 405 Blackrock Road, Connewarre, approximately 18 km south of Geelong. The Black Rock WRP is an established organic waste recycling facility that treats wastewater and produces Class A and Class C recycled water, as well as processing approximately 60,000 t/y of biosolids.

The RRON facility is proposed to process approximately 40,000 t/y of comingled food organics and garden organic (FOGO) waste predominately from local Municipalities. This FOGO stream will be pre-processed and separated into a food organics (FO) rich stream and a garden organics (GO) rich stream. The facility will also process other feedstocks including bulk green waste (~9,000 t/y), commercial and industrial (C&I) organic waste (~2,000 t/y), and biosolids (from BW's WRPs). The main processes proposed for the RRON include:

– Thermal processing via carbonisation of the GO-rich stream (separated from FOGO), bulk green waste and biosolids
– Plug flow anaerobic digestion (PFAD) of the FO-rich stream (separated from FOGO) and FO-rich C&I organic waste

The RRON will produce the following product streams:

– Biochar (from carbonisation), a high-value product for agriculture and production of advanced sustainable materials
– Syngas (from carbonisation), which will be used within the RRON facility to dry the carbonisation feedstocks down to a suitable moisture content for carbonisation
– Digestate (from the PFAD), a product containing high levels of nutrients, which is beneficial in agricultural applications
– Biogas (from the PFAD), which will be transferred to the neighbouring biosolids drying facility and converted into heat via a biogas boiler, reducing the demand for natural gas

Further information on the environmental setting of the RRON facility and a detailed process description are provided in the DLA report. This report should be read in conjunction with the DLA report.

1.2 Purpose of this report

The purpose of this report is to undertake a quantitative air human health risk assessment in preparation of a development licence application, to assess the impact of the proposed RRON on sensitive receptors surrounding the site.

This report should be read in conjunction with the Air Quality Assessment report.

1.3 Limitations

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

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

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

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

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

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

GHD has prepared the exposure model ("Model") for, and for the benefit and sole use of, Barwon Water to support this health risk assessment and must not be used for any other purpose or by any other person.

The Model is a representation only and does not reflect reality in every aspect. The Model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Model. Accordingly, the outputs of the Model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of the Barwon Water, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

1.4 Assumptions

– All air quality emission concentrations and flow rates have been provided to GHD from Barwon Water, Hitachi Zosen Inova (HZI) Australia and Mavitec Environmental (Mavitec) and are assumed to be representative of the proposed process on site
– All information pertaining to emission controls such as any ventilation/extraction system to be installed at the site (such as location, height of stacks/vents, diameter of stack and exit velocity) was provided to GHD by Barwon Water, HZI and Mavitec and is assumed to be representative of the proposed site
– The information obtained from client and third parties is correct and free from error or omission
– Emissions are assumed to occur at the maximum rate identified, 24 hours per day, every day of the year
– Uncertainties in published emission factors used to estimate the RRON emissions. The air pollutant emission factors may be influenced by site specific and temporal factors such as equipment selection, and local meteorological conditions. The published factors currently represent the best available estimates of emissions in Australia and may or may not provide an accurate estimate of the RRON emissions. The modelling assessment assumes referenced values from BW, HZI and Mavitec are applicable for the RRON site.
– Computational dispersion modelling uses current knowledge of meteorological and atmospheric processes approximated by mathematical equations to represent these complex processes, which can then be predicted with minimal computational resources. This simplification comes at the expense of the accuracy of model predictions. To address these shortcomings, dispersion models tend to provide conservative estimates of pollutant concentrations.
– Health risk estimates resulting from emissions from the proposed facility have been based on the assumption that surrounding properties with sensitive receptors do not contain existing contamination from other sources. No sampling of soil and/or water for analytes have been undertaken for surrounding properties

1.5 Risk assessment framework and methodology

The HHRA has been prepared with reference to the following guidance:

– enHealth (2012a) Australian exposure factor guidance
– enHealth (2012b) Environmental health risk assessment: guidelines for assessing human health risks from environmental hazards

– National Environmental Protection Council (NEPC, 2016) National Environment Protection (Ambient Air Quality) Measure (the “Air Quality NEPM’)
– NEPC (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure (the “ASC NEPM’)
– NEPC (2011) National Environmental Protection (Air Toxics) Measure
– NSW Environment Protection Authority (NSW EPA, 2016) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (the ‘Approved Methods’)
– Heads of EPA Australia and New Zealand (2021) PFAS National Environmental Management Plan, Version 2.0
– OEHHA. (2015). Air Toxics Hot Spots Program, Risk Assessment Guidelines, Guidance Manual for Preparation of Health Risk Assessments. Air, Community, and Environmental Research Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency

HHRA is the process of estimating the potential impact of a chemical hazard on a specified human population, under a specific set of conditions. HHRA are typically intended to provide risk managers, policy makers and regulators with the information necessary to make decisions surrounding the management of these hazards (enHealth, 2012b).

Fundamental to the HHRA process is the development of a Conceptual Site Model (CSM), which is a description of the plausible mechanisms (‘pathways’), by which people (‘receptors’) may be exposed to chemicals in the environment (‘sources’). Potential risks to human health cannot occur unless there is a complete Source-Pathway-Receptor (SPR) linkage associated with a source of contamination. Conversely, complete SPR linkages do not by default, indicate a receptor will be at risk; the risk assessment process is used to evaluate the extent of the potential risks.

The key steps in the enHealth (2012b) HHRA process are outlined in Figure 1 below and can be summarised as follows:

– **Issues identification**: establishes the objectives of and drivers for the HHRA and establishes a preliminary CSM. The issues identification process for this HHRA is outlined in sections 1 to 4, including descriptions of the Proposal operation and surrounding environment in sections 2 and section 3 respectively
– **Hazard assessment**: establishes the relationships between chemical exposure and potential health effects, using published toxicological information, as presented in section 5
– **Exposure assessment**: produces estimates of the chemical exposure that may be experienced by the people in association with emissions to the atmosphere generated by the proposal. This information is presented in section 6
– **Risk characterisation**: combines the results of the toxicity assessment and exposure assessment, to estimate the potential health risks to the human receptors identified in the CSM. This information is presented in section 7
– **Uncertainty and sensitivity assessment**: evaluates the uncertainty associated with the HHRA and sensitivity of the assessment outcomes to the various assumptions and inputs. This information is presented in section 8

The outcomes of the HHRA have been used to define risk mitigation measures, as presented in section 9.

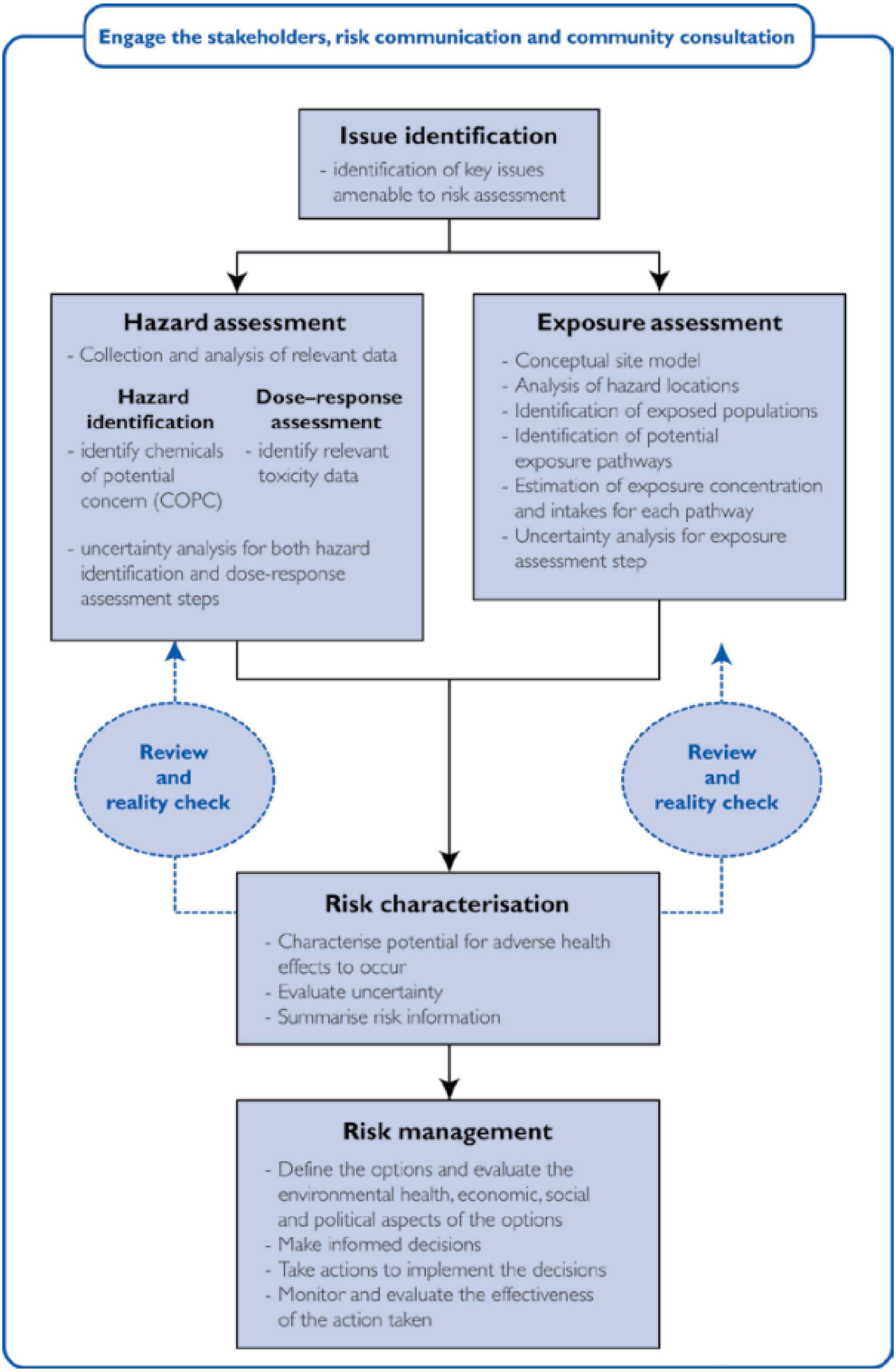


Figure 1 ***Human health risk assessment process (enHealth, 2012b)***

1.6 Abbreviations

Table 1 Project abbreviations

Abbreviation	Definition
AQA	Air Quality Assessment
ABS	Australian Bureau of Statistics
ADI	Acceptable daily intake
APAC	Air quality assessment criteria
AS	Australian Standard
BRWRP	Black Rock Water Reclamation Plant
BW	Barwon Water
C&I	Commercial and Industrial
CHP	Combined Heat and Power
COPC	Contaminants of potential concern
CSM	Conceptual Site Model
ECI	Early Contractor Involvement
DAF	Dermal absorption factor
DLA	Development Licence Application
EPA	Environmental Protection Authority (Victoria)
ERS	Environment Reference Standard
ESD	Emergency Stop Device
FSANZ	Food Standards Australia and New Zealand
FOGO	Food Organics and Garden Organics
GAF	Gastrointestinal absorption factor
GLC	Ground Level Concentration
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HZI	Hitachi Zosen Inova Australia Pty Ltd
IARC	International Agency for Research on Cancer
ILCR	Incremental Lifetime Cancer Risk
IRSD	Index of Relative Socio-economic Disadvantage
LOAEL	Lowest-observed-adverse-effect level
NEMP	National Environment Management Plan
NEPM	National Environment Protection Measure
NOAEL	No-observed-adverse-effect level
PAH	Polynuclear Aromatic Hydrocarbon
PFAD	Plug Flow Anaerobic Digestion
PFAS	Perfluoroalkyl and polyfluoroalkyl substances
PFHxS	Perfluorohexane sulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate

Abbreviation	Definition
POD	Point of departure
PUZ	Public Use Zone
RAAF	Royal Australian Air Force
RRON	Regional Renewable Organics Network
SCADA	Supervisory control and data acquisition
SEIFA	Socio-Economic Indexes for Areas
SPR	Source-Pathway-Receptor
TDI	Tolerable daily intake
TF	Transfer Factor
TRV	Toxicity reference value
TSP	Total suspended particulate
UF	Uncertainty factor
WRP	Water reclamation plant

2. Project description

2.1 Site location

The Black Rock WRP (the Site) is located at 405 Blackrock Road, Connewarre, approximately 18 km south of Geelong CBD. An aerial image of the Site is shown in Figure 2. The proposed RRON will be sited within the boundary of the existing WRP precinct. The overall site layout is displayed in Figure 3.

2.2 Process description

The proposed RRON facility will consist of the following primary process units located across the facility both externally and internally.

- Feedstock pre-processing
- Plug Flow Anaerobic Digester
- Biogas co-generation equipment
- Digestate dewatering and drying
- Carbonisation
- Syngas combustion and associated heat integration equipment
- Ancillary pumps, pipework, and conveyers

Process flow diagrams for the RRON facility are included in Appendix B of the DLA report. A brief summary of each main process unit is included below, and a more detailed process description is included in the DLA report.

2.2.1 Pre-processing

Organic feedstock will be delivered to the site into an unloading area within the main process building. From the feedstock storage area, feedstock will be loaded into the pre-processing equipment which will comprise of contaminant removal & size reduction equipment including picking line/s, shredding, screening, magnetic separation, etc as well as associated transfer equipment (conveyers, pumps, pipes, etc) and interim storages. All of the pre-processing activities are undertaken indoors within the main process building (labelled as “proposed building one” on the site layout). Following pre-processing of the feedstock;

- The FO-rich stream (separated from FOGO) and FO-rich C&I organic waste will be fed to the PFAD train
- The GO-rich stream (separated from FOGO), the bulk green waste and the biosolids will be fed to the carbonisation train

2.2.2 Plug flow anaerobic digestion

The gas-tight horizontally mounted digester is heated and includes internal paddles mounted on a large shaft to facilitate the passing of the feedstock in a plug flow manner through the length of the digester. Organic feedstock is anaerobically digested producing biogas which is collected and extracted from the top of the digester. After a 14 to 21-day residence time, digestate will be discharged from the end of the digester.

2.2.3 Biogas utilisation

Collected biogas is transferred to a biogas storage vessel. From here, the biogas will be utilised by one of the following two approaches and any excess will be flared:

- Transferred to the neighbouring biosolids drying facility and used in a biogas burner for use in biosolids drying (Year 1 – 7). In this instance, a portion of the biogas will be utilised for heating the digester
- Power generation via cogeneration (Years 8 – 25). In this instance, the electricity output of cogeneration will be used at the neighbouring Black Rock WRP, and the heat output will be utilised for heating the digester

2.2.4 Digestate dewatering and drying

A screw press will separate digestate into liquid digestate and a dry fraction. Liquid digestate will be recycled as process water to the head of the PFAD process and any excess will be discharged as wastewater to the neighbouring wastewater treatment plant. Digestate dewatering takes place indoors within a compartment of the main processing building (labelled as “proposed building one” on the site layout).

Dewatered (solid) digestate will be loaded using front end loaders into a digestate drying process, which involves arranging the digestate into windrows on a perforated concrete slab and blowing air through the material to remove moisture. The dried digestate will be around 49% moisture content and will be loaded onto trucks from an enclosed area for offsite reuse.

2.2.5 Carbonisation

The GO-rich stream (separated from FOGO), the bulk green waste and the biosolids will be fed into a multi pass rotary drum dryer’s inlet using a high-speed hot air stream. Hot gasses from the gasifier/oxidiser will directly dry the material as it is tumbled through the drum. A downstream cyclone will separate exiting dry material and moist air. The separated dry material will be transferred as the feed material to the gasifier and the moist air will continue through to the air treatment processes before being discharged.

The gasifier will carbonise the dried material in an oxygen-starved environment, producing a combustible syngas and biochar. The fixed bed gasifier will control inputs and outputs with variable frequency drives. Produced syngas exits towards the oxidiser, where air is introduced to create heat through combustion, from which the hot gases continue to the dryer. The solid products will be collected with a discharge conveyer and transferred to a mixing bin, where temperature and moisture can be adjusted using spray water for quenching. Finished biochar will be bagged at a semi-automatic bag rack. Drying and carbonisation occurs indoors within the carbonisation building (labelled as “proposed building two” on the site layout).

2.2.6 Air treatment

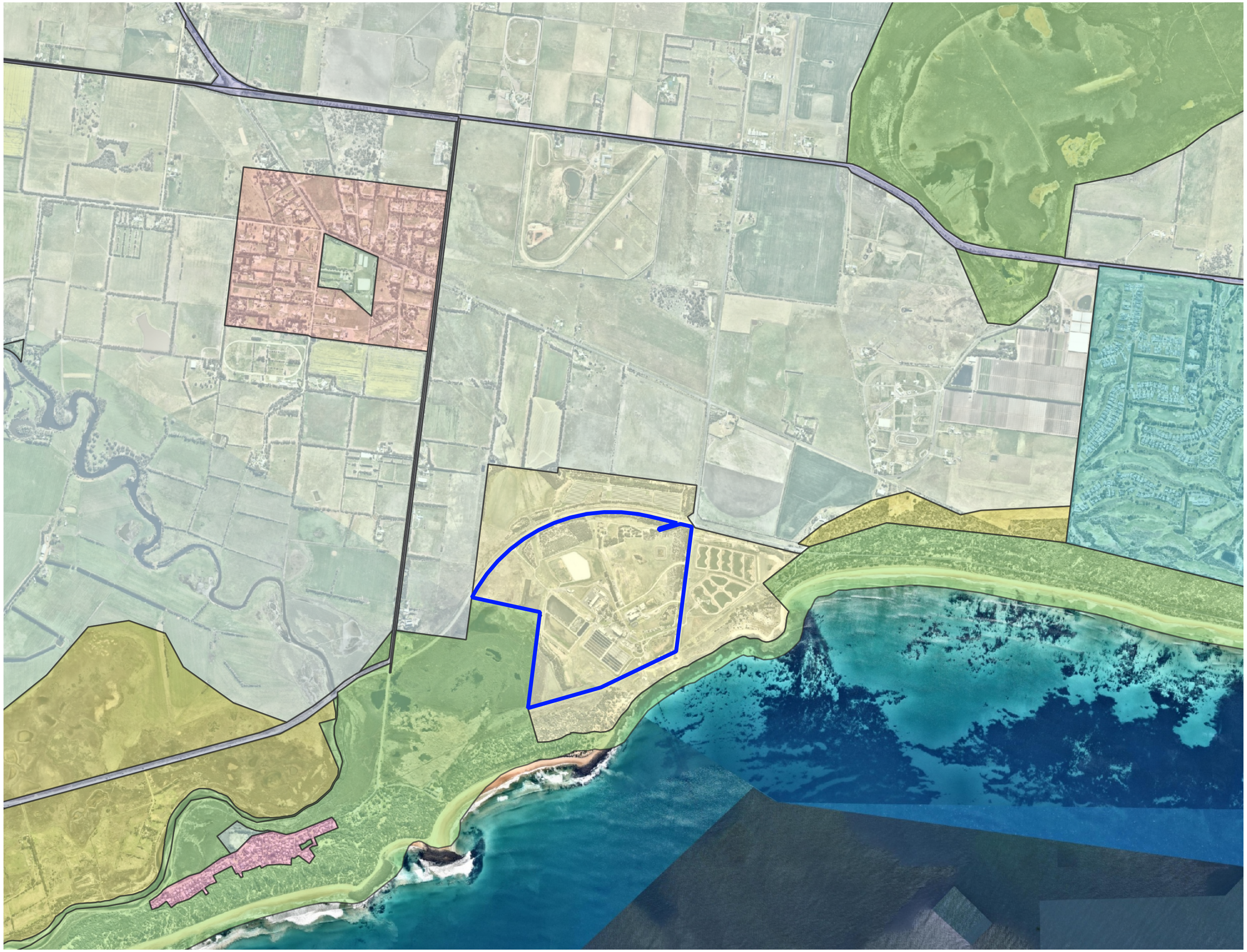
Moist air from the dryer will be transferred to the air pollution control system which includes wet scrubber and a 2-stage chemical scrubber system before being discharged to atmosphere via a biofilter and stack.

2.3 Feedstock

The detailed assessment of feedstock is discussed in the GHD Waste Management Report provided as Appendix K of the DLA report. Table 2 summarises the expected feedstocks to be processed by the RRON facility. Based on upper limit quantity projections for council and C&I waste in Year 8 an annual throughput of around 87,600 t/y is expected for the RRON facility.

Table 2 Summary of expected feedstock quantities

Waste source	Quantity, Year 1 (wet t/y)	Quantity, Year 8 (wet t/y)
FOGO	~40,900	~49,600
C&I waste	~2,000	~2,000
Bulk green waste	~9,000	-
WRP sludge	~10,000	~36,000
Bioprill	~7,900	-
Total	**~69,800**	**~87,600**



Legend

Site Layer

- Site Boundary

Maps

Planning Zone

- COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 1
- COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 2
- FARMING ZONE
- LOW DENSITY RESIDENTIAL ZONE
- LOW DENSITY RESIDENTIAL ZONE - SCHEDULE 1
- PUBLIC CONSERVATION AND RESOURCE ZONE
- PUBLIC PARK AND RECREATION ZONE
- PUBLIC USE ZONE - SERVICE AND UTILITY
- RURAL CONSERVATION ZONE
- RURAL CONSERVATION ZONE - SCHEDULE 10
- RURAL CONSERVATION ZONE - SCHEDULE 4
- SPECIAL USE ZONE - SCHEDULE 3
- TOWNSHIP ZONE
- TRANSPORT ZONE 2 - PRINCIPAL ROAD NETWORK
- TRANSPORT ZONE 3 - SIGNIFICANT MUNICIPAL ROAD
- URBAN GROWTH ZONE - SCHEDULE 2

Paper Size ISO A4

0 0.5 1 km

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 55

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Barwon Water

Barwon Water RRON Functional Design

Site Location

Project No. **12585384**
Revision No. **-**
Date. **21/11/2023**

FIGURE 2

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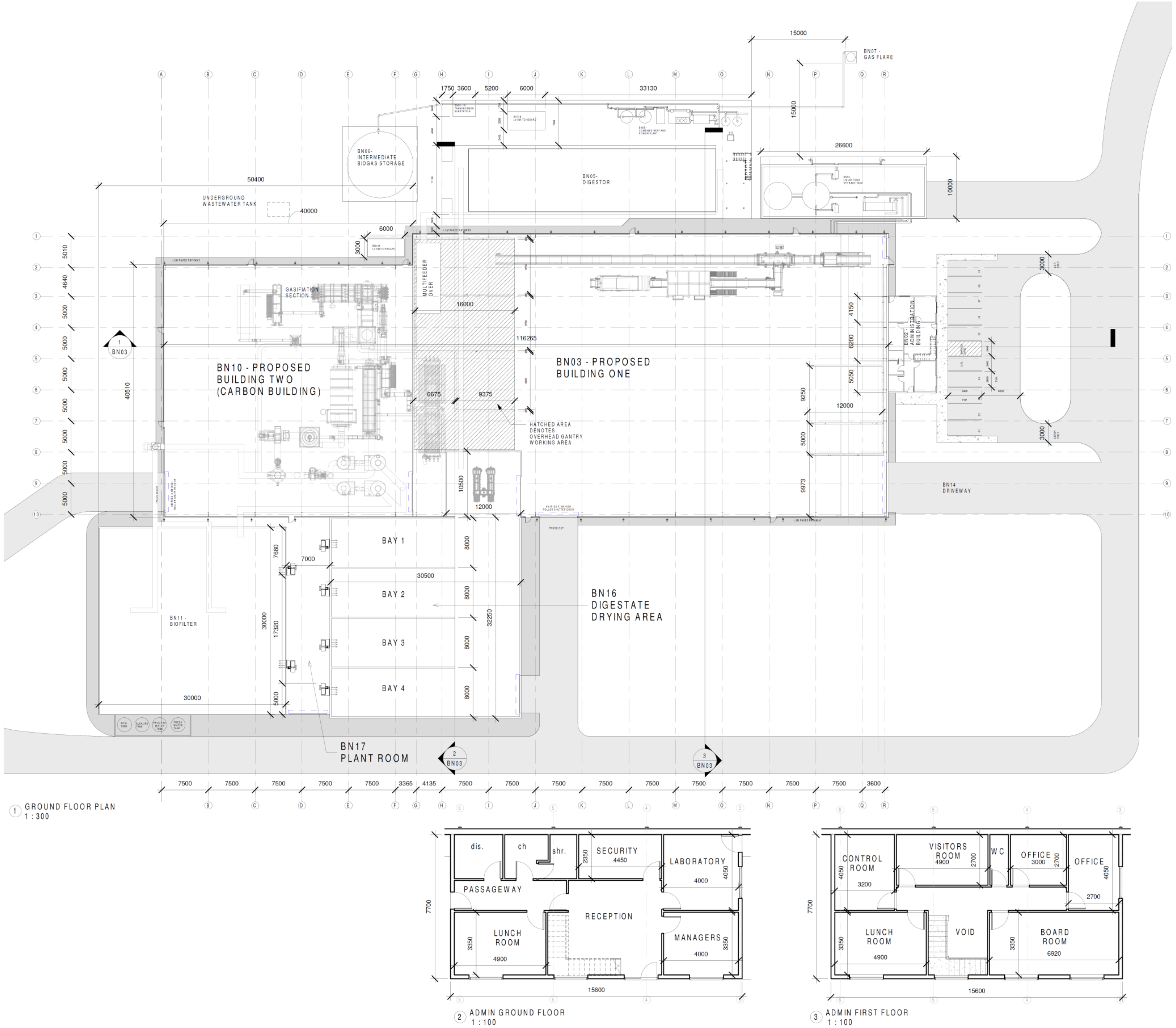
Print Date: 21/11/2023

Data Source:Google Earth Imagery 2023.
Created By: ylim

Bill N of Bill		Element	unit	BN 00
A	ROADS & PAVING			
	A1	Roadworks	m2	
	A2	Geotextile/vapour barrier	m2	
	A3	Curbstones	m1	
	A4	Road gullies and channel gutters	m1	
	A5	Pavements for personnel car parking and pedestrain walks	m2	
	A5	Street lighting	nos	
	A7	Exterior Fire Fighting Main Ring and Hydrants	m1	
B	SOFT LANDSCAPING			
	B1	Landscaping	m3	
	B2	Green areas planting and seeding	m2	
C	FENCING & GATES			
	C1	Fence	m1	
	C2	Gates and barriers	nos	

Notes:

- Applies for layout A
- The detailing and constructing provisions (concrete slab thickness. sand bedding thickness. gravel bed thickness....) must be adapted according to the conditions (soil. climate) and as per Australian standards and regulations.
- This design should be viewed along with the structural engineer specifications prior to construction.
- Water for cleaning hose reel provided by recycle water / rain water tank. - Water for fire fighting hose reel with in the building and fire hydrant provided by the fire water tank network.
- Location of processing equipment is subject to adjustment during detail engineering.



Project-No. BN722100

ProjectName BARWON WATER RRON

Title FLOOR PLAN

Scale As indicated

Status Basic Design

Sheet 1/1

Drawing-NO. BN01

NALG | Hitachi Zosen INOVA

Figure 3 Site layout

3. Receiving environment

This section provides an overview of the area surrounding the Proposal, which plays a critical role in the potential for Project emissions to lead to health impacts, as follows:

– The land use within the area surrounding the proposal will have an influence on the magnitude of the potential impacts and the potential exposure mechanisms;
– The environment of the area surrounding the Proposal, including the climate, terrain and hydrology will have an influence on how pollutants disperse within an environment;
– The profile of the population of the area surrounding the Proposal will influence the vulnerability of the potentially impacted communities

The environment of the area surrounding the Proposal and the details of the community profile are discussed in the following sections.

3.1 Surrounding land uses

The Site is zoned as a mix of Public Use Zone – Service and Utility (PUZ1). The areas surrounding the Site ranges from farming land to public conservation areas within the Connewarre township. A summary of the surrounding areas and relevant zoning levels for identified activities are listed in Table 3 below.

Table 3 Zoning levels of surrounding areas

Direction	Activity	Zoning
North	Bicycle path then farming land	FZ
East	Thirteenth Beach	PCRZ
South	Zeally Bay and Breamlea Beach	PCRZ
West	Breamlea Flora and Fauna Reserve	PCRZ
	Farming land	FZ

3.2 Surrounding environment

3.2.1 Terrain

Surface elevate varies on site from approximately 1 to 18 mAHD. In general, the elevation of the site increases towards the south and east: elevation increases from approximately 6 to 10 mAHD north to south and 3 to 10 mAHD from west to east.

One slightly elevated area (20 mAHD) was identified in the southwest corner of the site.

3.2.2 Climate and meteorology

Based on the Breakwater (Geelong Racecourse) Bureau of Meteorology monitoring site (087184), the region generally has warm summers (mean maximum temperature in January of 26.1 ^{o}C) and cool winters (mean maximum temperature in July of 14.4 ^{o}C). The annual median rainfall is 516 mm.

Detailed wind data is described in the Air Quality Assessment report. GHD has been provided meteorological data (one and a half years at one-hour intervals) from the Blackrock site for the years of 1998 to 1999.

The average wind rose for the entire data period is shown in Figure 4. The wind distributions show the following features:

- The predominant annual average wind directions are from the west segment comprising 16% of all incident winds
- The incidence of westerly winds is significantly higher than easterlies occurring >2% of the time
- The average wind speed measured was 3.7 m/s
- Light winds (<2 m/s) comprised 25% of the monitoring period
- The observed wind speed distribution indicates that the largest proportion of high wind speeds (> 5 m/s) are from the south and west sectors
- The largest proportion of light winds (<2 m/s) are from the west (~6%)

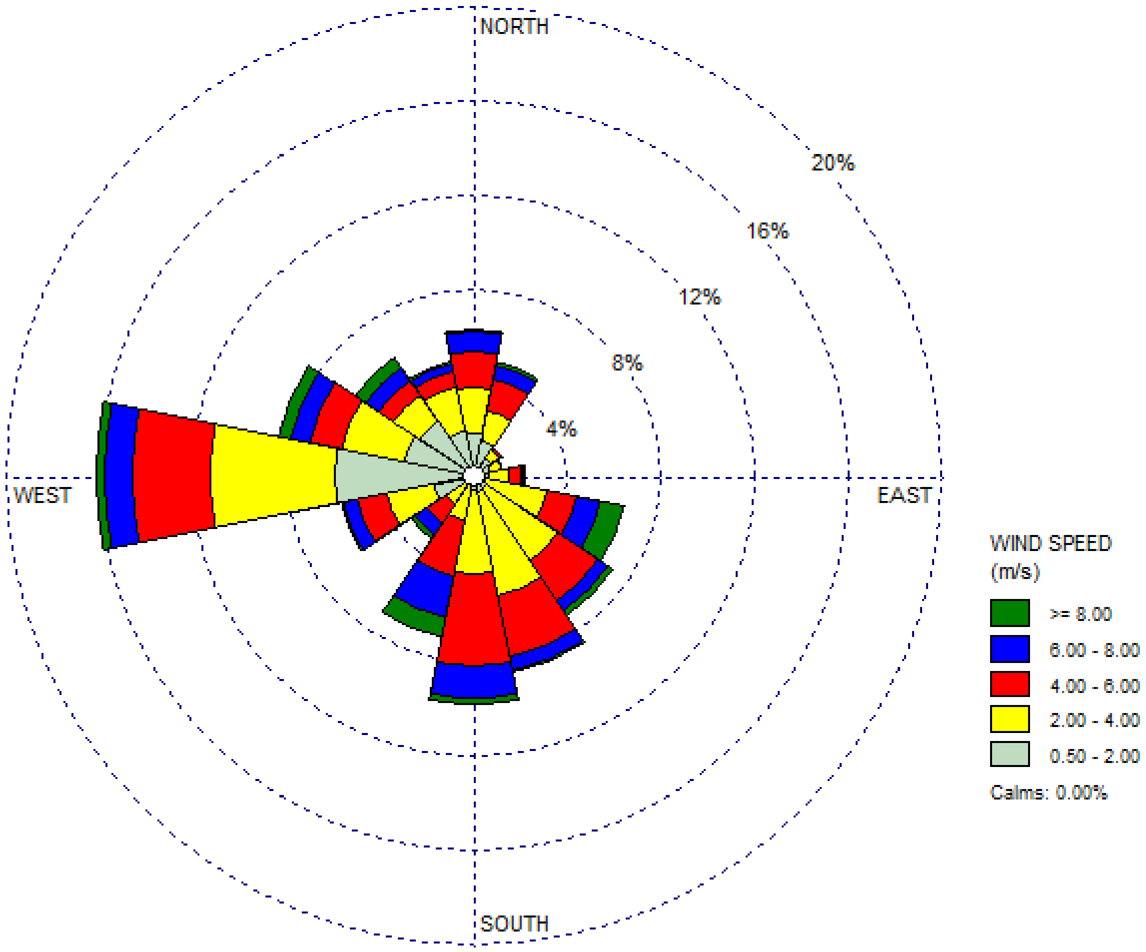


Figure 4 ***Wind rose (1998 – 1999)***

3.3 Sensitive receptors

The definition of a sensitive receptor or sensitive land use is defined by EPA[1] (2022, p. 46) as:

'Any land use that requires a focus on protecting human health and wellbeing, local amenity and aesthetic enjoyment." Examples of such sensitive land uses include but not limited to, '*dwellings, hospitals, aged care facilities, education centres, childcare centres, places of worship, corrective institutions'.*

A sensitive land use is further defined in Publication 1961 (EPA Victoria 2021, p. 8) as:[2]

[1] EPA Publication 1949, Separation distance guideline (2022)
[2] The definition provided in the Consultation Draft version of EPA Publication 1961 may change in the final revision of the guideline, however, any changes are not expected to affect the outcomes of this assessment.

"A land use where is it plausible for humans to be exposed over durations greater than 24 hours, such as residential premises, education and childcare facilities, nursing homes, retirement villages, hospitals."

The closest residential areas from each direction of the site have been identified and summarised in Table 4. The closest sensitive receptor is located approximately 922 m to the north-northeast of the activity boundary (the area of the RRON facility operations). The closest identified sensitive receptors have been identified displayed in Figure 5 and the activity boundary is also shown.

Table 4 Closest Sensitive Receptors

Receptor ID	X	Y	Address	Distance to site	Direction from site
1	272625.409	5758539.292	1A Horwood Dr, Breamlea VIC 3227	1715 m	SW
2	272769.442	5759572.895	291 Breamlea Rd, Connewarre VIC 3227	1265 m	W
3	272832.503	5760162.086	211- 229 Breamlea Rd, Connewarre VIC 3227	1345 m	NW
4	273741.476	5761095.686	262- 290 Bluestone School Rd, Connewarre 3227	1510 m	N
5	274571.063	5760722.451	342 - 400 Bluestone School Rd, Connewarre 3227	1076 m	NNE
6	274995.3252	5760630.285	550 Thirteenth Beach Rd, Connewarre 3227	922 m	NNE

3.4 Population profile

An overview of the land uses and sensitive receptors surrounding the site is provided section 3.1. EPA Publication 1961 states that in addition to the identification of sensitive land uses, it is useful to consider additional descriptive data to characterise the potentially exposed population, such as the size and vulnerability of the exposed population.

The population density of an area is reported by the Australian Bureau of Statistics (ABS) by Mesh Blocks. The relevant Mesh Block for the site is 20632001270, with an area of 1.469 m^2 and 0 persons living in the block. The relevant sensitive receptors surrounding the site (Greater Geelong) have a population density of 191.2 persons per km^2 as reported in the 2016 census. This is more than the surrounding areas of Surf Coast, Golden Plains and Moorabool which have a population density of 19.6, 8.1 and 15.5 persons per km^2 respectively. However, the population density in Wyndham is much larger than these areas with a population density of 420.8 persons per km^2 respectively. Overall, the population density surrounding the site is considered low.

The vulnerability of a community is classified through the Socio-Economic Indexes for Areas (SEIFA) by the ABS, which ranks areas according to their relative socio-economic advantages and disadvantages. Of particular interest is the index of relative socio-economic disadvantage (IRSD) for the statistical area level 1 (SA1). EPA Publication 1961 states that if the IRSD score is in quintile one (most disadvantaged), then the population is likely to be particularly vulnerable to pollution. The SEIFA index for the area surrounding the site has a quintile rating of five (i.e., least disadvantaged) and therefore the population surrounding the site is not expected to be particularly vulnerable to pollution.

Legend

- Site Boundary
- Sensitive receptors

Paper Size ISO A4

0 0.25 0.5 km

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 55

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Barwon Water RRON Functional Design

Closest Sensitive Receptors

Project No. **12585384**
Revision No. **-**
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FIGURE 5

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Print Date: 21/11/2023

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4. Conceptual site model for proposed emissions

4.1 Project emission sources

The primary emission source from the facility is from the biofilter. The emissions are discharged from a stack height of approximately 13 m above ground level.

4.1.1 Emission inventory

Modelled emission rates were calculated based on emission parameters provided by BW for discharge rates based on air emission recommendations and discharge rates from primarily three sources (confirmed by HZI and Mavitec as being the most relevant references for the proposed RRON project):

– Loganholme biosolids gasification facility measured in 2023 from the full-scale installation (Appendix A) and measured in 2020 from the demonstration plant installation (Appendix B)
– Mavitec reference plants that operate overseas
– 15MW woodfired biomass boiler at Dongwha Sawmill, NSW

Where no emissions (i.e., 0 mg/Nm3) were measured at the full scale Loganholme facility in 2023, emission values measured at Loganholme demonstration facility in 2020 have been adopted. The provided emission rates have been summarised in Table 5.

Refer to the AQA report for detailed information on reference plant emissions.

Table 5 Emission rate summary

Parameter	Emission rate (g/s.m^2)	Adopted concentration basis
Particulate Matter	1.16E-03 g/s.m^2	Biomass data
Cabon Monoxide	2.85E-04 g/s.m^2	Logan 2023 data
Nitrogen Dioxide	1.20E-03 g/s.m^2	Biomass data
Sulfur Dioxide	2.78E-04 g/s.m^2	Logan 2023 data
Hydrogen Chloride	2.22E-05 g/s.m^2	Logan 2023 data
Hydrogen Fluoride	3.52E-05 g/s.m^2	Logan 2023 data
Total VOCs as n-propane	7.41E-04 g/s.m^2	Biomass data
Dioxin and furans	3.89E-15 g/s.m^2	Logan 2020 data - 100 hr run
Polycyclic aromatic hydrocarbons (PAHs) as Benzo(a)pyrene (BaP)	9.44E-09 g/s.m^2	Logan 2020 data - 100 hr run
Odour	16944 OU/m^3	provided by HZI/Mavitec
Hydrogen Sulphide	2.22E-05 g/s.m^2	Logan 2020 data - 100 hr run
Sulfur Trioxide	8.89E-05 g/s.m^2	Logan 2020 data - 100 hr run
Hexavalent Chromium	2.22E-07 g/s.m^2	Logan 2020 data - 100 hr run
Total heavy metals	7.41E-06 g/s.m^2	Logan 2023 data
Cadmium	8.33E-08 g/s.m^2	Logan 2023 data
Mercury	9.26E-07 g/s.m^2	Logan 2023 data
PFAS	2.41E-10 g/s.m^2	Logan 2023 data

4.2 Summary of air quality emission modelling

The dispersion model results show the predicted Ground Level Concentrations (GLCs) for all pollutants discharging from all sources are below their respective air quality assessment criteria (APAC). NO_2 was found to be the highest percentage limit at 40% excluding background concentrations. The remaining pollutants were all found to have percentage limits of 15% or less.

The dispersion model results show that when venting, the discharges of pollutants from the site are predicted to be low at the site boundary and at all identified sensitive receptors and are not anticipated to lead to unacceptable health risk to the receiving environment.

A level 2 odour risk assessment was also undertaken in accordance with EPA Publication 1883. The overall level 2 assessment score was 6, meaning activity is low risk in accordance with the Level 2 assessment. As the risk of odour is low, EPA Publication 1883 requires no further assessment and directs the user to proceed to reporting of the results.

4.3 Deposition screening assessment

The Environment Reference Standard (ERS) used in the EP Act primarily addresses the issues of inhalation risk of vapour and particulates, and odour. However, the ERS do not directly address potential health risk associated with deposition and accumulation of toxicants attached to particulate matter in the soil in surrounding properties. Accumulation of toxicants can occur over the design-life of the proposed facility of 25 years.

A screening assessment of potential risk from deposition was undertaken to identify the chemicals with the highest contribution to risk. The process of the screening process was as follows:

– All emissions from the biofilter stack were taken from Table 5 above. All non-particulate contaminants of potential concern (COPC) removed
– Deposition modelling from the AQA based on particulate matter (TSP) was reported to be 0.119 g/m2/month at the site boundary
– All the COPC deposition rates for the COPC were estimated by linear scale of emission rates of chemical to that of particulate matter
– An estimate of soil concentration was calculated based on 25 years accumulated deposition within 0.02 m of soil cover
– The soil concentration was compared with residential health-based soil criteria, and a ratio of concentration to criteria calculated

Note dioxins and furans were included as a COPC regardless of screening score as it is strongly bioaccumulative.

The detailed deposition screening assessment is provided in Appendix A. The five chemicals with the highest ratios were selected as COPC for detailed health risk assessment. These COPC are:

– Dioxins and furans
– PAHs as Benzo(a)pyrene
– Cadmium
– Mercury
– PFAS

Based on the comparison of residential screening criteria, these five COPC represent 93% of potential health risk associated with deposition and accumulation of non-volatile chemicals in the surrounding environment.

4.4 Exposure pathways

Atmospheric emissions from the facility may be present in the air and deposited on ground. The main pathways via which people may be exposed to emissions from the proposal include:

- Inhalation of airborne emissions, including gases and particulates
- Deposition of particulates onto soil, including:
  - Direct dermal contact with soil/dust
  - Inhalation of dust
  - Incidental ingestion of soil/dust
  - Uptake into homegrown fruit and vegetable crops and the subsequent consumption of this produce
  - Uptake into chickens and the subsequent consumption of homegrown eggs
  - Uptake into livestock and the subsequent consumption of homegrown meat or milk
- Deposition of particulates onto a roof, runoff into a rainwater tank and the subsequent consumption and domestic use of tank water

The crops and livestock produced in the area surrounding the site may be subject to both sale and homegrown consumption. Homegrown consumption by individuals living on individual properties has been evaluated in this HHRA, as this scenario is associated with a higher exposure potential than produce subject to sale.

As discussed in section 4.2, the air quality assessment modelled dispersion of COPC and compared GLCs at all the sensitive receptors with the ERS and all chemicals were below their respective APAC. It is the conclusion of the AQA that health risk via inhalation of volatile and non-volatile chemicals, including the Class 1 indicator chemicals, is low and acceptable.

The remainer of this HHRA will focus on the risk posed by deposition of non-volatile chemicals, for the COPC identified in section 4.3 above.

5. Toxicity assessment

5.1 Introduction

The toxicity assessment component of a HHRA is the process of determining whether exposure to a chemical could cause an increase in the incidence of an adverse health condition (NEPC, 2013). In this HHRA, the outcomes of the toxicity assessment process are a set of toxicity criteria that have been used in conjunction with exposure estimates to estimate health risks.

Where possible, the toxicity assessment component of this HHRA has primarily been based on the toxicological information endorsed by Australian regulators. Pertinent additional information from reputable international sources has, however, also been reviewed in this assessment, for chemicals where Australian guidance is limited.

This section focuses on the selected COPC identified in section 4.3.

5.2 Chronic toxicity

5.2.1 Overview

For most chemicals there is a dose below which no adverse health effect will occur (i.e., a threshold). In contrast, the initiating event in the process of genotoxic chemical carcinogenesis is the induction of a mutation in the genetic material (DNA) of somatic cells and there is a theoretical risk of this occurring at any level of exposure (i.e., non threshold). There are also carcinogens that are capable of producing tumours without genotoxic activity, but these generally demonstrate a threshold dose and are assessed as such within the HHRA process.

A distinction is made in the toxicity assessment methodology applied for compounds classified as threshold vs non-threshold, as outlined in the following subsections. A summary of the carcinogenicity classification and toxicity assessment approach adopted for each of the COPC outlined in Table 6.

Table 6 Summary of toxicity assessment approach

Pollutant	Dose response assessment methodology	Rationale
Cadmium	Threshold	Classified by the IARC (2012) as a Group 1 – 'carcinogenic to humans' via the inhalation exposure route. The review presented in the ASC NEPM concluded that there is mixed evidence as to genotoxicity and that a threshold approach is appropriate.
Mercury (inorganic)	Threshold	Classified by the IARC (1992) as Group 3—'not classifiable'. A threshold approach is appropriate.
Dioxins and furans	Threshold	Classified by the IARC (2012) as Group 1 —' carcinogenic to humans'. An Australian Department of Health and Ageing (2004) review suggests that the evidence for a threshold to the carcinogenicity of dioxins is mixed but that a threshold approach is appropriate and will provide an adequate margin of safety for possible increased risk of cancer.
Benzo(a)pyrene TEQ	Non-threshold	PAH are a large and diverse group of compounds. Benzo(a)pyrene has been classified by the IARC (2012) as Group 1 – 'carcinogenic to humans'. The ASC NEPM considered that benzo(a)pyrene acts via a mutagenic mode of action and recommends that susceptibility associated with early lifetime exposures be addressed. A non-threshold approach is appropriate.

Pollutant	Dose response assessment methodology	Rationale
PFAS	Threshold	PFAS is a large group of compounds. Most of the focus of toxicity studies have been on PFOS and PFOA. Studies in laboratory animals suggest that PFOS and PFOA may promote some cancers in those animals, but it is not clear if these results have any implications for human health. In 2023 the International Agency for Cancer (IARC) revised their assessment of PFOS and PFOA. PFOA is carcinogenic to humans (Group 1), on the basis of sufficient evidence for cancer in experimental animals and strong mechanistic evidence (for epigenetic alterations and immunosuppression) in exposed humans. There was also limited evidence for cancer in humans (renal cell carcinoma and testicular cancer). PFOS is possibly carcinogenic to humans (Group 2B), on the basis of strong mechanistic evidence across test systems, including in exposed humans (for epigenetic alterations and immunosuppression, as well as several other key characteristics of carcinogens). The Commonwealth Department of Health has established 'health based guidance values' in the form of a Tolerable Daily Intake (TDI) for PFOS/PFHxS and PFOA. These values are based on a review of the scientific evidence by Food Standards Australia and New Zealand (FSANZ). FZANZ undertook a review in 2021 on data for immunomodulation and concluded that the there was uncertainties and limitations in the evidence base, immunomodulation is not currently considered suitable as a critical endpoint for quantitative risk assessment for PFAS.

5.2.2 Non-threshold chemicals

Where the chemical substance has the potential for non-threshold carcinogenic effects, it is assumed that any level of exposure may result in DNA damage that this may translate in the development of cancer during the lifetime. For these chemicals, the toxicity assessment process is based on a linear non-threshold approach using slope factors or inhalation unit risk values, which produces a measure of excess lifetime cancer risk.

As outlined in Table 6, the COPC assessed using a non-threshold approach were limited to PAH, (assessed as benzo(a)pyrene TEQ). The chronic non-threshold toxicity reference value (TRV) for benzo(a) pyrene was sourced from the ASC NEPM. The chronic non-threshold TRV are summarised in Table 7.

Table 7 Summary of chronic non-threshold TRV

Compound	Oral Slope Factor $(mg/kg/day)^{-1}$	Inhalation Unit Risk $(mg/m^3)^{-1}$	Source
Benzo(a)pyrene TEQ	0.5	0.143	ASC NEPM

5.2.3 Threshold chemicals

Chronic health risks associated with exposure to COPC with a threshold mode of toxicity are assessed by comparing the estimated intake doses with chronic TRVs. TRVs are a measure of tolerable daily exposure and include values that are referenced by different agencies using a range of different terms, including:

– Acceptable daily intake (ADI)
– Tolerable daily intake (TDI)
– Reference dose (RfD) of Reference Concentration (RfC)
– Minimal risk level (MRL) and
– Reference exposure level (REL)

All of these values estimate the daily dose of a chemical to the human population (including sensitive subpopulations) that is likely to be without risk of deleterious non-cancer effects during a lifetime. TRVs for oral and dermal exposures are typically expressed in mg/kg per kg body weight/day and TRVs for inhalation exposure are typically expressed in mg/m^3. For threshold chemicals, intakes and exposure concentrations lower than the TRV are considered safe.

The derivation of chronic threshold TRVs is a two-step process:

1. Defining a point of departure (POD); and
2. Extrapolating from the POD for relevance to human exposure

The POD for the dose response assessment is typically the no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) derived from relevant animal or human data. To derive the TRVs for threshold health effects, the POD is typically adjusted downwards (i.e., made more conservative) to account for the uncertainty that is associated with extrapolation from experimental animals to humans and to account for the variability in the health responses of individuals. Downwards adjustments are also made to the POD in response to limitations in the available toxicological dataset (e.g., limited study durations or the absence of studies addressing specific potential endpoints) and when the POD is a LOAEL rather than an NOAEL. The adjustments are made using uncertainty factors (UF) of up to 10 for each potential source of uncertainty.

The ASC NEPM has been used as the primary source of chronic TRV in this HHRA. For chemicals not addressed in the ASC NEPM chronic TRV have been sourced from a variety of reputable Australian and international sources, which include a transparent and robust derivation processes. The additional referenced guidance documents include the following:

– Department of Environment and Heritage (DoEH, 2004) TDI value for dioxins and furan (total TEQ)
– Heads of EPA Australia and New Zealand (2021) *PFAS National Environmental Management Plan (PFAS NEMP), Version 2.0*

Where inhalation-specific TRV were not identified inhalation exposures were assessed using route-to-route extrapolation from the oral TRV; a daily inhalation rate of 20 m^3/day for a 70 kg adult was used in this calculation. This approach aligns with that used in the ASC NEPM.

The chronic TRV are summarised in Table 8.

Table 8 Summary of chronic TRV

Compound	Oral/Dermal TRV (mg/kg/day)	Source	Inhalation TRV (mg/m^3)	Source
Cadmium	0.0008	ASC NEPM	0.000005	ASC NEPM
Mercury	0.0006	ASC NEPM	0.0002	ASC NEPM
Dioxins and furans	2.33E-09	DoEH (2004)	8.17E-09*	DoEH
PFAS (based on PFOS)	0.00002	PFAS NEMP	0.00007*	PFAS NEMP
*Derived using route-to-route extrapolation from the oral/dermal TRV				

5.3 Toxicokinetic parameters

The ASC NEPM defines bioavailability as the proportion of the intake of a substance, which is absorbed into the body. 'Bioavailability' can be separated into two distinct elements:

1. The ability of the substance to be liberated from a medium (e.g., plant or meat) within the gut or lung – often referred to as the bio-accessibility
2. The ability of the substance to enter the bloodstream and be taken up by the body organs, once it has entered the lung or gut – this is often referred to as bioavailability (NEPC, 2013)

The toxicity data derived from experiments involving direct oral administration of COPC to an animal or human intrinsically incorporates bioavailability as defined in Point 2 above. There has been limited research into bioaccessibility of individual COPC in different media and therefore a conservative assumption of 100% bioaccessibility has generally been adopted in this assessment for oral exposure pathways.

The lack of dermal-specific TRVs for most compounds means that a dermal dose has been compared to the ingestion TRV, modified by the following factors:

– A gastrointestinal absorption factor (GAF) to adjust for the absorption of the chemical across the gastrointestinal tract
– A dermal absorption factor (DAF) to represents the proportion of the chemical that can be absorbed into the bloodstream through the skin

The toxicokinetic parameters adopted in this HHRA are detailed in Appendix B.

6. Exposure assessment

6.1 Introduction

The exposure assessment has been undertaken on the basis of the AQA (GHD, 2023). The AQA generated estimated GLCs for the COPC outlined in section 4.2, relevant to the assessment of ERS (primarily based on 1-hour averages) and long term (annual average) inhalation exposures and the exposure occurring in association with particulate deposition.

As discussed in section 4.2, all COPC was below the ERS values and therefore it is concluded that inhalation risk is low and acceptable. This section will focus on the selected COPC from section 4.3 which are the most significant chemicals with respect to deposition and accumulation.

Refer to the AQA report for details on the modelling process and input parameters.

6.2 Exposure scenarios

The primary exposure scenario assessed in the HHRA is operation of the proposed facility for the design life of 25 years. Health risk has been assessed for the surrounding residential and agricultural properties.

6.3 Exposure point concentrations

The AQA undertook air dispersion modelling for the COPC at multiple sites along the site boundary, and the sensitive receptors shown in section 3.3. The annual average ground level concentrations for the COPC have been modelled for the highest site boundary, and the maximum sensitive receptor location. The results of the modelling is presented in Table 9.

Table 9 Summary of modelled ground level concentrations

Chemical	Maximum site-boundary concentration (µg/m^3)	Maximum sensitive receptor concentration (µg/m^3)
Cadmium	3.7E-04	9.7E-06
Mercury	5.9E-06	1.5E-07
Dioxins and furans	1.7E-11	4.5E-13
PFAS (as PFOS)	1.1E-06	2.8E-08
PAHs (as BaP)	4.2E-05	1.1E-06

Deposition rate of particulate matter was modelled in the AQA and the results of the modelling were as follows:

– Deposition rate on site boundary: 0.0846 g/m^2/month
– Maximum deposition rate at sensitive receptors: 0.00544 g/m^2/month

In a similar process as that described in section 4.3, the deposition rate of individual COPC was calculated by scaling the maximum deposition rate at sensitive receptors by the ratio of COPC to particulate matter in the biofilter emission estimate. The estimated maximum COPC deposition rate for sensitive receptors is shown in Table 10.

Table 10 Summary of estimated maximum COPC deposition rate for sensitive receptors

Chemical	Deposition rate (g/m²/year)
Cadmium	4.7E-06
Mercury	5.2E-05
Dioxins and furans	2.2E-13
PFAS (as PFOS)	1.4E-08
PAHs (as BaP)	5.3E-07

6.4 Exposure parameters

6.4.1 Background exposure assessment approach

Exposures to COPC may be associated with emissions attributable to the RRON facility, as well as impacts that originate from other sources in the wider environment (e.g., vehicular, industrial or agricultural emissions), exposure in occupational settings and naturally occurring sources. Exposure to sources of COPC external to the proposal is referred to hereafter as ‘background exposure’.

In accordance with the approach outlined in the ASC NEPM, the TRV used to assess chronic background exposures to COPC from background has been incorporated on a chemical-specific basis by applying a factor to the threshold TRV. The background exposure assumptions made for each COPC are detailed in Appendix B.

6.4.2 Human behaviour and physiological inputs

The approaches outlined in Schedule B4 of the ASC NEPM have been used to select exposure assessment inputs that are adequately protective of the users of the area surrounding the site, as follows:

– Physical characteristics such as age, life expectancy and body weight have been sourced from enHealth (2012a)
– The ASC NEPM Schedule B7 provides behavioural and exposure duration assumptions for standard exposure scenarios, and these have also been adopted in this assessment for the residential exposure settings
– Where appropriate, area-specific behavioural and exposure duration assumptions have been adopted, based on best professional judgement. This includes the assumptions made around the production and consumption of home-grown fruits, vegetables, and livestock for the agricultural exposure settings.

The exposure human behavioural and physiological inputs used in the HHRA are detailed in Appendix C, with specific assumption outlined below.

Water intake

The Australian drinking water guidelines (NHMRC, 2011) adopt default drinking water consumption rates of 2 L/day and 1 L/day for adults and children, respectively. These values have been adopted in this HHRA for harvested rainwater. NHMRC (2011) acknowledges that the amount of water consumed by an adult each day can vary with season and climate but considers that the consumption rate of 2 L/day is appropriate, on average, for Australian conditions. NHMRC (2011) also notes that the derived drinking quality guidelines include a range of safety factors (e.g., uncertainty factors incorporated into the TRVs) and therefore always err on the side of safety.

People using the area surrounding the proposal may also potentially ingest small volumes of harvested rainwater water during activities such as bathing, using a sprinkler or swimming in a pool. The incidental ingestion of water would generally be expected to make only a minor contribution to overall water intake. enHealth (2012a) recommends average incidental ingestion rates of 25 mL/hr and 50 mL/hr for adults and children swimming, respectively. These values have been adopted in this assessment in conjunction with the assumption that people living in the area surrounding the site may spend up to 1 hr per day undertaking activities that may involve the incidental ingestion of water (e.g., bathing, swimming, using sprinklers or hoses).

Homegrown produce consumption

The standard low density residential setting in the NEPM (Health Investigation Level A) uses a fraction of fruit and vegetables consumed that is homegrown as 10%. However, given the surrounding land is rural residential and agricultural land a more conservative value of 25% has been selected on the basis that there is likelihood of larger gardens and more potential for fruit and vegetable to be grown.

6.5 Exposure modelling methodology

To estimate the chronic intake of COPC the exposure parameters have been combined with the exposure point concentrations using mathematical algorithms detailed in Appendix B. The exposure assessment algorithms have been sources from the ASC NEPM, enHealth (2012) and OEHHA (2015), as recommended in Section 7.3 of the NSW (2016) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW.

For PFAS additional algorithms have been adopted that is representative of recent information on the uptake of PFAS in chicken eggs, meat and milk.

The exposure modelling methodology for individual exposure pathways is described in more detail below.

6.5.1 Soil deposition calculations

Soil concentration of COPC in surrounding locations is estimated through the accumulation of deposition over the design-life of the proposed facility. Two soil categories have been calculated:

- Tilled soil where top 20 cm of soil is routinely mixed. This category has been used to represent gardens and homegrown produce.
- Un-tilled soil where top 2 cm accumulates deposition and local dust. This category has been used for all other exposures including direct contact and pasture.

6.5.2 Uptake into eggs, meat and milk

The CSM (section 4) identified that people may be exposed to COPC in the air emissions, following deposition to soil and into rainwater storage tanks, via the consumption of homegrown eggs, meat and milk. These Source-Pathway-Receptor linkage have therefore been included in the HHRA.

The relationship between the concentrations of COPC in soil and stored rainwater the COPC exposure are associated with domestically produced eggs, meat and milk have been estimated using the methodology presented by OEHHA (2015) and US EPA (2005). This guidance document provides an approach for estimating COPC concentrations in eggs, meat and milk based on the measured concentrations in the diet (grain and pasture), drinking water and soil, the equations associated with which are provided in Appendix B.

The ratio between chemical intake rate to concentration in egg, meat or milk is known as the transfer factor (TF). Literature values are available for numerous chemicals, of which many are published in OEHHA (2015). These are used to estimate concentrations of COPC in eggs, meat and milk based on concentrations of COPC in soil and tank water.

A detailed description of the food transfer modelling algorithms and the modelling inputs and outputs are provided in Appendix B.

PFAS and chicken eggs

The Australian Department of Defence (2017a) completed a study in association with the RAAF BASE Williamtown (NSW) PFAS Investigation, examining the relationship between the PFAS concentrations in chicken eggs and the PFAS concentrations in their drinking water. The study involved 119, 30-week-old Hy-Line Brown hens that were provided drinking water with different concentrations of PFAS. The outcomes of this study were as follows:

- The amount of PFOS transferred to eggs each day was estimated, on average, to be equal to the amount of PFOS ingested by a chicken via their drinking water each day, with the majority of PFOS transferred to the yolk

– Approximately 70% of PFHxS consumed by the hen each day via their drinking water was transferred to the egg

In a study undertaken by Kowalczyk *et al.* (2020) on the transfer of these compounds from feed into chicken eggs, transfer rates of approximately 100% reported for both PFOS and PFHxS, with a transfer rate of approximately 49% reported for PFOA into eggs. The high rates of PFOS transfer into eggs estimated by DoD (2017a) and Kowalczyk *et al.* (2020) align with the data reported by EFSA (2020), which identifies that eggs and egg products are one of the most important contributors to PFAS exposure for the European population, with the higher transfer factors reported by Kowalczyk *et al.* (2020) adopted in this assessment as a conservative approach.

PFAS Transfer factors from the water to livestock serum

A critical factor determining the influence of PFAS concentrations in water on the PFAS concentrations in the livestock consuming it, is the efficiency with which PFAS is transferred from the water to livestock serum. Drew *et al.* (2021) studied the accumulation of PFAS in the serum of cattle raised on a hobby farm impacted by PFAS. The predominant source of PFAS exposure identified in this study was water, with grass and soil making minimal contributions to total PFAS exposure. Drew *et al.* (2021) derived transfer factors for cattle by dividing steady state serum PFAS concentration by the PFAS concentration in water, with the average values as follows:

– Cattle: 140 and 65 ng/mL serum per µg/L of water intake for PFOS and PFHxS respectively.

The findings of Drew *et al.* (2021) generally align with the outcomes of Mikkonen *et al.* (2023) which studied the migration pathways of PFAS across agricultural properties in Victoria, Australia, and their bioaccumulation in cattle blood serum. The study found the main exposure pathway for cattle was drinking of contaminated water. On this basis, Mikkonen *et al.* (2023) performed a regression analysis to extrapolate concentrations of PFOS and PFHxS in cattle serum for a given water concentration. This information can be used to derive transfer factors which are comparable to those derived by Drew *et al.* (2021).

Transfer from soil and feed to livestock serum

The draft PFAS NEMP 3.0 (HEPA, 2022) presents criteria for PFAS in biosolids, derived on the basis of the uptake of PFAS from soil into the blood of dairy cattle and transfer into milk. This approach, which involves estimating the intake of PFAS (in mg/kg/day) via the consumption of feed and incidental ingestion of soil has been adopted in this HHRA, as follows:

$$C_{serum} = \frac{Intake \times t_{1/2}}{0.693 \times V_d}$$

$t_{1/2}$ is the serum elimination half-life, which is compound and species specific. The values adopted include:

– Cattle: 56 days for PFOS and 1.3 days for PFOA (van Asselt, et al., 2013; Vestergren, Orata, Berger, & Cousins, 2013)

V_d is the volume distribution (expressed in L/kg) and is a parameter used to assess the extent of a chemical distribution throughout the body. It is typically calculated as the fraction of the dose (mg/kg) and plasma concentrations (mg/L) and is both species and chemical specific. The V_d values adopted in this HHRA are as follows:

– Cattle: a value of 0.26 L/kg, with this value based on the assessment of extracellular fluid volume studied by Maksiri *et al.* (2005) and Chaiyabutr *et al.* (2008)

The value of 0.693 is a factor (ln2) based on pharmacokinetic models and is correlated to the half-life and the rate of elimination of the chemical.

Transfer factors from serum to meat and milk

Another critical factor determining the influence of PFAS concentrations in water on the PFAS concentrations in the livestock consuming it, is the efficiency with which PFAS is transferred from the blood to edible meats and milk. Two studies undertaken by Kowalczyk *et al.* (2012; 2013) have demonstrated that there are clear relationships between the concentrations of PFAS in the blood of dairy cows, and the concentrations of PFAS in their meat and milk. Similar studies have been conducted by Numata, *et al*. (2014) and Death *et al.* (2021) for various animals including pigs. The ratios of the average PFOS and PFHxS concentrations in meat, milk and serum, as reported in these studies have been adopted in this HHRA as follows:

– Cattle:
  - PFOS: 0.076 (meat) and 1.06 (liver and kidneys - average) mg/kg meat per mg/L serum
  - PFOS (milk) 0.015 mg/kg milk per mg/L serum

6.5.3 Uptake into homegrown produce

The algorithms for estimating health risk from consumption of home-grown produce is taken from the ASC NEPM 2013. Produce has been divided into four categories:

– Green vegetables
– Root vegetables
– Tuber vegetables
– Tree fruit

Uptake factors for COPC are presented in the ASC NEPM and have been adopted. For PFAS, the same categories of produce have been adopted in the PFAS NEMP 2.0 and transfer factors published for PFOS have been adopted.

6.5.4 Rainwater tank impact calculations

The residential properties located around the site typically receive sufficient potable water from Barwon Water for their potable and domestic use. Some residential properties may also have rainwater tanks and it is possible that, in some instances, the water captured in these tanks is connected to their household supply and used as the primary source for drinking and domestic activities. Thus, one of the potential exposure pathways to COPC emitted from the RRON facility is the potable and domestic use of rainwater which has been washed into rainwater tanks.

The equations used to estimate the concentrations of COPC in rainwater tanks in the area surrounding the site are presented in Appendix B. Critical assumptions incorporated in the rainwater tank assessment are as follows:

– It has been assumed that 100% of the deposited dust on roofs is mobilised by rainwater. This is a conservative assumption, as some of the dust will be resuspended and deposit elsewhere.
– The equations conservatively assume 80% of rainwater containing deposited dust is collected by a tank and that 2 mm of the rainfall deposited on the roof monthly is lost through the wetting and absorption into the surfaces. These assumptions were sourced from the Department of Health (DoH, 2011).
– It has been assumed that all of the COPC that potentially washes into the rainwater tanks could be either dissolved or suspended and available for consumption. This is a conservative assumption as, in reality, some of the dust that washes into a rainwater tank will settle to the bottom.

A review of the scientific literature indicates that multiple factors influence the degree to which COPC dissolve from dust into harvested rainwater and the degree to which particulates are suspended in the water column within rainwater tanks, including the pH of the water, timing of a rainfall event, roofing construction material, water inflow rate, tanks construction details and the depth of sediment and sediment particle size in the tank (Magyar, Ladson, & Diaper, 2011a; M. van der Sterren, Rahman, & Dennis, 2013; Magyar M. , Ladson, Mitchell, & Diaper, 2011b). Notably, rainwater is typically slightly acidic, with a pH value of 5.0 and 5.5 and as such contributions of NO_X, SO_2, HCl and HF from the facility to rainwater captured in the vicinity of the site will be assessed. In this context, the adoption of a conservative assumption around the availability of COPC in rainwater for consumption is considered appropriate and for the majority of the COPC.

7. Risk characterisation

In the quantitative risk characterisation process, the results of the toxicity assessment (section 5) and exposure assessment (Section 6) have been combined to provide numerical estimates of the potential risks to the identified receptors, using the emission predictions made in the AQA.

The methodology used in the risk characterisation process for chronic exposures to RRON facility emissions are outlined below. An evaluation of the uncertainty associated with the HHRA and sensitivity of the assessment outcomes to the various assumptions and inputs has also been undertaken and is presented in section 8.

7.1 Methodology

Potential risks associated with exposure to COPC emissions have been characterised by Hazard Quotients (HQs), which are ratios of estimated exposure to the adopted toxicity criteria (i.e., the TRVs defined in section 5), as follows:

– For chronic exposures to threshold chemicals, the average chronic daily intakes predicted for each scenario, across the range of potential exposure pathways and including background (external to the RRON facility) exposures have been compared with the chronic TRVs outlined in section 5.2.3

– For chronic exposures to non-threshold chemicals, the increased lifetime risk of cancer (ILCR) has been calculated by multiplying the average chronic daily intakes predicted for each scenario by the oral slope factor (ingestion and dermal exposures) or inhalation unit risk (inhalation exposures), as outline in section 5.2.2

For chronic exposures to threshold chemicals the HQs for multiple exposure pathways have been summed to calculate an overall risk level, or Hazard Index (HI) for each COPC. To assess exposure to mixtures of threshold COPC, the HI for all of the individual chemicals have been summed. The TRV have been conservatively established to identify an exposure level at which no adverse health effects are likely. Therefore, a HI less than or equal to 1 indicates that the estimated chemical exposure does not pose a risk.

For chronic exposures to non-threshold chemicals, the ILCR for multiple exposure pathways and COPC have been summed to calculate an overall ILCR for each exposure scenario. In accordance with the NSW EPA (2016) Approved Methods, ILCR of less than or equal to 1 in 1,000,000 have been considered acceptable and ILCR greater than 1 in 10,000 have been used to indicate situations where a sensitivity analysis must be carried to identify cost effective pollution control strategies.

The risk characterisation algorithms and all the calculations are provided in Appendix B.

7.2 Results – Maximum sensitive receptor

The resulting maximum HI and ILCR for the COPC at sensitive receptors is shown in Table 11.

Table 11 Risk characterisation for chronic exposure by sensitive receptors

Chemical	All Pathways HI/ILCR
Threshold COPC	
Cadmium	5.55E-03
Mercury (inorganic)	4.22E-02
Dioxins and furans	1.10E-04
PFAS (PFOS)	3.46E-03
TOTAL HI	**0.051 (<1.0)**
Non-threshold COPC	
Benzo(a)pyrene	5.50E-08
TOTAL ILCR	**5.50E-08 (<1.0E-06)**

The estimated Hazard Index (HI) for the highest exposed sensitive receptor from deposition is 0.051, which is well below the allowable HI of 1.0. The largest contributor to HI was mercury (82%). It is noted that the mercury emissions modelled in the AIQ were based on biosolids feedstock stream only, whereas in the RRON facility biosolids are expected to be a small proportion of the overall feedstock (~12%) and as such the actual mercury emissions from the RRON facility are expected to be less than the modelled values.

The estimated incremental lifetime cancer risk (ILCR) for the highest exposed sensitive receptor from deposition is 5.5×10^{-8}, which is below the acceptable level of 1×10^{-6} (or 1 in 1,000,000). The cancer risk for benzo(a)pyrene is based on early-life exposure model for protection of young children (0-1 years) from genotoxic carcinogens.

It is therefore concluded that human health risk of nearby sensitive receptors is low and acceptable.

7.3 Risk mitigation measures

As presented in section 7.2, the estimate of health risks from Project emissions is evaluated to be low and acceptable. This risk estimate is based on the long-term normal operating conditions of the project.

BW has proposed to implement a number of controls to minimise risks to human health and the environment. Section 8 of the AQA report demonstrates the proposed controls which will be implemented at the site once the RRON facility becomes operational. In summary, these include the following:

– Engineering controls to minimise emissions including pre-treatment screening processes, pre-treatment building maintain under constant negative pressure, carbonisation plant includes air pollution controls consisting of a thermal oxidiser, cyclone filter, wet scrubbing and a biofilter
– Administrative controls generally include the implementation of appropriate procedures and manual operations on a site including site cleaning, incident reporting, equipment maintenance and staff training
– Emission monitoring program

In addition, the Project has a number of engineering controls and procedures to manage emissions during unplanned events including start up and shutdown procedures.

8. Uncertainty and sensitivity assessment

8.1 Uncertainty analysis

The uncertainty analysis identifies the assumptions and data gaps associated with the HHRA. The main areas of uncertainty identified for this assessment include:

- Exposure assessment, including the potential for the local residents to employ a wide range of patterns of land and water use and the likelihood that air, soil and water concentrations present will differ at different times and in different places
- Toxicity assessment, including the wide range of TRV adopted internationally for COPC especially PFOS
- Risk characterisation, including using modelling approaches for air dispersion and exposure to estimate health risks

The approaches used to reduce the uncertainty associated with this HHRA have been to use site-specific data wherever possible and to adopt conservative assumptions from reputable Australian and international agencies, in the absence of site-specific data. Health conservative assumptions applied in this assessment include:

- Emission rates used in the air dispersion modelling are considered to be a reasonable worst-case emission for normal operating conditions
- The use of toxicological data recommended by Australian health agencies and intended to be well below any threshold for adverse health effects (based on no-observed-adverse-effect levels, with a number of safety factors applied to account for issues such as variability within populations)
- The use of conservative modelling assumptions and approaches with regards to pathways considered for agricultural land

Given the factors outlined above, the uncertainty in this assessment has been considered by erring on the side of the over estimation of potential health risks.

Key areas of uncertainty, which could influence the outcomes of the HHRA include:

- Inclusion of other non-volatiles chemicals in deposition
- Variability in emission rate

The sensitivity of the assessment outcomes to these inputs is further evaluated in section 8.2.

8.2 Sensitivity analysis

In a sensitivity analysis, key input parameters are varied to determine the degree to which these changes influence the risk estimates. A sensitivity analysis can therefore be used to help characterise uncertainty and to identify the key parameters influencing the assessment of risk.

The sensitivity analysis has focused on:

- The inclusion of other COPC in the risk calculation
- The effect of varying emission rate

Appendix C presents the results of the sensitivity analysis for changes in emission rate, and includes:

- Changes in the calculated health risks according to the various inputs
- An evaluation of the relative variable sensitivity

Overall, the sensitivity analysis demonstrated that the report outcomes are relatively insensitive to the key areas of uncertainty identified in section 8.1. Across the range emission rates, the outcomes of the HHRA generally did not change, with the derived HI remaining below 1 and ILCR below 1×10^{-6}. This outcome provides a high level of confidence that there is a low risk that the emissions depositing in surrounding land will result in an exceedance of the TRVs by sensitive receptors.

9. Summary and conclusions

BW proposes to host a Regional Renewable Organics Network (RRON) at the Black Rock Water Reclamation Plant (WRP) located at 395 – 405 Blackrock Road, Connewarre 3227 (the 'Site'). GHD has been engaged to prepare and submit a Development Licence Application (DLA) for the proposed facility. As part of the DLA submission, an air quality assessment is required to demonstrate that the proposed facility will not give rise to a risk to human health or the environment from emissions discharged from the proposed facility and that it will meet the obligations or duties that arise under the Environment Protection Act 2017 (EP Act).

This air quality assessment is undertaken in accordance with the EP Act utilising ERS, EPA Publication 1961 and EPA Publication 1883. As per EPA Publication 1961, this assessment responds to a risk management approach that involves a repeating cycle of four steps: identifying hazards, assessing risks, implementing controls and checking controls.

As part of the air quality assessment, this human health risk assessment is undertaken in accordance with the EP Act and follows risk assessment methodologies recommended by:

- enHealth (2012b) Environmental health risk assessment: guidelines for assessing human health risks from environmental hazards
- NEPC (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure (the "ASC NEPM')
- Heads of EPA Australia and New Zealand (2021) PFAS National Environmental Management Plan, Version 2.0
- OEHHA. (2015). Air Toxics Hot Spots Program, Risk Assessment Guidelines, Guidance Manual for Preparation of Health Risk Assessments. Air, Community, and Environmental Research Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency

9.1 Hazard identification

Description of emission sources

BW proposes to operate a RRON facility which will process approximately 40,000 t/y of comingled food organics and garden organic (FOGO) waste predominately from local Municipalities. The main processes proposed for the RRON include carbonisation and plug flow anaerobic digestion (PFAD) of organic feedstocks. This process train will produce biochar and syngas (from carbonisation), and biogas and digestate (from the PFAD). The generated biogas will initially be transferred to the neighbouring biosolids drying facility and utilised for heat via a biogas boiler. Following closure of the biosolids drying facility (~2032) the biogas will be sent to a biogas fired CHP units to provide behind-the-meter electricity for the RRON and the Black Rock WRP. Thermal energy from the combustion of syngas will be used within the RRON facility to dry the carbonisation feedstock down to a suitable moisture content for carbonisation. The exhaust air from the treatment train will be treated through a thermal oxidizer, scrubbers and a biofilter with the treated air vented from a stack. It is expected for the treated air to include low levels of compounds such as dioxin and furans, particulate matter, hydrogen chloride (HCL), hydrogen fluoride (HF), sulphur compounds (SOx), nitrogen compounds (NOx), polyfluoroalkyl substances (PFAS), polycyclic aromatic hydrocarbons (PAHs), volatile organic carbons (VOCs) and heavy metals.

Description of surrounding areas

The areas surrounding the site ranges from farming land to public conservation areas within the Connewarre township. Six residential properties have been identified close to the site. The closest sensitive receptor is located approximately 922 m to the north-north east of the site.

9.2 Summary of air quality assessment report

Dispersion modelling has been undertaken using the EPA Victoria regulatory model AERMOD and the results benchmarked against the APAC.

The measured stack emissions from the reference facility were used to calculate emission rates for the proposed biofilter and modelled to understand the risks when the proposed facility. Further, two stacks for the CHP units were modelled to understand the risks associated with NO_2 emissions from the unit. The pollutants modelled were dioxins and furans, acid gases (HCL, HF and HS), SO_2, SO_3, PAHs, heavy metals, VOCs, PM, TSP, NO_2, odour and CO.

The dispersion model results show the predicted GLCs for all pollutants discharging from all sources are below their respective APACs. NO_2 was found to be the highest percentage limit at 40% excluding background concentrations. Including background concentrations, the percentage limit of the APAC is 68%. The remaining pollutants were all found to have percentage limits of 15% or less (excluding background concentrations).

The dispersion model results show that when venting, the discharges of pollutants from the site are predicted to be low at the site boundary and at all identified sensitive receptors and are not anticipated to lead to unacceptable health risk to the receiving environment.

A level odour risk assessment was also undertaken in accordance with EPA Publication 1883. The overall level 2 assessment score was 6, meaning activity is low risk in accordance with the Level 2 assessment. As the risk of odour is low, EPA Publication 1883 requires no further assessment a directs the user to proceed to reporting of the results.

9.3 Summary of quantitative human health risk assessment

The focus of the HHRA was on deposition and accumulation of non-volatile COPC in soils and rainwater tanks in the surrounding properties. Accumulation of deposition in soil and domestic rainwater tanks has been based on the RRON facility design-life of 25 years. The identified COPC included dioxins and furans, PAHs (as benzo(a)pyrene), cadmium, mercury and PFAS (assumed to all be PFOS).

Exposure to COPC by adults and children were calculated for a rural residential/agricultural setting and included the following exposure pathways:

- Inhalation of airborne emissions
- Deposition of particulates onto soil, including:
  - Direct dermal contact with soil/dust
  - Inhalation of dust
  - Incidental ingestion of soil/dust
  - Uptake into homegrown fruit and vegetable crops and the subsequent consumption of this produce
  - Uptake into chickens and the subsequent consumption of homegrown eggs
  - Uptake into livestock and the subsequent consumption of homegrown meat or milk
- Deposition of particulates onto a roof, runoff into a rainwater tank and the subsequent consumption and domestic use of tanks water

The estimated Hazard Index (HI) for the highest exposed sensitive receptor from deposition is 0.051, which is well below the allowable HI of 1.0. The largest contributor to HI was mercury (82%). It is noted that the mercury emissions modelled in the AQA were based on biosolids feedstock stream only, whereas in the RRON facility biosolids are expected to be a small proportion of the overall feedstock (~12%) and as such the actual mercury emissions from the RRON facility are expected to be less than the modelled values.

The estimated incremental lifetime cancer risk (ILCR) for the highest exposed sensitive receptor from deposition is 5.5×10^{-8}, which is below the acceptable level of 1×10^{-6} (or 1 in 1,000,000). The cancer risk for benzo(a)pyrene is based on early-life exposure model for protection of young children (0-1 years) from genotoxic carcinogens.

Based on the air quality assessment report and the quantitative HHRA for deposition, it is concluded that human health risk of nearby sensitive receptors is low and acceptable.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the report.

10. Recommendations

GHD recommends BW undertake monitoring of all modelled pollutants upon commissioning, including Class 3 substances PAHs, hexavalent chromium and nickel in the exhaust gas, under normal operating conditions to demonstrate that the emissions of the pollutants at the site are low as predicted in the Level 2 assessment of risk and that the emissions do not pose unacceptable risk to the receiving environment.

The emissions monitoring to be undertaken as part of the RRON facility commissioning shall be assessed as part of the commissioning process. In the event that the emission monitoring results are greater than the concentrations adopted in the AQA report the air dispersion modelling and this HHRA report should be updated to assess if the quantitative risk findings for deposition have changed.

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Appendices

Appendix A

Deposition screening assessment

BARWON WATER REGIONAL RENEWABLE ORGANICS NETWORK
APPENDIX A
DEPOSITION SCREENING ASSESSMENT

Chemical	Emission g/s.m2	Deposition at boundary (g/m2/month)	25 years deposition (mg/m2)	Accumulated soil conc (mg/kg)	Residential soil criterion (mg/kg)	Ratio (conc/criterion)
Particulate Matter (TSP)	1.16E-03	0.085				
Cabon Monoxide	2.85E-04					
Nitrogen Dioxide	1.20E-03					
Sulfur Dioxide	2.78E-04					
Hydrogen Chloride	2.22E-05					
Hydrogen Fluoride	3.52E-05					
Total VOCs as n-propane	7.41E-04					
Dioxin and furans *	3.89E-15	2.84E-13	8.53E-08	2.84E-09	5.10E-05	5.57E-05
PAHs—BaP	9.44E-09	6.90E-07	2.07E-01	6.90E-03	3	2.30E-03
Odour						
Hydrogen Sulphide	2.22E-05					
Sulfur Trioxide	8.89E-05					
Hexavalent Chromium	2.22E-07	1.62E-05	4.87E+00	1.62E-01	100	1.62E-03
Total heavy metals	7.41E-06					
Antimony	0.00E+00					
Arsenic	0.00E+00					
Cadmium	8.33E-08	6.09E-06	1.83E+00	6.09E-02	20	3.05E-03
Mercury	9.26E-07	6.77E-05	2.03E+01	6.77E-01	40	1.69E-02
Beryllium	0.00E+00					
Chromium (trivalent)	0.00E+00					
Cobalt	0.00E+00					
Manganese	0.00E+00					
Selenium	0.00E+00					
Vanadium (as V2O5)	0.00E+00					
PFAS	2.41E-10	1.76E-08	5.29E-03	1.76E-04	0.01	1.76E-02
CF4	0.00E+00					
(breakdown of heavy metal)						
Copper	2.11E-06	1.55E-04	4.64E+01	1.55E+00	6000	2.58E-04
Lead	1.11E-07	8.11E-06	2.43E+00	8.11E-02	300	2.70E-04
Nickel	1.85E-07	1.35E-05	4.06E+00	1.35E-01	400	3.38E-04
Zinc	4.76E-06	3.48E-04	1.04E+02	3.48E+00	7400	4.70E-04

* Dioxins and furans has been included as a deposition COPC due to its bioaccumulative nature and focus of emissions

Appendix B

Health risk assessment equations and model

Project Number	12585384
Project Name	Barwon Water Regional Renewable Organics Network
Client	Barwon Water
Report Name	Air Human Health Risk Assessment (Appendix B1)
Model Details	Sensitive Receptor Deposition Risk

Receptors

Adults	Children (0 - 5 years)
Yes	Yes

Pathway Selection

Exposure to compounds in soil							
Soil Ingestion	Soil Dermal	Dust Inhalation	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Exposure to compounds in water								
Water Ingestion - deliberate	Water Ingestion - incidental	Water Inhalation	Water Dermal	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk
Yes	Yes	No	No	No	Yes	Yes	Yes	Yes

Exposure to compounds in air		
Particulate Inhalation	Gas Inhalation	Gas / Particulate Inhalation
Yes	Yes	Yes

Exposure Point Concentration Inputs - Other Pollutants

1	6	7	8	9	10	11	18	22	23	24
Compound	Untilled Soil	Source	Tilled Soil	Source	Potable water - tank	Source	Form in air	Air (Long-term)	Averaging Time	Source
	Soil (C_{s_ut})		Soil (C_{s_t})		Water (C_{pw})			$C_{a\text{-}long}$		
	mg/kg		mg/kg		mg/L			mg/m^3	Days	
Cadmium	3.92E-03	Calc.	3.92E-04	Calc.	9.56E-06	Calc.	Particulate	9.73E-09	365	AQIA Max Sensitive
Mercury (inorganic)	4.35E-02	Calc.	4.35E-03	Calc.	1.06E-04	Calc.	Particulate	1.54E-10	365	AQIA Max Sensitive
Dioxins and furans	1.83E-10	Calc.	1.83E-11	Calc.	4.46E-13	Calc.	Particulate	4.54E-16	365	AQIA Max Sensitive
PFAS (PFOS)	1.13E-05	Calc.	1.13E-06	Calc.	2.77E-08	Calc.	Particulate	4.80E-07	365	AQIA Max Off Property
Benzo(a)pyrene	4.35E-04	Calc.	4.35E-05	Calc.	1.08E-06	Calc.	Particulate	1.10E-09	365	AQIA Max Sensitive
Benzo(a)pyrene (Early-Life)	4.35E-04	Calc.	4.35E-05	Calc.	1.08E-06	Calc.	Particulate	1.10E-09	365	AQIA Max Sensitive

Toxicity Input Parameters

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Compound	**Acute Inhalation Criteria**	**Averaging Time**	**Source**	**Toxicity Reference Value Oral**	**Source**	**Non-Threshold Slope Factor Oral**	**Source**	**GI Absorption**	**Source**	**Toxicity Reference Value Dermal**	**Source**	**Non-Threshold Slope Factor Dermal**	**Source**	**Oral Bioavailability**	**Source**	**Dermal Absorption Factor**	**Source**	**Background Intake Oral/Dermal**	**Toxicity Reference Value**	**Tolerable Daily Intake Inhalation**	**Inhalation Unit Risk**	**Background Intake Inhalation**	**Source**
	TRV_{IA}			**TRVo**		**SFo**		**GAF**		**TRV_D**		**SFd**		**BA_O**		**DAF**		**BI_O**	**TRV_I**	**TDI**	**URi**	**BIi**	
	mg/m^3	hr		mg/kg/day		$mg/kg/day^{-1}$		unitless		mg/kg/day		$mg/kg/day^{-1}$		**%**		unitless		%	mg/m^3	mg/kg/day	mg/m^{3-1}	%	
Cadmium	0.0054	1	TCEQ ESL	0.0008	ASC NEPM			1	ASC NEPM	0.0008	ASC NEPM			100%	ASC NEPM	0	ASC NEPM	60%	0.000005	1.4E-06		20%	ASC NEPM
Mercury (inorganic)	0.00025	1	TCEQ ESL	0.0006	ASC NEPM			0.07	ASC NEPM	0.000042	ASC NEPM			100%	ASC NEPM	0.001	ASC NEPM	40%	0.0002	5.7E-05		10%	ASC NEPM
Dioxins and furans	0.00013	1	US DoE PAC-1	2.33E-09	DoEH			1	Assumption	2.33E-09	DoEH			100%	Assumption	0.03	DoEH	54%	8.17E-09	2.33E-09		54%	DoEH
PFAS (PFOS)				0.00002	FSANZ 2017			1	Assumption	0.00002				100%	Assumption	0		10%	7.00E-05	2.0E-05		10%	
Benzo(a)pyrene	0.00003	1	TCEQ ESL			0.5	ASC NEPM	1	ASC NEPM			0.5	ASC NEPM	100%	ASC NEPM	0.06	ASC NEPM				0.14		ASC NEPM
Benzo(a)pyrene (Early-Life)		1				0.5	ASC NEPM	1	ASC NEPM			0.5	ASC NEPM	100%	ASC NEPM	0.06	ASC NEPM				0.14		ASC NEPM

Chronic Exposure Input Parameters

Exposure Parameters	Receptor	Abbreviation	Units	Parameter	References
Soil and Dust Ingestion Rate	Young children (0-5 years)	IR_{SC}	mg/day	100	ASC NEPM, Schedule B7, Table 5
	Adults	IR_{SA}	mg/day	50	ASC NEPM, Schedule B7, Table 5
Fraction of soil ingestion from the site	All	FI_s	-	1	ASC NEPM, Schedule b7; assumes 100% of soil ingestion occurs at the site
Surface Area of Skin Exposed to Soil	Young children (0-5 years)	SA_{SC}	cm^2/day	2700	ASC NEPM, Schedule B7, Table 5
	Adults	SA_{SA}	cm^2/day	6300	ASC NEPM, Schedule B7, Table 5
Soil-to-Skin Adherence Factor	All	AF	mg/cm^2/day	0.5	ASC NEPM, Schedule B7, Table 5
Fraction of day exposed	All	FE	-	1	ASC NEPM, Schedule B7; assumes washing once per day
Time Spent Outdoors	All	ETo	hours	4	ASC NEPM, Schedule B7, Table 5
Time Spent Indoors	All	ETi	hours	20	ASC NEPM, Schedule B7, Table 5
Lung Retention Factor	All	RF	-	0.375	ASC NEPM, Schedule B7, Table 5; escribes the percentage of inhalable (<10 μm) dust that is small enough to be retained in lungs and is associated with health effects (<2.5 μm)
Particulate Emission Factor	All	PEFo	(m^3/kg)	4.6E+08	Calculated for scenario, refer to Equations 19 and 20 and assumptions in Schedule B7
Indoor Air Dust Factor	All	PEFi	(m^3/kg)	2.6E+07	As per Equation 21 based assumptions presented in Schedule B7
Fraction of indoor dust comprised of outdoor soil	All	TF	-	0.5	ASC NEPM; assumes 50% soil concentration present in indoor dust
Indoor Air-to-Soil Gas Attenuation Factor	All	a	-	0.1	ASC NEPM, Schedule B7, Section 5.5
Body weight	Young children (0-5 years)	BW_C	kg	15	ASC NEPM, Schedule B7, Table 5
	Adults	BW_A	kg	70	ASC NEPM, Schedule B7, Table 5
Exposure Frequency	All	EF	days/year	365	ASC NEPM, Schedule B7, Table 5
Exposure Duration	Young children (0-5 years)	ED_C	years	6	ASC NEPM, Schedule B7, Table 5
	Adults	ED_A	years	29	ASC NEPM, Schedule B7, Table 5
Averaging Time Ingestion (non-carcinogenic)	Young children (0-5 years)	AT_{T_C}	days	2190	ASC NEPM, Schedule B7; ED x 365
	Adults	AT_{T_A}	days	10585	ASC NEPM, Schedule B7; ED x 365
Averaging Time Inhalation (non-carcinogenic)	Young children (0-5 years)	AT_{T_C}	hrs	52560	ASC NEPM, Schedule B7; ED x 365 x 24
	Adults	AT_{T_A}	hrs	254040	ASC NEPM, Schedule B7; ED x 365 x 24
Averaging Time Ingestion (carcinogenic)	All	AT_{NTing}	days	25550	ASC NEPM, Schedule B7; based on lifetime of 70 years
Averaging Time Inhalation (carcinogenic)	All	AT_{NTinh}	hrs	613200	ASC NEPM, Schedule B7; based on lifetime of 70 years
Conversion Factor Dermal Soil	All	$CF_{DermalSoil}$	kg/mg	1.00E-06	ASC NEPM, Schedule B7; conversion factor of 1x10-6 to convert mg to kg
Conversion Factor Ingestion Soil	All	$CF_{IngestionSoil}$	kg/mg	1.00E-06	ASC NEPM, Schedule B7; conversion factor of 1x10-6 to convert mg to kg
Fruit and Vegetable Consumption Rate	Young children (0-5 years)	IR_{PC}	kg/day	0.4	ASC NEPM, Schedule B7
	Adults	IR_{PA}	kg/day	0.28	ASC NEPM, Schedule B7
Fraction of Homegrown Produce	All	FH	-	0.25	Agricultural land
Drinking Water Ingestion Rate - deliberate	Young children (0-5 years)	IR_{pwc}	L/day	2	NHMRC (2011)
	Adults	IR_{pwa}	L/day	1	NHMRC (2011)
Drinking Water Ingestion Rate - incidental	Young children (0-5 years)	IR_{pwic}	L/day	0.05	NHMRC (2011)
	Adults	IR_{pwia}	L/day	0.025	NHMRC (2011)
Fraction of Drinking Water Ingestion from the Site	All	FI_{dw}	-	1	ASC NEPM, Schedule b7; assumes 100% of soil ingestion occurs at the site
Egg Consumption Rate	Young children (0-5 years)	IR_{EC}	kg/day	0.036	FSANZ (2017) 90^{th} percentile egg consumption rate for young children (2-6 years)
	Adults	IR_{EA}	kg/day	0.059	FSANZ (2017) 90^{th} percentile egg consumption rate for adults
Chicken Ingestion Rate	Young children (0-5 years)	IR_{CC}	kg/day	0.108	FSANZ (2017) 90^{th} percentile other meat consumption rate for young children (2-6 years)
	Adults	IR_{CA}	kg/day	0.221	FSANZ (2017) 90^{th} percentile other meat consumption rate for adults
Beef Ingestion Rate	Young children (0-5 years)	IR_{BC}	kg/day	0.085	FSANZ (2017) 90^{th} percentile beef consumption rate for young children (2-6 years)
	Adults	IR_{BA}	kg/day	0.163	FSANZ (2017) 90^{th} percentile beef consumption rate for adults
Milk Ingestion Rate	Young children (0-5 years)	IR_{MC}	kg/day	1.097	FSANZ (2017) 90^{th} percentile milk consumption rate for young children (2-6 years)
	Adults	$IR_{S=MA}$	kg/day	1.295	FSANZ (2017) 90^{th} percentile milkegg consumption rate for adults
Bathing Event Exposure Time	Young children (0-5 years)	ET_{BC}	hr/event	1	Assumption; assumes that residents may spend up to an hour a day immersed in water
	Adults	ET_{BA}	hr/event	1	Assumption; assumes that residents may spend up to an hour a day immersed in water
Skin surface are exposed to water	Young children (0-5 years)	SA_{WC}	cm^2/day	9500	enHealth (2012); 95^{th} percentile total body surface area (3-6 year old)
	Adults	SA_{WA}	cm^2/day	20000	enHealth (2012); 95^{th} percentile total body surface area (3-6 year old)
Conversion Factor Ingestion	All	$CF_{Ingestion}$	kg/mg	1.00E-06	ASC NEPM, Schedule B7; conversion factor of 1x10-6 to convert mg to kg
Dermal Exposure Event Frequency	All	EF_{WD}	events/day	1	Assumption

Physicochemical Input Parameters

1	2	3	4	5
Compound	**Half life in soil**	**Source**	**Dermal permeability**	**Source**
	$t_{1/2}$		K_p	
	days		cm/hr	
Cadmium	100000000	OEHHA (2015)	1.00E-03	RAGS E
Mercury (inorganic)	100000000	OEHHA (2015)	1.00E-03	RAGS E
Dioxins and furans	7000	OEHHA (2015)	8.10E-01	RAGS E
PFAS (PFOS)	365000			
Benzo(a)pyrene	430	OEHHA (2015)	7.13E-01	RAGS E
Benzo(a)pyrene (Early-Life)	430	OEHHA (2015)	7.13E-01	RAGS E

Exposure Model

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Compound	Exposure to compounds in soil - Child								Exposure to compounds in soil - Adult								Exposure to compounds in water - Child								
	Soil Ingestion	Soil Dermal	Dust Inhalation	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk	Soil Ingestion	Soil Dermal	Dust Inhalation	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk	Water Ingestion - deliberate	Water Ingestion - incidental	Water Inhalation	Water Dermal	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk
	Intake	Intake	Exposure concentration	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Exposure concentration	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake	Intake
	mg/kg/day	mg/kg/day	mg/m^3	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/m^3	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day
	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 5	Equation 5	Equation 5	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 5	Equation 5	Equation 5	Equation 6	Equation 7	Equation 8	Equation 9	Equation 4	Equation 5	Equation 5	Equation 5	Equation 5
Cadmium	2.61E-08	0.00E+00	2.44E-11	2.92E-07	1.38E-11	1.33E-09	1.75E-10	1.38E-10	2.80E-09	0.00E+00	2.44E-11	1.59E-07	4.86E-12	5.84E-10	7.20E-11	3.49E-11	1.27E-06	3.19E-08				1.32E-11	1.38E-09	1.22E-10	9.61E-11
Mercury (inorganic)	2.90E-07	3.92E-09	2.71E-10	4.53E-07	2.13E-08	4.99E-09	6.11E-09	3.37E-08	3.11E-08	1.96E-09	2.71E-10	2.02E-07	7.49E-09	2.19E-09	2.51E-09	8.53E-09	1.42E-05	3.54E-07				1.17E-08	3.06E-09	2.71E-09	1.49E-08
Dioxins and furans	1.22E-15	4.93E-16	1.14E-18	1.02E-22	5.37E-17	1.57E-16	8.20E-15	7.36E-15	1.30E-16	2.47E-16	1.14E-18	3.13E-23	1.89E-17	6.87E-17	3.37E-15	1.86E-15	5.95E-14	1.49E-15				6.15E-16	1.16E-15	1.99E-14	1.79E-14
PFAS (PFOS)	7.56E-11	0.00E+00	7.07E-14	3.27E-09	3.60E-11		5.77E-10	1.47E-09	8.10E-12	0.00E+00	7.07E-14	1.70E-09	1.26E-11		2.37E-10	3.72E-10	3.69E-09	9.22E-11				1.46E-10		4.17E-10	1.06E-09
Benzo(a)pyrene	2.90E-09	2.35E-09	2.71E-12	4.35E-09	4.56E-14	1.38E-13	2.04E-09	9.15E-09	3.11E-10	1.18E-09	2.71E-12	1.33E-09	1.60E-14	6.04E-14	8.37E-10	2.31E-09	1.44E-07	3.61E-09				4.48E-13	9.36E-13	4.83E-09	2.18E-08
Benzo(a)pyrene (Early-Life)	2.90E-09	2.35E-09	2.71E-12	4.35E-09	4.56E-14	1.38E-13	2.04E-09	9.15E-09	3.11E-10	1.18E-09	2.71E-12	1.33E-09	1.60E-14	6.04E-14	8.37E-10	2.31E-09	1.44E-07	3.61E-09				4.48E-13	9.36E-13	4.83E-09	2.18E-08

Equation		Equation ID	Source
Intake via soil ingestion	$Intake = C_s \, x \, \frac{IR_S \, x \, FI \, x \, BA \, x \, CF_{Ingestion} \, x \, EF \, x \, ED}{BW \, x \, AT}$	1	ASC NEPM
Intake via dermal contact with soil	$Intake = C_s \, x \, \frac{SA \, x \, AF \, x \, FE \, x \, DAF \, x \, CF_{Dermal} \, x \, EF \, x \, ED}{BW \, x \, AT}$	2	ASC NEPM
Exposure concentration for dust inhalation	$Exposure \ concentration = C_s \, x \, \frac{\left(\frac{1}{PEF_o} \, x \, ET_o + \frac{1}{PEF_i} \, x \, ET_i \ \ x \, TF\right) x \, RF \, x \, EF \, x \, ED}{AT}$	3	ASC NEPM
Intake via the consumption of fruit and vegetables	$Intake = C_s \, x \, \frac{FHG \, x \, PUF \, x \, IR_P \, x \, CF_{Ingestion} \, x \, EF \ \ ED}{BW \, x \, AT}$	4	ASC NEPM
Intake via the consumption of eggs, livestock and milk	$Intake = C_F \, x \, \frac{IR_F \, x \, FI \, x \, BA \, x \, EF \, x \, ED}{BW \, x \, AT}$	5	ASC NEPM
Intake via deliberate water consumption	$Intake = C_{pw} \, x \, \frac{IR_{pw} \, x \, FI_w \, x \, BA \, x \, EF \, x \, ED}{BW \, x \, AT}$	6	ASC NEPM
Intake via incidental water consumption	$Intake = C_{pw} \, x \, \frac{IR_{piw} \, x \, FI_w \, x \, BA \, x \, EF \, x \, ED}{BW \, x \, AT}$	7	ASC NEPM
Intake via dermal contact with water (inorganics)	$Intake = C_w \, x \, \frac{K_p \, x \, ET_B \, x \, EF_B \, x \, SA \, x \, EF \, x \, ED}{BW \, x \, AT}$	8	
Intake via inhalation during bathing		9	
Exposure concentration for emissions inhalation - particulates	$Exposure \ concentration = C_a \, x \, \frac{ET \, x \, FI \, xRF \, x \, EF \, x \, ED}{AT}$	10	
Exposure concentration for emissions inhalation - gases	$Exposure \ concentration = C_a \, x \, \frac{ET \, x \, FI \, x \, EF \, x \, ED}{AT}$	11	

27	28	32	33	34	35	36	37	38	39	40	41
Exposure to compounds in water - Adult						**Exposure to compounds in air - Child**			**Exposure to compounds in air - Adult**		
Water Ingestion - deliberate	**Water Ingestion - incidental**	**Uptake in eggs**	**Uptake in chickens**	**Uptake in beef**	**Uptake in milk**	**Particulate Inhalation**	**Gas Inhalation**	**Gas / Particulate Inhalation**	**Particulate Inhalation**	**Gas Inhalation**	**Gas / Particulate Inhalation**
Intake	**Intake**	**Intake**	**Intake**	**Intake**	**Intake**	**Exposure concentration**	**Exposure concentration**	**Exposure concentration**	**Exposure concentration**	**Exposure concentration**	**Exposure concentration**
mg/kg/day	**mg/kg/day**	**mg/kg/day**	**mg/kg/day**	**mg/kg/day**	**mg/kg/day**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**
Equation 8	Equation 9	Equation 5	Equation 5	Equation 5	Equation 5	Equation 10 / 11	Equation 10 / 11	Equation 10 / 11	Equation 10 / 11	Equation 10 / 11	Equation 10 / 11
1.37E-07	3.41E-09	4.63E-12	6.03E-10	5.01E-11	2.43E-11	3.65E-09		3.65E-09	3.65E-09		3.65E-09
1.52E-06	3.79E-08	4.12E-09	1.34E-09	1.11E-09	3.78E-09	5.79E-11		5.79E-11	5.79E-11		5.79E-11
6.37E-15	1.59E-16	2.16E-16	5.07E-16	8.18E-15	4.54E-15	1.70E-16		1.70E-16	1.70E-16		1.70E-16
3.95E-10	9.88E-12	5.14E-11		1.71E-10	2.69E-10	1.80E-07		1.80E-07	1.80E-07		1.80E-07
1.55E-08	3.87E-10	1.57E-13	4.10E-13	1.99E-09	5.51E-09	4.14E-10		4.14E-10	4.14E-10		4.14E-10
1.55E-08	3.87E-10	1.57E-13	4.10E-13	1.99E-09	5.51E-09	4.14E-10		4.14E-10	4.14E-10		4.14E-10

Risk Characterisation Model - Chronic Exposure

Compound	Risk from compounds in soil										
	Soil Ingestion	Soil Dermal	Dust Inhalation	Uptake in plants	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk	Total - Residential	Total - Agricultural	Total
	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HI / ILCR	HI / ILCR	HI / ILCR
	-	-	-	-	-	-	-	-	-	-	-
	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	
Cadmium	8.16E-05	0.00E+00	6.10E-06	9.13E-04	4.33E-08	4.17E-06	5.47E-07	4.31E-07	5.44E-04	5.19E-06	5.49E-04
Mercury (inorganic)	8.06E-04	1.55E-04	1.51E-06	1.26E-03	5.92E-05	1.39E-05	1.70E-05	9.36E-05	1.59E-03	1.84E-04	1.78E-03
Dioxins and furans	1.13E-06	4.59E-07	3.03E-10	9.53E-14	5.00E-08	1.46E-07	7.64E-06	6.86E-06	1.59E-06	1.47E-05	1.63E-05
PFAS (PFOS)	4.20E-06	0.00E+00	1.12E-09	1.82E-04	2.00E-06		3.21E-05	8.17E-05	1.86E-04	1.16E-04	3.02E-04
Benzo(a)pyrene	1.89E-10	3.44E-10	1.94E-13	4.62E-10	5.28E-15	1.84E-14	2.61E-10	8.72E-10	5.33E-10	1.59E-09	2.13E-09
Benzo(a)pyrene (Early-Life)	7.72E-10	9.48E-10	4.48E-13	1.46E-09	1.60E-14	5.26E-14	7.59E-10	2.90E-09	1.72E-09	5.12E-09	6.84E-09

Compound	Soil Targets												
	Soil Target - Ingestion	Soil Target - Dermal	Soil Target - Inhalation	Soil Target - Plant Uptake	Soil Target - Egg Uptake	Soil Target Chicken Uptake	Soil Target - Beef Uptake	Soil Target - Milk Uptake	Soil Target Residential	*Check*	Soil Target Agricultural	Soil Target Total
	RBSL	RBSL	RBSL	RBSL	RBSL	RBSL	RBSL	RBSL	RBSL	*RBSL*	RBSL	RBSL
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	*mg/kg*	mg/kg	mg/kg
	Equation 2	Equation 2	Equation 2	Equation 2	Equation 2	Equation 2	Equation 2	Equation 2	Equation 2	*ASC NEPM*	Equation 2	Equation 2
Cadmium	4.80E+01		6.42E+02	8.58E+00	9.05E+04	9.41E+02	7.16E+03	9.09E+03	7	*15*	7.55E+02	7.13E+00
Mercury (inorganic)	5.40E+01	2.80E+02	2.89E+04	6.92E+01	7.35E+02	3.14E+03	2.57E+03	4.65E+02	27	*36*	2.37E+02	2.45E+01
Dioxins and furans	1.61E-04	3.98E-04	6.03E-01	1.92E+03	3.65E-03	1.25E-03	2.39E-05	2.66E-05	0.0001		1.24E-05	1.12E-05
PFAS (PFOS)	2.70E+00		1.01E+04	6.24E-02	5.68E+00		3.54E-01	1.39E-01	0.0610	0.009	9.80E-02	3.76E-02
Benzo(a)pyrene	2.31E+01	1.26E+01	2.25E+04	9.42E+00	8.25E+05	2.36E+05	1.67E+01	4.99E+00	8	*8*	2.73	2.05
Benzo(a)pyrene (Early-Life)	5.64E+00	4.59E+00	9.71E+03	2.98E+00	2.71E+05	8.27E+04	5.74E+00	1.50E+00	3	*3*	0.85	0.64

Equation	Equation ID	Source
$HI = \frac{Intake}{TRV\ x\ (1 - Backgrouind\ Intake)}$	1	ASC NEPM
$RBSL = C_s\ x\ \frac{1}{HI}$	2	ASC NEPM
$RBSL = C_w\ x\ \frac{1}{HI}$	3	ASC NEPM

Risk from compounds in water										Water Target				Risk from compounds in air			Risk Total
Water Ingestion - deliberate	Water Ingestion - incidental	Water Dermal	Uptake in eggs	Uptake in chickens	Uptake in beef	Uptake in milk	Total Residential	Total Agricultural HI	Total HI	Water Target Residential	*Check*	Water Target Agricultiral	Water Target Total	Particulate Inhalation	Gas Inhalation	Gas / Particulate Inhalation	All Pathway HI
HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HQ / ILCR	HI / ILCR	HI / ILCR	HI / ILCR	RBSL	*RBSL*	RBSL	RBSL	HI / ILCR	HI / ILCR	HI / ILCR	HQ / ILCR
-	-	-	-	-	-	-	-	-	-	mg/L	*mg/L*	mg/L	mg/L	-	-	-	-
Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	Equation 1	-	-	-	Equation 3	*NHMRC (2011)*	Equation 3	Equation 3	Equation 4	-	-	-
3.98E-03	9.95E-05	0.00E+00	4.12E-08	4.30E-06	3.81E-07	3.00E-07	4.08E-03	5.02E-06	4.09E-03	2.34E-03		1.90E+00	2.34E-03	9.12E-04	0.00E+00	9.12E-04	5.55E-03
3.93E-02	9.83E-04	0.00E+00	3.26E-05	8.49E-06	7.52E-06	4.15E-05	4.03E-02	9.01E-05	4.04E-02	2.63E-03		1.18E+00	2.63E-03	3.21E-07	0.00E+00	3.21E-07	4.22E-02
5.54E-05	1.38E-06	0.00E+00	5.73E-07	1.08E-06	1.85E-05	1.67E-05	5.68E-05	3.69E-05	9.37E-05	7.85E-09		1.21E-08	4.76E-09	4.53E-08	0.00E+00	4.53E-08	1.10E-04
2.05E-04	5.12E-06	0.00E+00	8.12E-06	0.00E+00	2.32E-05	5.90E-05	2.10E-04	9.03E-05	3.00E-04	1.32E-04		3.06E-04	9.21E-05	2.86E-03	0.00E+00	2.86E-03	3.46E-03
9.39E-09	2.35E-10	0.00E+00	5.18E-14	1.25E-13	6.19E-10	2.07E-09	9.63E-09	2.69E-09	1.23E-08	1.12E-03		4.02E-03	8.79E-04	2.95E-11		2.95E-11	1.45E-08
3.84E-08	9.61E-10	0.00E+00	1.58E-13	3.57E-13	1.80E-09	6.91E-09	3.94E-08	8.71E-09	4.81E-08	2.75E-04		1.24E-03	2.25E-04	5.83E-11		5.83E-11	5.50E-08

ILCR	5.50E-08
HI	5.13E-02

Soil-to-Air Particulate Emission Factor Calculations

Exposure Parameter	Abbreviation	Units	Parameter	References
Area of site	A_{site}	Acres	0.50	Assumed as default (minimum)
Constant	A	-	11.68	US EPA (2002); default value for the assessment of fugitive dust emissions at small sites
Constant	B	-	23.49	US EPA (2002); default value for the assessment of fugitive dust emissions at small sites
Constant	C	-	288.00	US EPA (2002); default value for the assessment of fugitive dust emissions at small sites
Dispersion factor	Q/C	$g/m^2/s$ per kg/m^3	89.03	Calculated according to US EPA (2002) methodology $Q/C = A \times \exp\left[\frac{(\ln A_{site} - B)^2}{C}\right]$
Fraction of vegetative cover	V	Unitless	0.75	ASC NEPM, Schedule B7; residential assumption
Mean annual windspeed	U_m	m/s	3.7	Site specific
Equivalent threshold value	U_t	m/s	7.2	Asc NEPM, Schedule B8; default as per UK EA (2009)
Constant	x	Unitless	1.7	Constant from Cowherd *et al.* (1985) $x = 0.886 \frac{U_t}{U_m}$
Windspeed distribution function	F_x	Unitless	0.568	Calculated on the basis of Equation 20
Indoor dust loading factor	DL	mg/m^3	0.039	ASC NEPM, Schedule B7; 95th percentile from Australian data (enHealth 2012)
Particulate emission factor outdoor	PEF_o	mg/m^3	4.6E+08	Relates the concentration of respirable dust particles (<10 µm) in the air with wind speed, vegetative cover and the area of the site occupied by exposed soil. Assumes 100% site-derived soil $PEF_o\,(m^3/kg) = \frac{Q/C \times 3600}{0.036 \times (1-V) \times (\frac{U_m}{U_t})^3 \times F_x}$
Particulate emission factor indoor	PEF_i	mg/m^3	2.6E+07	Indoor dust concentrations are assumed to equilibrate with outdoor dust concentrations through building ventilation. Indoor air is also enriched with dust compared to the outdoor environment, due to the movement of dust indoors on clothing, footwear, etc., as described by the indoor dust loading factor (DL) $PEF_i\,(m^3/kg) = \frac{1}{DL \times 10^{-6}}$

Soil to Plant Uptake Factor Calculations

Parameter	Symbol	Unit	Parameter	Details
Plant Uptake Factor	PUF	kg/day	See table below	$PUF = F_{HG} \times ([CF_{Tuber} \times C_{Tuber}])+[CF_{Root} \times C_{Root}])+[CF_{Green} \times C_{Green}])+[CF_{Tree} \times C_{Tree}]))$

Produce Group	Adults (%)	Adult Consumption Rate (kg/day)	Children (%)	Child Consumption Rate (kg/day)
Green Vegetables	59	0.1534	55	0.055
Root Vegetables	18	0.0468	17	0.017
Tuber Vegetables	23	0.0598	28	0.028
Tree Fruit	100	0.14	100	0.18
Total consumption		0.4		0.28

1	2	3	4	5	7	8	10	11	12
Compound	Soil to plant concentration factor (mg/kg fresh weight to mg/kg soil dry weight)						Plant Uptake Factor (kg/day) - Child	Plant Uptake Factor (kg/day) - Adult	Aboveground crops value adopted?
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Aboveground crops	Source	Adopted	Adopted	
Cadmium	0.052	0.029	0.031	0.0014	1.25E-01	RAIS	1.12E-03	2.85E-03	No
Mercury (inorganic)	0.0038	0.0069	0.0042	0.001	2.25E-01	RAIS	1.56E-04	3.24E-04	No
Dioxins and furans					1.20E-10	RAIS	8.40E-12	1.20E-11	Yes
PFAS (PFOS)	0.2	0.13	0.05	0.015	2.00E-01	NEMP	4.33E-03	1.05E-02	No
Benzo(a)pyrene					2.14E-03	RAIS	1.50E-04	2.14E-04	Yes
Benzo(a)pyrene (Early-Life)					2.14E-03	RAIS	1.50E-04	2.14E-04	Yes

Deposition to Soil Calculations

Parameter	Symbol	Unit	Parameter	Details	Source
Average soil concentration over the evaluation period - untilled soil	C_{s_ut}	mg/kg	See table below	$C_s = D_s \, x \, \frac{[1 - exp(-K_s \, x \, T_d)]}{K_s \, x \, Z_s \, x \, BD}$	US EPA (2005)
Average soil concentration over the evaluation period - tilled soil	C_{s_t}	mg/kg	See table below	$C_s = DEP \, x \, \frac{[1 - ex \quad (-K_s \, x \, T_d)]}{K_s \, x \, Z_s \, x \, BD}$	US EPA (2005)
Deposition rate onto soil per year	DEP	$mg/m^2.year$	See table below	Calculated in AQIA - Max receptor for all CoPC	GHD (2021)
Time period over which deposition occurs (time period of combustion)	T_d	years	25	25 Years design life	
Soil loss constant	K_s	$years^{-1}$	See table below	$K_s = \frac{0.693}{t_{1/2}}$	OEHHA (2015)
Soil mixing depth - untilled soil	Z_{s_ut}	m	0.02	Default for surface soils - used for direct contact pathways	US EPA (2005)
Soil mixing depth - tilled soil	Z_{s-t}	m	0.2	Default mixing depth for agricultural soils - used for food production pathways	US EPA (2005)
Soil bulk density	BD	kg/m^3	1500	Typical value for loamy soil	US EPA (2005)
Chemical specific soil half-life	$t_{1/2}$	days	See physchem data	Literature values	Chemical specific

Compound	C_{s_ut}	C_{s_t}	DEP	K_s	Source
	mg/kg	mg/kg	$mg/m^2/year$	$days^{-1}$	
Cadmium	0.003918	0.0003918	4.70E-03	6.93E-09	AQA Max Sensitive Receptor
Mercury (inorganic)	0.04353333	0.00435333	5.22E-02	6.93E-09	AQA Max Sensitive Receptor
Dioxins and furans	1.8261E-10	1.8261E-11	2.19E-10	9.90E-05	AQA Max Sensitive Receptor
PFAS (PFOS)	1.1345E-05	1.1345E-06	1.36E-05	1.90E-06	AQA Max Sensitive Receptor
Benzo(a)pyrene	0.00043521	4.3521E-05	5.33E-04	1.61E-03	AQA Max Sensitive Receptor
Benzo(a)pyrene (Early-Life)	0.00043521	4.3521E-05	5.33E-04	1.61E-03	AQA Max Sensitive Receptor

Rainwater Impact Calculations

Parameter	Symbol	Unit	Parameter	Details	Source
Concentration in rainwater	C_{dw}	mg/L	See table below	$C_{dw} = \frac{DEP\ x\ A\ x\ RCF}{V}$	DoH
Deposition rate onto rooves per year	DEP	$mg/m^2.year$	See table below	Calculated in AQIA	GHD (2023)
Area of roof	A	m^2	250	Typical floor area of a residential dwelling in Australia	Assumption
Annual rainfall	R	m/year	0.516	Average annual rainfall for Marulan	Bureau of Meteorology Climate Statistics for Breakwater Geelong Racecourse (2011 - 2023)
Percentage of runoff collected	RCF	-	0.8	Assumes a percentage of rainfall is not effectively captured in rainwater tanks (e.g. gutter overflow)	DoH
Runoff loss	RLF	m/year	0.024	Assumes 2 mm lost per month in association with the wetting of surfaces	DoH
Unit correction factor	CF_{dw}	m^3/L	1000	1000 L/m^3	Conversion
Volume of rainwater collected	V	L/year	98400	*V = (R - RLF) x A x RCF x* CF_{dw}	DoH
Total dust deposition	DEP_{TSP}	$kg/m^2.year$	0.00061	Calculated in AQIA - Max receptor	GHD (2023)
Total dust entering tank annually	DEP_{TSP}	kg/year	0.12		
Water-filled soil porosity	Θ_w	-	196800.00	Representative of large tank volume	Assumption
Air-filled soil porosity	Θ_a	-	0.00	Sediment assumed to be saturated	Assumption
Bulk density of dust	ρ	g/cm^3	0.5		

1	2	3	4	5	6	7	
Compound	**C_{dw} Total**	**DEP CoPC**	**DEP CoPC**	**Concentration CoPC in sediment**	**Concentration CoPC dissolved in tank water**	**Acid soluble fraction**	**Source**
	mg/L	$mg/m^2/year$	mg/year	mg/kg	mg/L	%	
Cadmium	9.56E-06	4.70E-03	9.40E-01	7.74E+00	2.55E-07	100%	
Mercury (inorganic)	1.06E-04	5.22E-02	1.04E+01	8.60E+01	2.69E-07	100%	
Dioxins and furans	4.46E-13	2.19E-10	4.39E-08	3.61E-07	2.29E-17	100%	
PFAS (PFOS)	2.77E-08	1.36E-05	2.72E-03	2.24E-02	5.53E-10	100%	
Benzo(a)pyrene	1.08E-06	5.33E-04	1.07E-01	8.77E-01	2.17E-06	100%	
Benzo(a)pyrene (Early-Life)	1.08E-06	5.33E-04	1.07E-01	8.77E-01	2.17E-06	100%	

Soil to Egg, Meat and Milk Calculations

Parameter	Symbol	Unit	Parameter	Details	Source
Concentration in produce	$C_{Produce}$	mg/kg	See table below	$C_{produce} = TC_A \times (Dose_{Inhal} + Dose_{Water} + Dose_{Pasture} + Dose_{Feed} + Dose_{Soil})$	OEHHA (2015)
Dose via inhalation	$Dose_{Inhal}$	mg/day	Calculated	$Dose_{Inhal} = BR_A \; x \; C_{A-long}$	OEHHA (2015)
Dose via water consumption	$Dose_{Water}$	mg/day	Calculated	$Dose_{Water} = IRW_A \; x \; FSW \; x \; C_w$	OEHHA (2015)
Dose via feed consumption	$Dose_{Plants}$	mg/day	Calculated	$Dose_{Feed} = (1 - FG) \; x \; IR_F \; x \; L \; x \; C_V$	OEHHA (2015)
Dose via pasture consumption	$Dose_{Pasture}$	mg/day	Calculated	$Dose_{Pasture} = FG \; x \; IR_F \; x \; C_V$	OEHHA (2015)
Dose via incidental soil ingestion	$Dose_{Soil}$	mg/day	Calculated	$Dose_{Soil} = C_s \; x \; SI_A$	OEHHA (2015)
Soil ingestion rate	SI_A	kg/day	Calculated	$SI_A = [(1 - FG) \; x \; FS_f \; x \; IR_F] + [FG \; x \; FS_p \; x \; IR_F]$	OEHHA (2015)
Transfer coefficient for produce	TC_A	day/kg	See table below	Chemical-specific transfer factor	OEHHA (2015)

Parameter	Symbol	Unit	Poultry - Egg Laying	Poultry - Meat	Beef Cattle	Dairy Cattle	Pigs	Source
Body weight	BW_A	kg	1.6	1.7	533	575	55	OEHHA (2015)
Inhalation rate	BR_A	m^3/day	0.4	0.4	107	115	7	OEHHA (2015)
Water consumption rate	IR_{WA}	kg/day	0.23	0.16	45	110	6.6	OEHHA (2015)
Food intake rate	IR_F	kg/day	0.12	0.13	9	22	2.4	OEHHA (2015)
Soil fraction of feed	FS_f	-	0	0	0.01	0.01	0	OEHHA (2015)
Soil fraction of pasture	FS_p	-	0.02	0.02	0.05	0.05	0.02	OEHHA (2015)
Fraction of water from site	FSW	-	1	1	1	1	1	Assumption
Fraction of diet that is pasture	FG	-	0.2	0.2	1	1	0.2	Assumption
Fraction of non-pasture feed that is sourced from the impacted area	L		0.2	0.2	0	0	0.2	Assumption
Soil ingestion rate	SI	kg/day	0.00048	0.00052	0.45	1.1	0.0096	Calculated

1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19
Compound	C_{eggs_soil}	$C_{chickens\_soil}$	C_{beef_soil}	C_{milk_soil}	C_{pigs_soil}	C_{V_soil}	C_{eggs_water}	$C_{chickens\_water}$	C_{beef_water}	C_{milk_water}	C_{pigs_water}	TC_{eggs}	$TC_{chicken}$	TC_{beef}	TC_{milk}	TC_{pork}	Source
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	d/kg	d/kg	d/kg	d/kg	d/kg	
Cadmium	2.31E-08	7.40E-07	1.24E-07	7.55E-09	2.31E-07	4.90E-05	2.20E-08	7.64E-07	8.60E-08	5.26E-09	3.15E-07	0.01	0.5	0.0002	5.00E-06	0.005	OEHHA (2015)
Mercury (inorganic)	3.55E-05	2.77E-06	4.31E-06	1.84E-06	1.78E-06	9.79E-04	1.95E-05	1.70E-06	1.91E-06	8.18E-07	1.40E-06	0.8	0.1	0.0004	7.00E-05	0.002	OEHHA (2015)
Dioxins and furans	8.95E-14	8.71E-14	5.79E-12	4.03E-13	1.78E-14	2.19E-21	1.03E-12	6.42E-13	1.40E-11	9.81E-13	2.94E-13	10	9	0.7	0.02	0.1	OEHHA (2015)
PFAS (PFOS)	6.00E-08		4.07E-07	8.04E-08		2.27E-07	2.44E-07		2.94E-07	5.81E-08							
Benzo(a)pyrene	7.61E-11	7.65E-11	1.44E-06	5.00E-07	3.04E-08	9.31E-08	7.47E-10	5.20E-10	3.41E-06	1.19E-06	4.29E-07	0.003	0.003	0.07	0.01	0.06	OEHHA (2015)
Benzo(a)pyrene (Early-Life)	7.61E-11	7.65E-11	1.44E-06	5.00E-07	3.04E-08	9.31E-08	7.47E-10	5.20E-10	3.41E-06	1.19E-06	4.29E-07	0.003	0.003	0.07	0.01	0.06	OEHHA (2015)

Concentrations in highlighted cells taken from PFAS exposure model (Appendix B2)

* Values from Baes, C F, Sharp, R. D., Sjoreen, A. L. and Shor, R. W. (1984) A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture

^ Eggs and poultry uptake factors assumed to be at the upper end of the range of values presented by OEHHA (2015) for As, Be, Cd, Pb and Ni

Emission Deposition Inputs

1	3	4	5	7	8
Pollutant	Averaging Period	Statistic	Unit	Increment	
				Max Site Boundary	Max Sensitive Receptor
Dioxins and furans	Annual	Maximum	g/m2/year	3.4E-12	2.2E-13
Benzo(a)pyrene	Annual	Maximum	g/m2/year	8.3E-06	5.3E-07
Mercury (inorganic)	Annual	Maximum	g/m2/year	8.1E-04	5.2E-05
Cadmium	Annual	Maximum	g/m2/year	7.3E-05	4.7E-06
PFAS (PFOS)	Annual	Maximum	g/m2/year	2.1E-07	1.4E-08

Ambient Concentration Inputs - Chronic

1	3	4	5	7	8
Pollutant	Averaging Period	Statistic	Unit	Increment	
				Max Site Boundary	Max Sensitive Receptor
Dioxins and furans	Annual	Maximum	µg/m³	1.7E-11	4.5E-13
Benzo(a)pyrene	Annual	Maximum	µg/m³	4.2E-05	1.1E-06
Benzo(a)pyrene (Early-Life)	Annual	Maximum	µg/m³	4.2E-05	1.1E-06
Mercury (inorganic)	Annual	Maximum	µg/m³	5.9E-06	1.5E-07
Cadmium	Annual	Maximum	µg/m³	3.7E-04	9.7E-06
PFAS (PFOS)	Annual	Maximum	µg/m³	1.1E-06	2.8E-08

References

Abbreviation	Details
ASC NEPM	NEPC (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure
OEHHA	OEHHA (2015) Air Toxics Hot Spots Program, Risk Assessment Guidelines, Guidance Manual for Preparation of Health Risk Assessments
RAGS E	US EPA (2005) Risk Assessment Guidance for Superfund (RAGS): Part E
RIVM	RIVM (2009) Re-evaluation of some human toxicological Maximum Permissible Risk levels earlier evaluated in the period 1991-2001
ADWG	NHMRC (2011) Australian drinking water guidelines
RAIS	RAIS (2021) Toxicity and chemical parameters database (accessed August 2021)
DoEH	DoEH (2005) Human Health Risk Assessment of Dioxins in Australia, National Dioxins Program Technical Report No. 12
CRC CARE	Friebel and Nadebaum (2011) CRC CARE Technical Report 10: Health screening levels for petroleum hydrocarbons in soil and groundwater
TCEQ ESL	Texas Commission on Environmental Quality (2016) Effects screening levels (ESLs)
US DoE PAC-1	US Department of Energy (2018) Protective Action Criteria (PAC)
DoH	DoH (2011) Guidance on the use of rainwater tanks, Determining the required size of tank to be installed
US EPA IRIS	US EPA IRIS Database
Cal EPA OEHHA	OEHHA 2008. Technical Supporting Document for Noncancer RELs
AQ NEPM	NEPC (2016) National Environment Protection (Ambient Air Quality) Measure

Area	Max Sensitive receptor
Exposure Meda	Tank Water
Exposure Scenario	Rural residential / agricultural
Chemicals of Potential Concern	PFOS+PFHxS

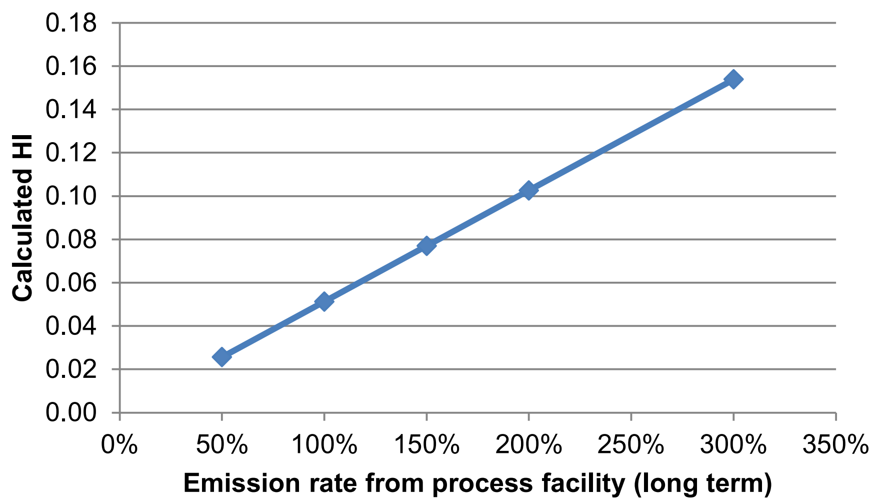
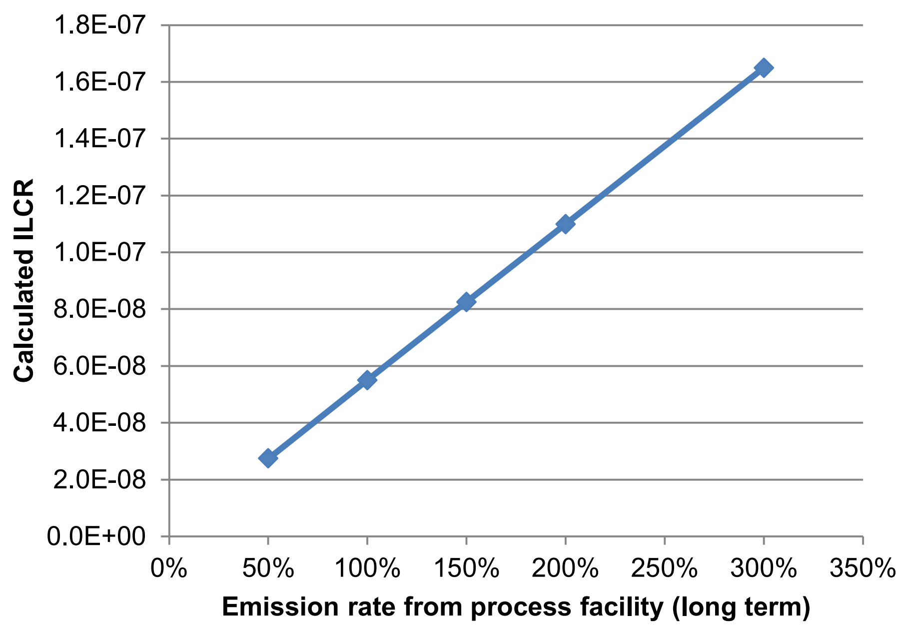
Parameter	Unit	Value	Details	Source
Water quality inputs				
Concentration in water	**µg/L**	**2.76702E-05**	Tank water resulting from 25 years of deposition on roof top	From deposition model
Concentration in water (C_w)	**mg/L**	**2.76702E-08**		
Percentage PFHxS	**%**	**0%**	Assume all PFOS	Site-specific
Egg consumption exposure inputs				
Fraction sourced from tank ($F_{Water\_Chickens}$)	%	100%	OEHHA (2015)	From deposition model
Concentration in edible portion of egg (C_{Eggs})	mg/kg	2.4E-07	$C_{Egg} = \frac{TF_{Egg}\ x\ C_{Water}\ x\ IR_{Water\_chicken}\ x\ F_{Chicken\_water}\ x\ BIO}{LR\ x\ W_{egg}\ x\ F_{Edible}}$	DoD (2017a)
Poultry water ingestion rate ($IR_{Water\_Chicken}$)	L/day	0.32	Average daily water consumption of a laying hen	ANZECC (2000)
Edible fraction of egg (F_{Edible})	%	0.87	Approximate portion of an egg that is edible	Kowalczyk *et al.* (2020)
Egg weight (W_{egg})	kg/egg	0.060	Weight of a typical egg	Assumption
Transfer factor to chicken eggs (TF_{Eggs})	mg/day edible egg per mg/day intake	1.1	TF of 1 have been estimated for PFOS and PFHxS. The TF has been adjusted upwards according the the equation TF/Fedible	Kowalczyk *et al.* (2020)
Poultry laying rate (LR)	eggs/day	8.0E-01	Laying hens can produce up to approximately 300 eggs per year	Assumption
Meat and offal consumption exposure inputs - cattle				
Fraction of water sourced from creek (F_{Water_Stock})	%	100%	OEHHA (2015)	From deposition model
Concentration in meat (C_{Meat})	mg/kg	2.9E-07	$C_{Meat} = TF_{Serum}\ x\ C_w\ x\ F_{Water\_stock}\ x\ CF_{Meat}$	Drew *et al.* (2021)
Meat (muscle) consumption rate (IR_{Muscle})	kg/day	0.085	90th %ile meat consumption rate reported for the Australian population (2-6 years)	FSANZ (2017)
Serum to meat concentration factor (CF_{Meat})	L/kg	0.08	Describes the transfer of PFAS from plasma to meat (mg/kg meat per mg/L plasma), with the combined value for PFOS+PFHxS refelcting the ratio of these compounds in water	Kowalczyk (2013)
Transfer factor to serum (TF_{Serum})	mg/L serum per mg/L water	140	Describes the relationship between the PFAS concentration in water and serum, with the combined value for PFOS+PFHxS relfecting the ratio of these compounds in water	Drew *et al.* (2021)
Milk consumption exposure inputs				
Fraction of water sourced from creek (F_{Water_Dairy})	%	100%	OEHHA (2015)	From deposition model
Concentration in milk (C_{Milk})	mg/kg	5.8E-08	$C_{Milk} = TF_{Serum}\ x\ C_w\ x\ F_{Water\_stock}\ x\ CF_{Milk}$	Drew *et al.* (2021)
Serum to milk concentration factor (CF_{Milk})	L/kg	0.02	Describes the transfer of PFAS from plasma to milk (mg/kg milk per mg/L plasma), with the combined value for PFOS+PFHxS refelcting the ratio of these compounds in water	Kowalczyk (2013)

Area	Max Sensitive receptor
Exposure Meda	Deposition in Soil
Exposure Scenario	Rural residential / agricultural
Chemicals of Potential Concern	PFOS+PFHxS

Parameter	Unit	Value	Details	Source
Water quality inputs				
Concentration in soil (C_s)	**mg/kg**	**1.13445E-05**	25 years accumulation of deposition from facility	From deposition model
Percentage PFHxS	**%**	**0%**	Assume all PFOS	Assumption
Egg consumption exposure inputs				
Time spent grazing in impacted area (F_I)	%	20%	OEHHA (2015)	From deposition model
Concentration in edible portion of egg (C_{Eggs})	mg/kg	6.0E-08	$C_{Eggs} = \frac{(EPC \times IR_{Soil\_Chickens} + C_p \times IR_{pasture\_Chickens}) \times F_I \times BIO \times TF_{Eggs}}{LR \times W_{Eggs}}$	DoD (2017a)
Poultry soil ingestion rate ($IR_{Soil\_Chicken}$)	kg/day	4.8E-04	Based on 2% of pasture intake comprised of soil	OEHHA (2015)
Poultry pasture ingestion rate ($IR_{Pasture\_Chicken}$)	kg/day	2.4E-02	Based on an average poultry dietary ingestion rate of 0.12 kg/day	
Proportion of diet that is pasture ($F_{Pasture}$)	%	20%	Proportion of the total diet of poultry that is obtained via local foraging - site specific	From deposition model
Concentration in pasture (C_p)	mg/kg	2.3E-07	$C_P = TF_{Pasture} \times C_s$	From deposition model
Transfer factor to pasture ($TF_{Pasture}$)	-	1.4	95th percentile transfer factors from soil to pasture from the literature	PFAS NEMP 3.0
Edible fraction of egg (F_{Edible})	%	0.87	Approximate portion of an egg that is edible	Kowalczyk *et al.* (2020)
Egg weight (W_{Eggs})	kg/egg	0.060	Weight of a typical egg	Assumption
Transfer factor to chicken eggs (TF_{Eggs})	mg/day edible egg per mg/day intake	1.1	TF of 1 have been estimated for PFOS and PFHxS. The TF has been adjusted upwards according the the equation TF/Fedible	Kowalczyk *et al.* (2020)
Poultry laying rate (LR)	eggs/day	8.0E-01	Laying hens can produce up to approximately 300 eggs per year	Assumption
Meat and offal consumption exposure inputs - cattle				
Time spent grazing in impacted area ($F_{ILivestock\_Cattle}$)	%	100%	Conservative assumption	Assumption
Concentration in meat (C_{meat_Beef})	mg/kg	4.1E-07	$C_{Meat} = CF_{meat} \times C_{serum} \times F_{ILivestock}$	Drew *et al.* (2021)
Meat (muscle) consumption rate (IR_{Muscle})	kg/day	0.085	90th %ile meat consumption rate reported for the Australian population (2-6 years)	FSANZ (2017)
Serum to meat concentration factor (CF_{Meat_Beef})	L/kg	0.08	Describes the transfer of PFAS from plasma to meat (mg/kg meat per mg/L plasma), with the combined value for PFOS+PFHxS refelcting the ratio of these compounds in soil	Kowalczyk (2013)
Concentration in serum (C_{serum_Cattle})	mg/L	5.4E-06	$C_{Serum} = \frac{Intake_{Livestock\_soil} \times T_{1/2}}{0.693 \times V_d}$	PFAS NEMP 3.0
Serum elimination half-life($T_{1/2}$)	days	56	Elimination half-life	PFAS NEMP 3.0
Volume distribution (V_d)	L/kg	0.26	Default value	PFAS NEMP 3.0
Livestock intake from soil ($Intake_{Soil\_Cattle}$)	mg/kg/day	1.72E-08	$Intake_{Livestock\_soil} = \frac{C_S \times IR_{Soil} \times BIO + C_p \times IR_{Pasture} \times BIO}{BW}$	OEHHA (2015)
Soil ingestion rate (IR_{Soil_Cattle})	kg/day	0.5	Based on a soil fraction of pasture of 5%	OEHHA (2015)
Pasture ingestion rate ($IR_{Pasture\_Cattle}$)	kg/day	13	Livestock plant ingestion rate	PFAS NEMP 3.0
Concentration in pasture (C_p)	mg/kg	2.3E-07	$C_P = TF_{Pasture} \times C_s$	From deposition model
Transfer factor to pasture ($TF_{Pasture}$)	-	1.4	95th percentile transfer factors from soil to pasture from the literature	PFAS NEMP 3.0
Livestock body weight (BW_{Cattle})	kg	500	Typical body weight of adult cattle	PFAS NEMP 3.0
Milk consumption exposure inputs				
Time spent grazing in impacted area (F_I)	%	100%	OEHHA (2015)	From deposition model
Concentration in milk (C_{Milk})	mg/kg	8.0E-08	$C_{milk} = CF_{milk} \times C_{serum} \times F_{IDairy}$	Drew *et al.* (2021)
Serum to milk concentration factor (CF_{Milk})	L/kg	0.02	Describes the transfer of PFAS from plasma to milk (mg/kg milk per mg/L plasma), with the combined value for PFOS+PFHxS refelcting the ratio of these compounds in water	Kowalczyk (2013)

Appendix C

Sensitivity assessment

Input Variable	Input Selection	HI/ILCR	% Change	Graphical Representation	Relative Variable Sensitivity	Relative Variable Uncertainty in HHRA
Influence of emission rate resulting from throughput of feed (HI)						
300%	300% of worst case emission for proposed RRON facility	0.15	200%		Moderate: The HI varied by 200% across the range of emission rates but the most sensitive receptor HI remained ≤1	Moderate: The emission rates are based on reference facilities and therefore there will be expected variations. However over the long term emissions would be expected to be below the worst case reference emissions provided by the facility designer.
200%	200% of worst case emission for proposed RRON facility	0.10	100%			
150%	150% of worst case emission for proposed RRON facility	0.077	50%			
100%	Worst case emission for proposed RRON facility	0.051	0%			
50%	50% of worst case emission for proposed RRON facility	0.026	-50%			
Influence of emission rate resulting from throughput of feed (ILCR)						
300%	300% of worst case emission for proposed RRON facility	1.6E-07	200%		Moderate: The HI varied by 200% across the range of emission rates but the most sensitive receptor ILCR remained ≤1E-06	Moderate: The emission rates are based on reference facilities and therefore there will be expected variations. However over the long term emissions would be expected to be below the worst case reference emissions provided by the facility designer.
200%	200% of worst case emission for proposed RRON facility	1.1E-07	100%			
150%	150% of worst case emission for proposed RRON facility	8.2E-08	50%			
100%	Worst case emission for proposed RRON facility	5.5E-08	0%			
50%	50% of worst case emission for proposed RRON facility	2.7E-08	-50%			

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