Appendix D
T4 Project Emissions Inventory

Air emission sources associated with the construction and operation phases of the T4 Project were identified and quantified through the application of Australian National Pollutant Inventory (NPI) emission estimation techniques and United States Environmental Protection Agency (US-EPA) AP-42 predictive emission factor equations.

Particulate releases were quantified for various particle size fractions, including TSP, PM_{10} and $PM_{2.5}$. Gaseous products of combustion for which emissions were quantified included SO_2, NO_x, CO, benzene, toluene, ethylbenzene and total xylene.

Given the extended period over which the T4 Project will ramp up, and the concurrence of construction and operational stages, the following scenarios were identified for quantitative assessment:

- Stage 1 Construction (2013 – 2016);
- Stage 1 Operations concurrent with Stage 2 Construction (2017 – 2019; 70 Mtpa); and
- Stage 3 Operations (2022 onwards; 120 Mpta).

CONSTRUCTION OPERATIONS

Combustion Emissions during Construction Operations

Particulate matter (PM), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO) and volatile organic compounds (VOC) emissions were estimated for diesel fuel combustion by the construction fleet.

Diesel-powered plant and equipment anticipated to be used during the Stage 1 and Stage 2 construction periods are listed in **Table D1** and **Table D3**. Emission factors used in the quantification of emissions from such plant were applied as follows[(13)]:

$$E_{exh} = EF_{exh} * A * L * P * N$$

E_{exh} = exhaust emissions (grams/hour)

EF_{exh} = exhaust emission factor (gram/hp-hr)

A = equipment activity (operating hours/year)

L = load factor (average portion of rated power used during operation, percent)

P = average rated power (hp)

N = equipment population (units)

Estimated plant numbers and operating hours were provided by PWCS (**Table D1, Table D3**) and are estimates only for use in this assessment. Actual construction equipment may differ. Emission factors, load factors and average power ratings were drawn from ENVIRON (2009)[(14)]. These emission factors are based on the emission factors within the US-EPA

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13 US-EPA (2004). Exhaust and Crankcase Emission Factors for Non-road Engine Modelling – Compression Ignition, EPA420-P-04-009, April 2004.

14 ENVIRON (2009). *Cleaner Non-road Diesel Engine Project – Identification and Recommendation of Measures to Support the Uptake of Cleaner Non-road Diesel Engines in Australia, Final Report, Revision 2*, Project undertaken by ENVIRON Australia Pty Limited on behalf of NSW OEH and the Commonwealth Department of the Environment, Water, Heritage and the Arts, December 2009.

NON-ROAD MOBILE 2008 model but reflect emission standard compliance profiles typical of construction plant sold into the Australian market.

Estimated combustion emissions during Stage 1 and Stage 2 construction operations are provided in **Table D2** and **Table D4** respectively. Emissions were calculated separately for each of the focus areas for construction activities (rail infrastructure; coal stockyard area; wharf facilities and shiploaders) to facilitate the spatial allocation of emissions for dispersion modelling and assessment purposes.

Fugitive Dust Emissions during Construction Operations

The year spanning 2014/2015 and the year spanning 2018/2019 were identified as comprising the greatest activity rates and emissions during Stage 1 and Stage 2 construction operations respectively. These years were therefore selected for the quantification of fugitive dust emissions and for inclusion in the dispersion modeling.

In the quantification of fugitive dust emissions daily process rates were assigned to each activity based on typical rates of operation of construction plant (**Table D5, Table D7**). Emission factors were derived based on US-EPA AP42 (Section 13) Emission Factors, with default values used for moisture content and silt content. A control efficiency of 50% was applied to account for dust control by wet suppression which is typically applied during construction. A maximum exposed area of 100 ha was projected for the Stage 1 construction period, with the remainder of the project area assumed not to be exposed to wind erosion. The US-EPA AP42 default emission factor for exposed areas (Section 11.9-1) was applied to estimate wind erosion from the 100 ha exposed area. For dispersion modelling purposes, hourly varying emissions were derived based on site-specific meteorological data. Annual averaged emission factors are included in the table.

Fugitive dust emissions estimated for Stage 1 and Stage 2 construction operations are provided in **Table D6** and **Table D8** respectively. As for combustion emissions, fugitive dust emissions were calculated separately for each of the focus areas for construction activities (rail infrastructure; coal stockyard area; wharf facilities and shiploaders) to facilitate the spatial allocation of emissions for dispersion modelling and assessment purposes.

Note: Emission factors for fugitive dust sources partially include particulate matter released during combustion. By calculating emissions separately for both fugitive particulate matter emissions and combustion related particulate matter releases, and summing the emission estimates for modelling and assessment purposes, the study provides an upper bound (conservative) projection of incremental airborne particulate concentrations.

Spatial Allocation of Construction Emissions

Combustion and fugitive dust emissions calculated for the rail infrastructure, coal stockyard, and wharf facilities and shiploader areas were summed and allocated to four volume sources within each area as illustrated in **Figure D1** for Stage 1 construction and **Figure D2** for Stage 2 construction. Wind-blown dust emissions from exposed areas during Stage 1 construction operations were simulated as area sources as illustrated in the relevant figure.

Whereas Stage 1 construction emissions were simulated and assessed independently, Stage 2 construction emissions were simulated and assessed together with Stage 1 operation emissions due to the concurrence of these activities.

Table D1: Stage 1 Construction – Mobile Plant assumed to be in Operation and Fuel-combustion Emission Factors Assigned														
Mobile Plant (model/capacity)	Period of Operation			Number of Construction Plant Operating			Emission Factors(a)					Ave Power Rating hp(a)	Ave Load (%) (a)
	Timing	Operating Hours	Hrs per Year	Rail Infra-structure Area	Coal Stockyard Area	Wharf Facilities and Shiploader Areas	PM_{10}	CO	VOC	NOx	SO_x (b)		
							g/Hp-hr	g/Hp-hr	g/Hp-hr	g/Hp-hr	g/Hp-hr		
Mobile Cranes (600 t)	2014/2015/2016	50 hrs /wk day	2600	0	2	3	0.3319	0.8306	0.3574	5.7824	0.0060	530	43
Mobile Cranes (150 t)	2014/2015/2016	50 hrs /wk day	2600	1	4	5	0.3319	0.8306	0.3574	5.7824	0.0060	503	43
Mobile Cranes (50 t)	2014/2015/2016	50 hrs /wk day	2600	1	3	3	0.3319	0.8306	0.3574	5.7824	0.0060	324	43
Mobile Cranes (25 t)	2014/2015/2016	50 hrs /wk day	2600	2	3	5	0.3319	0.8306	0.3574	5.7824	0.0060	152	43
Cherry Pickers	2014/2015/2016	50 hrs /wk day	2600	3	6	6	0.3894	2.1194	0.1944	2.8375	0.0060	172	59
Water Trucks	2013/2014/2015/2016	50 hrs /wk day	2600	2	3	1	0.2739	1.9093	0.1945	3.9880	0.0057	1123	36
Dump Trucks	2013/2014/2015	50 hrs /wk day	2600	4	8	4	0.2739	1.9093	0.1945	3.9880	0.0057	1123	36
Dozers	2013/2014/2015	50 hrs /wk day	2600	3	6	2	0.3630	2.1958	0.2002	3.2725	0.0054	535	52
Excavators	2013/2014/2015	50 hrs /wk day	2600	4	6	2	0.4929	2.0213	0.2553	2.9801	0.0060	120	34
Scrapers	2013/2014/2015	50 hrs /wk day	2600	0	4	0	0.3999	2.1227	0.1943	2.7566	0.0057	396	50
Rollers	2013/2014/2015	50 hrs /wk day	2600	2	4	1	0.4499	2.5178	0.4085	3.9270	0.0634	119	48
Graders	2013/2014/2015	50 hrs /wk day	2600	2	2	1	0.3676	1.8669	0.2481	2.9441	0.0056	198	45
Compactor	2013/2014/2015	50 hrs /wk day	2600	2	4	1	0.6093	4.3787	0.6444	4.5541	0.0060	8	43
Track Laying Machine	2015/2016	50 hrs /wk day	2600	2	1	0	0.3894	2.1194	0.1944	2.8375	0.0060	347	45
Drill Rigs	2013/2014/2015	50 hrs /wk day	2600	0	2	1	0.2038	0.9438	0.3386	4.0257	0.0060	176	43
Piling Rigs	2014/2015/2016	50 hrs /wk day	2600	1	4	4	0.3894	2.1194	0.1944	2.8375	0.0060	176	43
Loaders	2013/2014/2015	50 hrs /wk day	2600	2	4	2	0.3931	1.9355	0.2565	3.1004	0.0056	223	45
Heavy Lift float	2015/2016	1 week events	2600	0	10	2	0.3894	2.1194	0.1944	2.8375	0.0060	347	45

(a) Emission factors, average engine ratings and load factors drawn from ENVIRON (2009). *Cleaner Non-road Diesel Engine Project – Identification and Recommendation of Measures to Support the Uptake of Cleaner Non-road Diesel Engines in Australia, Final Report, Revision 2*, Project undertaken by ENVIRON Australia Pty Limited on behalf of NSW OEH and the Commonwealth Department of the Environment, Water, Heritage and the Arts, December 2009.

(b) Takes into account 10 ppm sulphur levels in Australia automotive diesel oil.

Table D2: Stage 1 Construction – Combustion Emissions

Mobile Plant	Timing	Emissions (tonnes)														
		Construction Activity within Rail Infrastructure Area					Construction Activity within Coal Stockyard Area					Construction Activity within Wharf Facilities and Shiploader Areas				
		PM_{10}	CO	VOC	NOx	SO_2	PM_{10}	CO	VOC	NOx	SO_2	PM_{10}	CO	VOC	NOx	SO_2
Mobile Cranes (600 t)	2014/2015/2016	0.000	0.000	0.000	0.000	0.000	0.393	0.984	0.424	6.853	0.007	0.590	1.476	0.635	10.279	0.011
Mobile Cranes (150 t)	2014/2015/2016	0.187	0.467	0.201	3.252	0.003	0.747	1.868	0.804	13.007	0.013	0.933	2.335	1.005	16.259	0.017
Mobile Cranes (50 t)	2014/2015/2016	0.120	0.301	0.129	2.095	0.002	0.361	0.903	0.388	6.284	0.006	0.361	0.903	0.388	6.284	0.006
Mobile Cranes (25 t)	2014/2015/2016	0.113	0.282	0.121	1.965	0.002	0.169	0.423	0.182	2.948	0.003	0.282	0.706	0.304	4.913	0.005
Cherry Pickers	2014/2015/2016	0.308	1.678	0.154	2.246	0.005	0.617	3.355	0.308	4.492	0.009	0.617	3.355	0.308	4.492	0.009
Water Trucks	2013/2014/2015/2016	0.576	4.014	0.409	8.384	0.012	0.864	6.021	0.613	12.576	0.018	0.288	2.007	0.204	4.192	0.006
Dump Trucks	2013/2014/2015	1.152	8.028	0.818	16.768	0.024	2.303	16.056	1.636	33.535	0.048	1.152	8.028	0.818	16.768	0.024
Dozers	2013/2014/2015	0.788	4.765	0.434	7.101	0.012	1.575	9.530	0.869	14.203	0.024	0.525	3.177	0.290	4.734	0.008
Excavators	2013/2014/2015	0.209	0.858	0.108	1.265	0.003	0.314	1.287	0.162	1.897	0.004	0.105	0.429	0.054	0.632	0.001
Scrapers	2013/2014/2015	0.000	0.000	0.000	0.000	0.000	0.823	4.371	0.400	5.676	0.012	0.000	0.000	0.000	0.000	0.000
Rollers	2013/2014/2015	0.134	0.748	0.121	1.166	0.019	0.267	1.496	0.243	2.333	0.038	0.067	0.374	0.061	0.583	0.009
Graders	2013/2014/2015	0.170	0.865	0.115	1.364	0.003	0.170	0.865	0.115	1.364	0.003	0.085	0.432	0.057	0.682	0.001
Compactor	2013/2014/2015	0.011	0.078	0.012	0.081	0.000	0.022	0.157	0.023	0.163	0.000	0.005	0.039	0.006	0.041	0.000
Track Laying Machine	2015/2016	0.316	1.721	0.158	2.304	0.005	0.158	0.860	0.079	1.152	0.002	0.000	0.000	0.000	0.000	0.000
Drill Rigs	2013/2014/2015	0.000	0.000	0.000	0.000	0.000	0.080	0.371	0.133	1.584	0.002	0.040	0.186	0.067	0.792	0.001
Piling Rigs	2014/2015/2016	0.077	0.417	0.038	0.558	0.001	0.307	1.668	0.153	2.233	0.005	0.307	1.668	0.153	2.233	0.005
Loaders	2013/2014/2015	0.205	1.010	0.134	1.618	0.003	0.410	2.020	0.268	3.236	0.006	0.205	1.010	0.134	1.618	0.003
Heavy Lift float	2015/2016	0.000	0.000	0.000	0.000	0.000	1.581	8.605	0.789	11.520	0.024	0.316	1.721	0.158	2.304	0.005
Emissions (tonnes/annum) (2014/2015)		**4.365**	**25.231**	**2.953**	**50.167**	**0.093**	**11.162**	**60.840**	**7.589**	**125.054**	**0.225**	**5.877**	**27.846**	**4.641**	**76.806**	**0.112**

Table D3: Stage 2 Construction – Mobile Plant assumed to be in Operation and Fuel-combustion Emission Factors Assigned

Mobile Plant (model/capacity)	Period of Operation			Number of Construction Plant Operating			Emission Factors(a)					Ave Power Rating hp(a)	Ave Load (%) (a)
	Timing	Operating Hours	Hrs per Year	Rail Infra-structure Area	Coal Stockyard Area	Wharf Facilities and Shiploader Areas	PM_{10} g/Hp-hr	CO g/Hp-hr	VOC g/Hp-hr	NOx g/Hp-hr	SO_x (b) g/Hp-hr		
Mobile Cranes (600 t)	2018/2019	50 hrs /wk day	2600	0	1	2	0.3319	0.8306	0.3574	5.7824	0.0060	530	43
Mobile Cranes (150 t)	2018/2019	50 hrs /wk day	2600	1	4	3	0.3319	0.8306	0.3574	5.7824	0.0060	503	43
Mobile Cranes (50 t)	2018/2019	50 hrs /wk day	2600	1	3	2	0.3319	0.8306	0.3574	5.7824	0.0060	324	43
Mobile Cranes (25 t)	2018/2019	50 hrs /wk day	2600	2	3	3	0.3319	0.8306	0.3574	5.7824	0.0060	152	43
Cherry Pickers	2018/2019	50 hrs /wk day	2600	3	6	6	0.3894	2.1194	0.1944	2.8375	0.0060	172	59
Water Trucks	2017/2018/2019	50 hrs /wk day	2600	1	3	1	0.2739	1.9093	0.1945	3.9880	0.0057	1123	36
Dump Trucks	2017/2018	50 hrs /wk day	2600	2	6	4	0.2739	1.9093	0.1945	3.9880	0.0057	1123	36
Dozers	2017/2018	50 hrs /wk day	2600	0	3	2	0.3630	2.1958	0.2002	3.2725	0.0054	535	52
Excavators	2017/2018	50 hrs /wk day	2600	0	4	2	0.4929	2.0213	0.2553	2.9801	0.0060	120	34
Rollers	2017/2018	50 hrs /wk day	2600	1	3	1	0.4499	2.5178	0.4085	3.9270	0.0634	119	48
Graders	2017/2018	50 hrs /wk day	2600	1	2	1	0.3676	1.8669	0.2481	2.9441	0.0056	198	45
Compactor	2017/2018	50 hrs /wk day	2600	1	3	1	0.6093	4.3787	0.6444	4.5541	0.0060	8	43
Track Laying Machine	2018	50 hrs /wk day	2600	2	1	0	0.3894	2.1194	0.1944	2.8375	0.0060	347	45
Drill Rigs	2017	50 hrs /wk day	2600	0	2	1	0.2038	0.9438	0.3386	4.0257	0.0060	176	43
Piling Rigs	2018	50 hrs /wk day	2600	1	4	4	0.3894	2.1194	0.1944	2.8375	0.0060	176	43
Loaders	2017/2018	50 hrs /wk day	2600	2	4	2	0.3931	1.9355	0.2565	3.1004	0.0056	223	45
Heavy Lift float	2018	50 hrs /wk day	2600	0	2	1	0.3894	2.1194	0.1944	2.8375	0.0060	347	45

Darker shading indicates activity and emissions during the 2018/2019 period, with the lighter shading indicative of activity and emissions during the 2017/2018 period.

(a) Emission factors, average engine ratings and load factors drawn from ENVIRON (2009). *Cleaner Non-road Diesel Engine Project – Identification and Recommendation of Measures to Support the Uptake of Cleaner Non-road Diesel Engines in Australia, Final Report, Revision 2*, Project undertaken by ENVIRON Australia Pty Limited on behalf of NSW OEH and the Commonwealth Department of the Environment, Water, Heritage and the Arts, December 2009.

(b) Takes into account 10 ppm sulphur levels in Australia automotive diesel oil.

Table D4: Stage 2 Construction – Combustion Emissions

Mobile Plant	Timing	Emissions (tonnes)														
		Construction Activity within Rail Infrastructure Area					Construction Activity within Coal Stockyard Area					Construction Activity within Wharf Facilities and Shiploader Areas				
		PM_{10}	CO	VOC	NOx	SO_2	PM_{10}	CO	VOC	NOx	SO_2	PM_{10}	CO	VOC	NOx	SO_2
Mobile Cranes (600 t)	2018/2019	0.000	0.000	0.000	0.000	0.000	0.197	0.492	0.212	3.426	0.004	0.393	0.984	0.424	6.853	0.007
Mobile Cranes (150 t)	2018/2019	0.187	0.467	0.201	3.252	0.003	0.747	1.868	0.804	13.007	0.013	0.560	1.401	0.603	9.755	0.010
Mobile Cranes (50 t)	2018/2019	0.120	0.301	0.129	2.095	0.002	0.361	0.903	0.388	6.284	0.006	0.240	0.602	0.259	4.189	0.004
Mobile Cranes (25 t)	2018/2019	0.113	0.282	0.121	1.965	0.002	0.169	0.423	0.182	2.948	0.003	0.169	0.423	0.182	2.948	0.003
Cherry Pickers	2018/2019	0.308	1.678	0.154	2.246	0.005	0.617	3.355	0.308	4.492	0.009	0.617	3.355	0.308	4.492	0.009
Water Trucks	2017/2018/2019	0.288	2.007	0.204	4.192	0.006	0.864	6.021	0.613	12.576	0.018	0.288	2.007	0.204	4.192	0.006
Dump Trucks	2017/2018	0.576	4.014	0.409	8.384	0.012	1.728	12.042	1.227	25.151	0.036	1.152	8.028	0.818	16.768	0.024
Dozers	2017/2018	0.000	0.000	0.000	0.000	0.000	0.788	4.765	0.434	7.101	0.012	0.525	3.177	0.290	4.734	0.008
Excavators	2017/2018	0.000	0.000	0.000	0.000	0.000	0.209	0.858	0.108	1.265	0.003	0.105	0.429	0.054	0.632	0.001
Rollers	2017/2018	0.067	0.374	0.061	0.583	0.009	0.200	1.122	0.182	1.750	0.028	0.067	0.374	0.061	0.583	0.009
Graders	2017/2018	0.085	0.432	0.057	0.682	0.001	0.170	0.865	0.115	1.364	0.003	0.085	0.432	0.057	0.682	0.001
Compactor	2017/2018	0.005	0.039	0.006	0.041	0.000	0.016	0.117	0.017	0.122	0.000	0.005	0.039	0.006	0.041	0.000
Track Laying Machine	2018	0.316	1.721	0.158	2.304	0.005	0.158	0.860	0.079	1.152	0.002	0.000	0.000	0.000	0.000	0.000
Drill Rigs	2017	0.000	0.000	0.000	0.000	0.000	0.080	0.371	0.133	1.584	0.002	0.040	0.186	0.067	0.792	0.001
Piling Rigs	2018	0.077	0.417	0.038	0.558	0.001	0.307	1.668	0.153	2.233	0.005	0.307	1.668	0.153	2.233	0.005
Loaders	2017/2018	0.205	1.010	0.134	1.618	0.003	0.410	2.020	0.268	3.236	0.006	0.205	1.010	0.134	1.618	0.003
Heavy Lift float	2018	0.000	0.000	0.000	0.000	0.000	0.316	1.721	0.158	2.304	0.005	0.158	0.860	0.079	1.152	0.002
Emissions (2017/2018)		1.619	10.014	1.067	18.362	0.038	4.930	30.709	3.330	57.534	0.115	2.779	17.350	1.844	32.275	0.059
Emissions (2018/2019)		0.728	2.728	0.606	9.558	0.012	2.406	8.763	2.052	32.461	0.041	2.138	7.626	1.854	29.389	0.036
Emissions (Total 30 months, 2017-2019)		**2.347**	**12.742**	**1.673**	**27.919**	**0.050**	**7.336**	**39.472**	**5.382**	**89.995**	**0.156**	**4.916**	**24.976**	**3.698**	**61.664**	**0.095**

Darker shading indicates activity and emissions during the 2018/2019 period, with the lighter shading indicative of activity and emissions during the 2017/2018 period.

Table D5: Stage 1 Construction – Activities associated with Fugitive Dust Emissions

Activity	Timing	Hrs per Year	Numbers of Construction Equipment in Operation			Daily Process Rate (per unit)(a)	Units	Emission Factors Applied(b)		
			Rail Infrastructure Area	Coal Stockyard Area	Wharf Facilities and Shiploaders Area			$PM_{2.5}$ Emission Factor	PM_{10} Emission Factor	TSP Emission Factor
								g/unit	g/unit	g/unit
Water Trucks	2013/2014/2015/2016	2600	2	3	1	10.94	VKT	99.790	644.101	2576.403
Dump Trucks - unpaved road travel	2013/2014/2015	2600	4	8	4	4.83	VKT	104.326	675.988	2703.953
Dump Trucks - unloading	2013/2014/2015	2600	4	8	4	367.50	tonnes	0.007	0.023	0.065
Dozers	2013/2014/2015	2600	3	6	2	7.00	hr	52.163	95.118	396.326
Excavators	2013/2014/2015	2600	4	6	2	735.00	tonnes	0.007	0.023	0.048
Scrapers - excavation	2013/2014/2015	2600	0	4	0	7.00	hr	52.163	95.118	297.245
Scrapers - unpaved road travel	2013/2014/2015	2600	0	4	0	18.35	VKT	120.202	785.576	3142.304
Graders	2013/2014/2015	2600	2	2	1	10.94	VKT	4.536	62.460	249.838
Compactor - unpaved road travel	2013/2014/2015	2600	2	4	1	10.94	VKT	4.536	62.460	249.838
Loaders - loading	2013/2014/2015	2600	2	4	2	367.50	tonnes	0.007	0.023	0.054

Activity	Timing	Potential hrs per year	Extent of Exposed Area Assumed Subject to Continuous Disturbance		Emission Factors Applied(d)		
					$PM_{2.5}$ Emission Factor (kg/ha/annum)	PM_{10} Emission Factor (kg/ha/annum)	TSP Emission Factor (kg/ha/annum)
Wind erosion of exposed areas(c)	2013/2014/2015/2016	8760	100 ha(c)		31.9	212.5	425.0

VKT – vehicle kilometres travelled

(a) Daily process rates assigned based on typical rates of operation of construction plant.

(b) Emission factors derived based on US-EPA AP42 (Section 13) Emission Factors, with default values used for moisture content and silt content. A control efficiency of 50% applied for wet suppression.

(c) Exposed area of 100 ha was projected for the intensive Stage 1 construction period.

(d) US-EPA AP42 (Section 11.9-11) Emission Factor for Exposed Areas. PM_{10} and $PM_{2.5}$ fractions taken to be 0.5 and 0.075 (as a fraction of TSP) based on the US-EPA AP42 Industrial Wind Erosion Emission Factor (Section 13.2.4). A control efficiency of 50% applied for wet suppression. Emissions varied on an hourly basis for input to dispersion modelling based on a wind scaling factor derived from the AP42 Industrial Wind Erosion Emission Factor.

Table D6: Stage 1 Construction – Fugitive Dust Emissions

Activity	Timing	PREDICTED EMISSIONS (tpa)								
		Construction Activity within Rail Infrastructure Area			Construction Activity within Coal Stockyard Area			Construction Activity within Wharf Facilities and Shiploader Areas		
		$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Water Trucks	2013/2014/2015/2016	0.797	5.146	20.582	1.196	7.718	30.873	0.399	2.573	10.291
Dump Trucks - unpaved road travel	2013/2014/2015	0.735	4.765	19.060	1.471	9.530	38.120	0.735	4.765	19.060
Dump Trucks - unloading	2013/2014/2015	0.004	0.012	0.035	0.008	0.024	0.070	0.004	0.012	0.035
Dozers	2013/2014/2015	0.400	0.729	3.038	0.800	1.458	6.076	0.267	0.486	2.025
Excavators	2013/2014/2015	0.008	0.024	0.052	0.012	0.037	0.078	0.004	0.012	0.026
Scrapers - excavation	2013/2014/2015	-	-	-	0.533	0.972	3.038	-	-	-
Scrapers - unpaved road travel	2013/2014/2015	-	-	-	3.220	21.042	84.170	-	-	-
Graders	2013/2014/2015	0.036	0.499	1.996	0.036	0.499	1.996	0.018	0.249	0.998
Compactor - unpaved road travel	2013/2014/2015	0.036	0.499	1.996	0.072	0.998	3.992	0.018	0.249	0.998
Loaders - loading	2013/2014/2015	0.002	0.006	0.014	0.004	0.012	0.029	0.002	0.006	0.014
Wind erosion of exposed areas	2013/2014				3.188	21.250	42.500			
Total Emissions		**2.019**	**11.680**	**46.773**	**10.539**	**63.541**	**210.940**	**1.447**	**8.353**	**33.447**

Table D7: Stage 2 Construction – Activities associated with Fugitive Dust Emissions										
Activity	Timing	Hrs per Year	Numbers of Construction Equipment in Operation			Daily Process Rate (per unit)(a)	Units	Emission Factors Applied(b)		
			Rail Infrastructure Area	Coal Stockyard Area	Wharf Facilities and Shiploaders Area			$PM_{2.5}$ Emission Factor g/unit	PM_{10} Emission Factor g/unit	TSP Emission Factor g/unit
Water Trucks	2017/2018/2019	2600	1	3	1	10.94	VKT	99.790	644.101	2576.403
Dump Trucks - unpaved road travel	2017/2018	2600	2	6	4	4.83	VKT	104.326	675.988	2703.953
Dump Trucks - unloading	2017/2018	2600	2	6	4	367.50	tonnes	0.007	0.023	0.065
Dozers	2017/2018	2600	0	3	2	7.00	hr	52.163	95.118	396.326
Excavators	2017/2018	2600	0	4	2	735.00	tonnes	0.007	0.023	0.048
Graders	2017/2018	2600	1	2	1	10.94	VKT	4.536	62.460	249.838
Compactor - unpaved road travel	2017/2018	2600	1	3	1	10.94	VKT	4.536	62.460	249.838
Loaders - loading	2017/2018	2600	2	4	2	367.50	tonnes	0.007	0.023	0.054

VKT – vehicle kilometres travelled

(a) Daily process rates assigned based on typical rates of operation of construction plant.

(b) Emission factors derived based on US-EPA AP42 (Section 13) Emission Factors, with default values used for moisture content and silt content. A control efficiency of 50% applied for wet suppression.

Table D8: Stage 2 Construction – Fugitive Dust Emissions

Activity	Timing	EMISSIONS (tpa)								
		Construction Activity within Rail Infrastructure Area			Construction Activity within Coal Stockyard Area			Construction Activity within Wharf Facilities and Shiploader Areas		
		$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Water Trucks	2018/2019/2020	0.399	2.573	10.291	1.196	7.718	30.873	0.399	2.573	10.291
Dump Trucks - unpaved road travel	2018/2019	0.368	2.382	9.530	1.103	7.147	28.590	0.735	4.765	19.060
Dump Trucks - unloading	2018/2019	0.002	0.006	0.017	0.006	0.018	0.052	0.004	0.012	0.035
Dozers	2018/2019	-	-	-	0.400	0.729	3.038	0.267	0.486	2.025
Excavators	2018/2019	-	-	-	0.008	0.024	0.052	0.004	0.012	0.026
Graders	2018/2019	0.018	0.249	0.998	0.036	0.499	1.996	0.018	0.249	0.998
Compactor - unpaved road travel	2018/2019	0.018	0.249	0.998	0.054	0.748	2.994	0.018	0.249	0.998
Loaders - loading	2018/2019	0.002	0.006	0.014	0.004	0.012	0.029	0.002	0.006	0.014
Total Emissions		**0.806**	**5.466**	**21.849**	**2.807**	**16.897**	**67.624**	**1.447**	**8.353**	**33.447**

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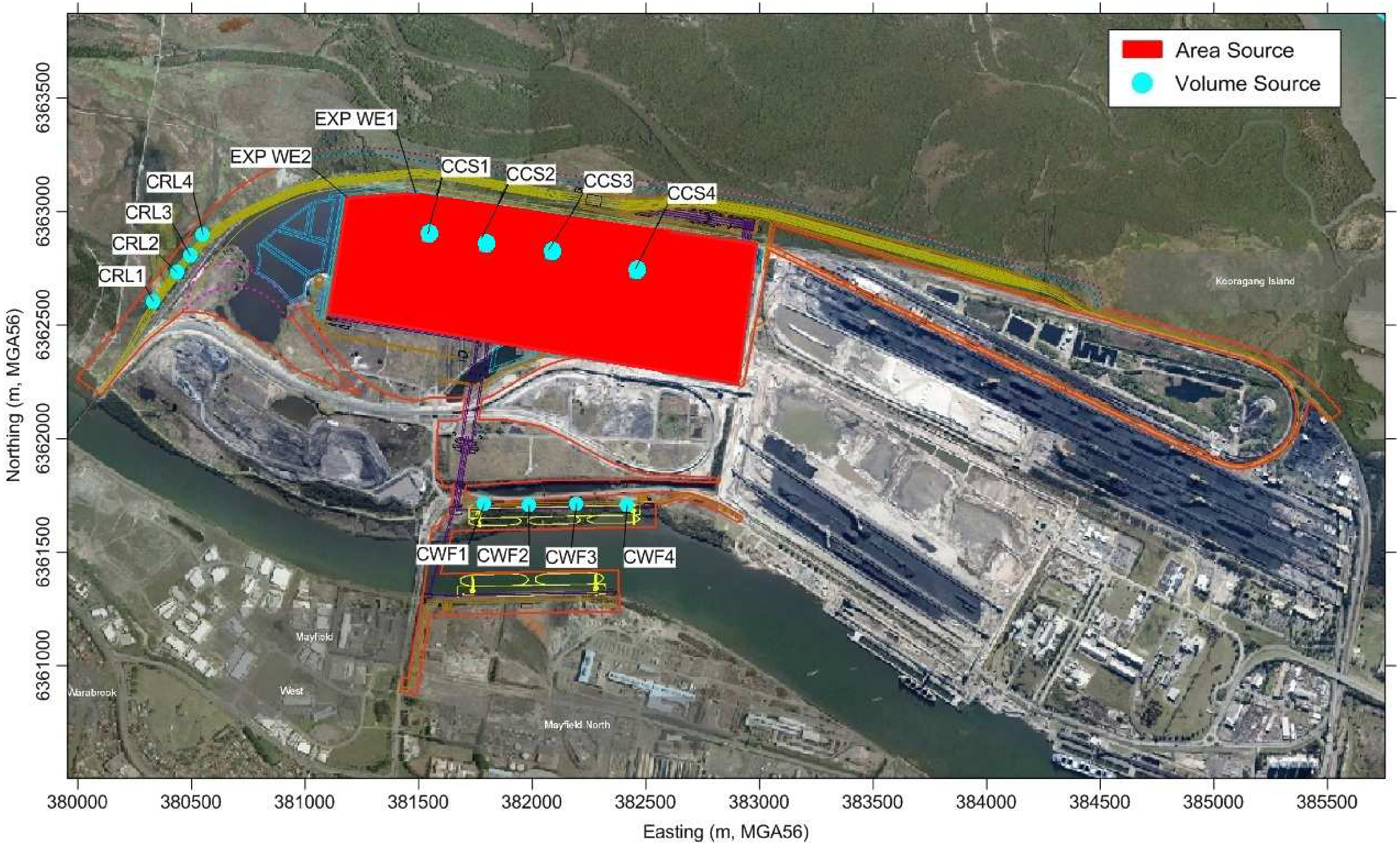

Figure D1 – Spatial allocation of Stage 1 Construction Emissions

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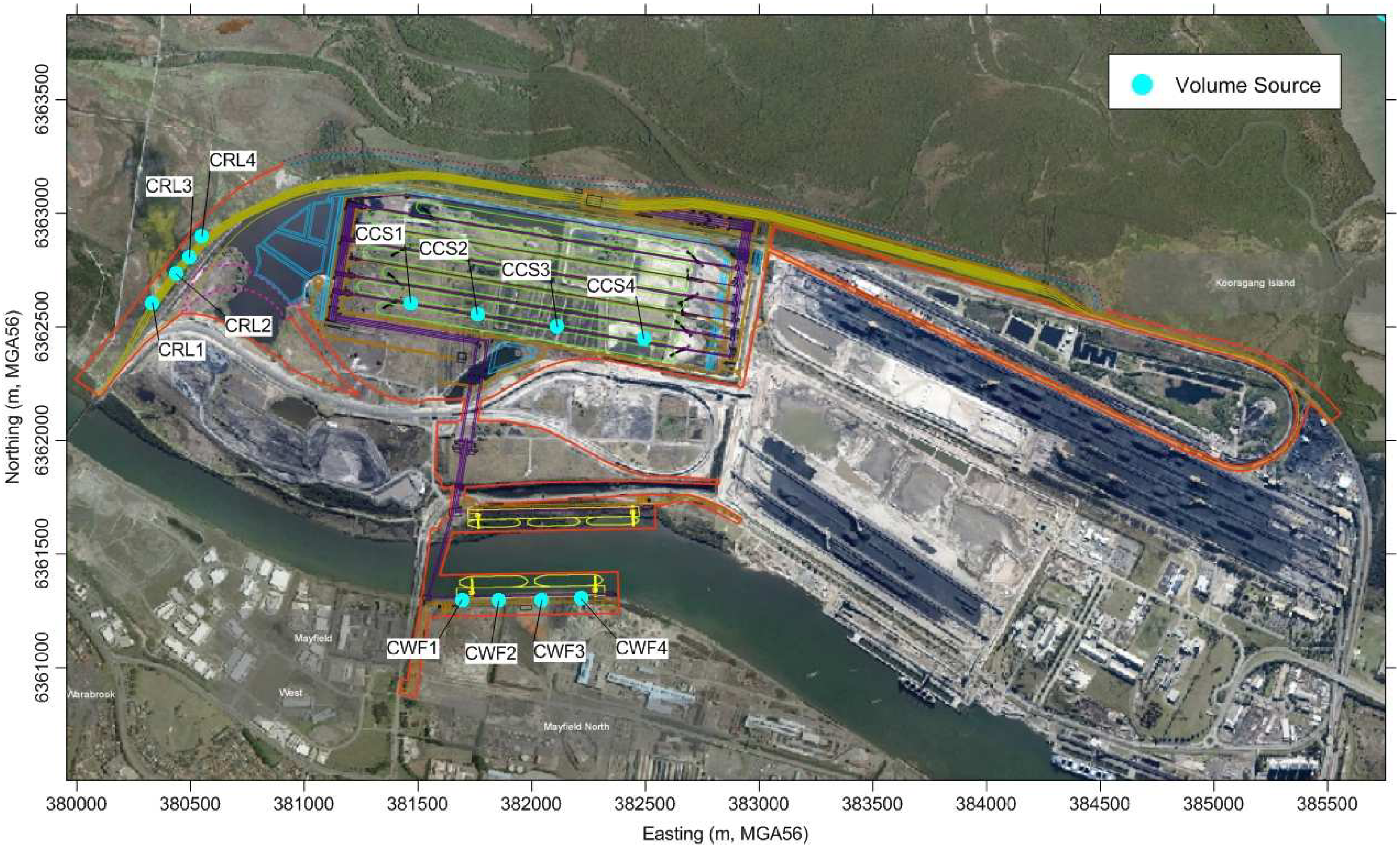

Figure D2 – Spatial allocation of Stage 2 Construction Emissions

STAGE 1 AND 3 OPERATIONS

For the operational stages of the T4 Project air emissions were calculated for the following sources:

- Rail transport operations (locomotive combustion);
- Rail receival (dump stations);
- Conveyors and transfers;
- Wind erosion of stockpiles;
- Stacking and reclaiming;
- Ship loading;
- Dozer / front end loader operations (limited activity; minor source); and
- Marine vessel combustion emissions.

A number of control measures have been integrated into the design of the T4 Project. Such controls have been accounted for as far as practical in the emissions inventory through the assignment of control efficiencies from the literature as documented in **Table D9**.

Table D9 – Air Pollution Control Efficiencies Applied in the Emission Estimates

Activity	Measure	Control Efficiency
Rail receival (dump station)	Partially enclosed (roof and side walls with openings for train entry and exit) Bottom dumping of coal	70%(a)
Transfer points	'Soft' flow hood and spoon type chutes (reduce coal degradation potential). Water sprays on coal in transit will be provided where appropriate	85%(a)(b)
Belt conveyors	Partially enclosed, where practical (c), with the exception of the yard and ship conveyors. A belt cleaning system will be provided on all conveyors.	85%(a)(b)
Coal stockpiles	Dust suppression (water) sprays	50%(a)
Yard machinery	Variable height stackers	25%(a)
Ship loaders	Discharge chute at the end of the boom conveyor is enclosed to minimise dust (d)	70%(a)

(a) Reference: Environment Australia, 2001
(b) Control efficiency comprises combined effectiveness of water sprays (50%) and enclosure (70%)
(c) Partial enclosure on belt conveyors is defined as a roof and a side wall on the windward side of the conveyor.
(d) Design must be suited for coal loading to large vessels.

Material Transfer Operations

Particulate matter emissions from material transfer operations were calculated through the application of the US-EPA predictive emission factor equation for continuous and batch drop loading and tipping operations (AP42, Section 13.2.4), given as follows:

$$E = k(0.0016) * \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right)$$

where,

E = Emissions (kg/tonne transferred)

U = mean wind speed (m/s)

M = material moisture content (%)

k = 0.74 for TSP, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$

The above equation was used to quantify emissions from the following activities:

- Rail receival (dump stations);
- Conveyor transfers;
- Stacking and reclaiming; and
- Ship loading.

Emission rates were calculate on an hourly basis to reflect hourly variations in the wind field. The annual average wind speed recorded during 2010 was 2.86 m/s.

Coal moisture was given as being in the range of 8% to 10%. It was agreed that a coal moisture content of 8% be applied across all activities to provide an upper estimate of emission potentials.

Based on the average wind speed (2.86 m/s) and the lower bound coal moisture content (8%), the average emission factors for material handling operations were estimated to be:

- 0.239 g TSP/tonne;
- 0.113 g PM_{10}/tonne; and
- 0.017 g $PM_{2.5}$/tonne.

Wind Erosion from Coal Stockpiles

Wind entrained particulate matter from coal stockpiles were estimated through the application of the US-EPA AP42 predictive emission factor equation for industrial wind erosion (Section 13.2.5) given as:

$$Emission\ factor = k \sum_{i=1}^{N} Pi$$

Where,

k = particle size multiplier (k = 1 for TSP, 0.5 for PM_{10} and 0.075 for $PM_{2.5}$)

N = number of disturbances per year

P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the i^{th} period between disturbances (g/m²), calculated by:

$$P = 58(u^* - u_t^*) + 25(u^* - u_t^*)$$

$$P = 0 \text{ for } u^* \leq u_t^*$$

u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

The stockpiles were conservatively assumed to be subject to disturbance on a continuous basis to provide an upper bound estimate of emissions. Emissions were calculated on an hourly basis for 2010 based on measured wind speed from the PWCS KCT monitoring station. The fastest mile of wind was calculated from the hourly average wind speed based on the gust factor range documented by Pitts (2005)[(15)] drawing on the work of Krayer and Marshall (1992)[(16)]. Fastest mile wind speeds are given by Pitts (2005) as being in the range of approximately 1.18 to 1.27 times the hourly wind speed. A factor of 1.27 was used in this study, to provide an upper bound estimate of emissions.

The threshold wind speed was conservatively assumed to be 5.4 m/s to provide an upper bound estimate of emissions.

To convert the wind speed and wind speed threshold from a reference height of 10 m to the equivalent friction velocity and threshold friction velocity, the logarithmic wind speed profile was referenced to yield the following equation (US-EPA, 2006):

$$u* = 0.053\ u_{10}^{+}$$

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15 Pitts O. (2005). Improvement of NPI Fugitive Particulate Matter Emission Estimation Techniques, Final Report, Sinclair Knight Merz, RFQ No. 0027/2004.
16 Krayer, W.R, and Marshall, R.D. 1992. *Gust factors applied to Hurricane Winds*. Bulletin American Meteorological Society, 73, 613-617.

Where,

u* = friction velocity (m/s)

u_{10}^{+}= gust wind speed at reference height of 10 m for periods between disturbances (m/s)

There will be up to four stockpiles during Stage 1 operations and up to seven stockpiles during Stage 3 operations. The average dimensions of each stockpile will be 1400m in length by 50m wide, by 21m high. The stockpiles are estimated to have a footprint of 7ha and a surface area of approximately 10ha.

The average PM emission rates, given a 50% control efficiency, was estimated to be as follows:

- TSP emission factor: 0.242 kg/ha/hr;
- PM_{10} emission factor: 0.121 kg/ha/hr; and
- $PM_{2.5}$ emission factor: 0.018 kg/ha/hr.

Dozer Operations

Dozers and front end loaders will not be used to transfer coal, nor to manage stockpiles. It is however likely that one dozer and one front end loader will be active on the site. To account for such operations, a dozer was assumed to be operating for 1 hour a day during Stage 1 operations and for 2 hours a day during Stage 3 operations in the vicinity of the stockyard.

The US-EPA AP42 emission factors for bulldozing operations involving coal (AP42, Section 11.9.2) were applied. These emission factors are given as follows:

$$E_{TSP} = \frac{35.6(s)^{1.2}}{(M)^{1.3}}$$

$$E_{PM10} = 0.75\frac{8.44(s)^{1.5}}{(M)^{1.4}}$$

Where,

E_{TSP} = emission factor for TSP (kg/hr)

E_{PM10} = emission factor for PM_{10} (kg/hr)

M = moisture content (%)

s = silt content (%)

$PM_{2.5}$ is given as 2.2% of TSP emissions.

The coal moisture content was taken to be 8% and the coal silt content 6.2% (based on the geometric mean coal silt content from *US-EPA AP42 Aggregate Handling and Storage Piles*).

Marine Vessel Combustion Emissions

Air emissions from marine vessels include combustion emissions from propulsion engines (when the vessel is in transit), auxiliary engines and auxiliary boilers. Auxiliary engines (typically compression ignition / internal combustion engines) are mainly used for the ship's electrical power system. All ocean going vessels have auxiliary boilers (external combustion), which are used for heat, hot water and other energy needs.

Given that the scope of the assessment was restricted to vessels at berth, combustion emissions were calculated for auxiliary engines and auxiliary boilers. Emissions from propulsion engines during the transit of vessels into and out of port were not quantified.

Combustion emissions were primarily calculated for Stage 3 (120 Mpta, maximum throughput) operations, and were subsequently scaled to reflect the lower capacity of Stage 1 operations (70 Mtpa), i.e. Stage 1 emissions were taken to be equivalent to 58.3% of Stage 3 emissions.

The following emission factor was applied for the quantification of auxiliary engine emissions:

$$E = N \times EF \times P \times TIW$$

Where,

E = Emissions (kg/year)

N = Number of ships visiting the T4 Project berths each year

EF = emission factor (kg/kWh)

P = Auxiliary power (taking the load into account) (kWh)

TIW = time in wharf per ship (hrs/ship)

Reference was made to the ocean going vessel types visiting the KCT facility during 2010 to determine the likely mix of bulk carriers to be used during the T4 Project. Information on the auxiliary power ratings was then obtained from the Lloyd's Register for use in this assessment.

A summary is provided for the data derived for T4 Project Stage 3 operations for use in the estimation of auxiliary engine emissions in **Table D10**. A total number of 1065 ship calls are estimated for the T4 Project at maximum production (120 Mtpa). Based on the duration of time spent in wharf per ship, it is estimated that there will be 2.6 ships at berth at any given time. Emissions are therefore assumed to occur on a continuous basis.

Table D10 – Stage 3 Operations, Inputs for Auxiliary Engine Emission Estimation			
	Bulk Carrier - Average Gross Tonnage Categories		
	200,000+	**100,000-199,999**	**60,000-99,999**
% of tonnage (based on KCT vessel mix)	3	51	45
Average dry weight tonnage	205886	154999	83980
No. ships visiting port each year	19	397	649
Auxiliary power (average across ships servicing KCT in each tonnage category, power based power ratings for individual vessels from Lloyd's Register)	2045	2033	1515
Aux Power (taking load into account)	1227	1220	909
Time in wharf per ship (hours/ship) – based on average time in wharf of KCT-related vessels	34	27	17
Average load (%)	60	60	60

Emission factors were taken from the NPI *Emission Estimation Technique Manual for Marine Operations*, Version 2.0, July 2008 for application in the estimation of auxiliary engine emissions for Stage 3 operations (**Table D11**). Emission factors reflect findings from international shipping surveys that 71% of auxiliary engines use residual oil with 31% of vessels using marine diesel fuel.

Table D11 – Stage 3 Operations, Emission Estimates for Auxiliary Engines					
		Emissions from Auxiliary Engines (kg/year)			
		Bulk Carrier - Average Gross Tonnage Categories			
Pollutant	**EF for weighted fuel mix(a) (kg/kWh)**	**200,000+**	**100,000-199,999**	**60,000-99,999**	**Sum (kg/year)**
NOx	0.0145	11,921	190,028	144,693	**346,641**
CO	0.0011	904	14,416	10,977	**26,297**
TVOC	0.00038	312	4,980	3,792	**9,084**
$PM_{2.5}$	0.00086	707	11,271	8,582	**20,559**
PM_{10}	0.001	822	13,105	9,979	**23,906**
SO_2	0.0097	7,975	127,122	96,794	**231,891**
Benzene	0.0000076	6.25	99.60	75.84	**182**
Toluene	0.0000076	6.25	99.60	75.84	**182**
Total xylene	0.00000388	3.19	50.85	38.72	**93**
Ethylbenzene	0.000000247	0.20	3.24	2.46	**6**

(a) 71% residual oil use and 31% of vessels use marine diesel fuel (USEPA, 2006), as referenced in the NPI *Emission Estimation Technique Manual for Marine Operations*, July 2008.

The following emission factor was applied for the quantification of auxiliary boiler emissions:

$$E = FC \times N \times EF \times TIW$$

Where,

E = Emissions (kg/year)

FC = fuel consumption (tonnes/hour)

N = Number of ships visiting the T4 Project berths each year

EF = emission factor (kg/tonne of fuel)

TIW = time in wharf per ship (hrs/ship)

The NPI EETM for Marine Operations (2008) specified a default fuel consumption rate of 0.0125 tonnes/hour for use if the fuel consumption rate is not known. However, a study conducted by the Chamber of Shipping (2007) estimated boiler fuel consumption for ocean going vessels to be in the range of 0.14 to 0.18 tonnes/hour. A fuel consumption rate of 0.18 tonnes/hour was applied in this assessment.

Reference was made to the ocean going vessel types visiting the KCT facility during 2010 to determine the likely mix of bulk carriers likely to be used during the T4 Project. A summary is given of the data derived for T4 Project Stage 3 operations for use in the estimation of auxiliary boiler emissions in **Table D12**.

Table D12 – Stage 3 Operations, Inputs for Auxiliary Boiler Emission Estimation

	Bulk Carrier - Average Gross Tonnage Categories		
	200,000+	**100,000-199,999**	**60,000-99,999**
No. ships visiting port each year	19	397	649
Fuel consumption (tonnes/hour)	0.18	0.18	0.18
Time in wharf per ship (hours/ship)	34	27	17

Emission factors were taken from the NPI *Emission Estimation Technique Manual for Marine Operations*, Version 2.0, July 2008 for application in the estimation of auxiliary boiler emissions for Stage 3 operations (**Table D13**).

Table D13 – Stage 3 Operations, Emission Estimates for Auxiliary Boilers

Pollutant	**Emission Factor for Residual Oil (kg/tonne)(a)**	**Emissions from Auxiliary Boilers (kg/year)**			
		Bulk Carrier - Average Gross Tonnage Categories			**Sum (kg/year)**
		200,000+	**100,000-199,999**	**60,000-99,999**	
NOx	12.3	1,483	1,652	1,688	**4,823.4**
CO	4.6	555	618	631	**1,803.9**

Table D13 – Stage 3 Operations, Emission Estimates for Auxiliary Boilers					
		Emissions from Auxiliary Boilers (kg/year)			
Pollutant	Emission Factor for Residual Oil (kg/tonne)(a)	Bulk Carrier - Average Gross Tonnage Categories			Sum (kg/year)
		200,000+	100,000-199,999	60,000-99,999	
TVOC	0.36	43	48	49	**141.2**
$PM_{2.5}$	1.04	125	140	143	**407.8**
PM_{10}	1.3	157	175	178	**509.8**
SO_2	54	6,513	7,251	7,412	**21,175.9**
Benzene	0.0072	0.87	0.97	0.99	**2.8**
Toluene	0.0072	0.87	0.97	0.99	**2.8**
Total xylene	0.0037	0.45	0.50	0.51	**1.5**
Ethylbenzene	0.00023	0.03	0.03	0.03	**0.1**

(a) Emission factors taken from NPI *Emission Estimation Technique Manual for Marine Operations*, July 2008 (references ICF 2006).

Rail Locomotives Combustion Emissions

Combustion emissions for locomotives accessing the T4 project area were primarily calculated for Stage 3 operations (120 Mpta, maximum throughput) operations, and were subsequently scaled to reflect the lower capacity of Stage 1 operations (70 Mtpa); i.e. Stage 1 emissions were taken to be equivalent to 58.3% of Stage 3 emissions.

Train capacities servicing the T4 Project have been indicated to be restricted to 6,100 tonnes. For the purpose of this assessment the following input data was derived for use in the estimation of combustion emissions from locomotives accessing the T4 project area for Stage 3 operations:

No. trains per year (6,100 t capacity trains delivering a total of 120 Mtpa of coal)	19,672
No. trains per day	54
No. of locomotives per train	2
Hours on-site per train (assumed)	2
Average Load Factor	0.28
Average power rating (hp)	4000
Calculated On-port line-haul rail activity (hp-hrs per day)	241,455

Calculated on-port line-haul rail activity rates were multiplied by emission factors drawn from ICF (2009) and the *NPI EETM for Railway Yard Operations V2.0 June 2008* to derive combustion emissions from locomotives for Stage 3 operations (**Table D14**).

Table D14: Stage 3 Operations – Combustion Emissions from Rail Locomotives		
	Emission Rates for Line-Haul Locomotives (g/bhp-hr)(a)	**Emission Estimates (kg/year)**
NO_x	4.95	436,249
CO	1.28	112,808
VOC	0.13	11,457
$PM_{2.5}$	0.0776	6,839
PM_{10}	0.08	7,050
SO_2(b)	0.000828	73
Benzene(c)		229
Toluene(c)		201
Total xylene(c)		32
Ethylbenzene(c)		7

(a) ICF International (2009). *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report*, Report Prepared for the U.S. Environmental Protection Agency, April 2009.

(b) Adjusted to reflect sulphur content of local fuel, based on NPI *EETM for Railway Yard Operations V2.0* June 2008.

(c) Estimated from estimated VOC emissions, based on the Profile Number 0008 (USEPA, 2002) from US-EPA Speciate V4.2.

Spatial Allocation of Operational Stage Emissions

Particulate emissions for Stage 1 and Stage 3 operations are given by point of emission in **Table D15** and **Table D16** respectively. The locations of sources referenced are illustrated in **Figure D3** for Stage 1 operations and **Figure D4** for Stage 3 operations. Gaseous emissions from rail and marine vessels, documented above, were allocated on the same basis to the source locations depicted.

Source Configuration for Operational Stage Emissions

Coal transfer points, dozer operations and combustion emissions from locomotives were simulated as volume sources. Wind entrainment from stockpiles was represented as area sources as depicted in **Figure D3** and **Figure D4**.

Auxiliary engine and boiler emissions from ocean going vessels were simulated as point sources. Emissions from auxiliary engine and auxiliary boiler emissions were combined for each berth and simulated using the following stack parameters:

Stack Height (m)	Stack Diameter (m)	Stack Gas Exit Velocity (m/s)	Gas Exit Temperature (K)
20	0.8	25	555

Source:

Mason R, Dolwick P and Carey P. (2010). Emissions Processing and Sensitivity Air Quality Modeling of Category 3 Commercial Marine Vessel Emissions, Paper presented at the 17th Annual International Emission Inventory Conference "Inventory Evolution - Portal to Improved Air Quality", Portland, Oregon - June 2 - 5, 2008.

Boulton J.W., van Altena M., Devine D., Qiu X., di Cenzo C. and Green A. (2008). Generating an Hour-by-hour Model-ready Marine Emission Inventory, Paper presented at the 17th Annual International Emission Inventory Conference "Inventory Evolution - Portal to Improved Air Quality", Portland, Oregon - June 2 - 5, 2008.

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Table D15: Stage 1 Operations – Predicted Particulate Matter Emissions							
Category	**Sources**	**Source Number**	**Activity Rates**	**CE(%)**	**TSP (tpa)**	**PM_{10} (tpa)**	**$PM_{2.5}$ (tpa)**
Dump Station	Dump Station	DS	70,000 ktpa	70	5.020	2.374	0.360
Conveyor transfer	Conveyor Transfer 1 between Dump Station and Stockyard	CV1	70,000 ktpa	85	2.510	1.187	0.180
Conveyor transfer	Conveyor Transfer 2 between Dump Station and Stockyard	CV2	23,333 ktpa	85	0.837	0.396	0.060
Conveyor transfer	Conveyor Transfer 3 between Dump Station and Stockyard	CV3	23,333 ktpa	85	0.837	0.396	0.060
Conveyor transfer	Conveyor Transfer 4 between Dump Station and Stockyard	CV4	23,333 ktpa	85	0.837	0.396	0.060
Stacker/reclaimer	Stacker/Reclaimer 1	SR1	31,500 ktpa	25	5.647	2.671	0.404
Stacker/reclaimer	Stacker/Reclaimer 2	SR2	31,500 ktpa	25	5.647	2.671	0.404
Stacker/reclaimer	Stacker/Reclaimer 3	SR3	31,500 ktpa	25	5.647	2.671	0.404
Stacker/reclaimer	Stacker/Reclaimer 4	SR4	31,500 ktpa	25	5.647	2.671	0.404
Stacker/reclaimer	Stacker 1	SR9	14,000 ktpa	25	2.510	1.187	0.180
Conveyor transfer	Conveyor Transfer 8 between Stockyard and Buffer Bin	CV8	17,500 ktpa	85	0.627	0.297	0.045
Conveyor transfer	Conveyor Transfer 9 between Stockyard and Buffer Bin	CV9	17,500 ktpa	85	0.627	0.297	0.045
Conveyor transfer	Conveyor Transfer 12 between Stockyard and Buffer Bin	CV12	70,000 ktpa	85	2.510	1.187	0.180
Conveyor transfer	Conveyor Transfer 13 between Stockyard and Buffer Bin	CV13	70,000 ktpa	85	2.510	1.187	0.180
Conveyor transfer	Conveyor Transfer 14 between Buffer Bins and Shiploaders	CV14	35,000 ktpa	85	1.255	0.594	0.090
Conveyor transfer	Conveyor Transfer 15 between Buffer Bins and Shiploaders	CV15	35,000 ktpa	85	1.255	0.594	0.090
Dozer	Dozer /FEL in Stockyard	DZ	365 hrs/year	0	7.773	1.941	0.171
Shiploading	Shiploader 1	SL1	35,000 ktpa	70	2.510	1.187	0.180
Shiploading	Shiploader 2	SL2	35,000 ktpa	70	2.510	1.187	0.180

Table D15: Stage 1 Operations – Predicted Particulate Matter Emissions

Category	Sources	Source Number	Activity Rates	CE(%)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Stockpiles	Stockpile 1	WE1	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 2	WE2	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 3	WE3	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 4	WE4	10 ha surface area	50	21.195	10.598	1.590
Rail	Trains idling on inbound	RL1	31 trains (6,100 t capacity) accessing the site per day	0	1.092	1.828	1.773
Rail	Train entering dump station (wagons full)	RL2		0	0.468	0.457	0.443
Rail	Train in dump station (half wagons unloaded)	RL3		0	0.468	0.457	0.443
Rail	Tran exiting dump station (wagons empty)	RL4		0	0.468	0.457	0.443
Rail	Train departed dump station (wagons empty)	RL5		0	0.468	0.457	0.443
Rail	Train idling on outbound (wagons empty)	RL6		0	0.468	0.457	0.443
Ships	Berth 1	BT1	1 to 2 ships at berth at any given time	0	4.883	4.883	4.193
Ships	Berth 2	BT2		0	4.883	4.883	4.193
Ships	Berth 3	BT3		0	4.883	4.883	4.193
Total					**159.579**	**86.241**	**26.605**

		CE(%)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Summary by Activity	Dump Station	70	5.020	2.374	0.360
	Conveyor Transfers	85	13.804	6.529	0.989
	Stacker/Reclaimers	25	25.098	11.871	1.798
	Stockpiles (wind erosion)	50	84.780	42.390	6.359
	Dozer/FEL in Stockyard	0	7.773	1.941	0.171
	Ship Loaders	70	5.020	2.374	0.360
	Locomotives (combustion emissions)	0	3.434	4.113	3.989
	Vessels at Berth (combustion emissions)	0	14.650	14.650	12.580
Total			**159.579**	**86.241**	**26.605**

Table D16: Stage 3 Operations – Particulate Matter Emissions

Category	Sources	Source Number	Activity Rates	CE(%)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Dump Station	Dump Station	DS	120,000 ktpa	70	8.605	4.070	0.616
Conveyor transfer	Conveyor Transfer 1 between Dump Station and Stockyard	CV1	120,000 ktpa	85	4.303	2.035	0.308
Conveyor transfer	Conveyor Transfer 2 between Dump Station and Stockyard	CV2	20,000 ktpa	85	0.717	0.339	0.051
Conveyor transfer	Conveyor Transfer 3 between Dump Station and Stockyard	CV3	20,000 ktpa	85	0.717	0.339	0.051
Conveyor transfer	Conveyor Transfer 4 between Dump Station and Stockyard	CV4	20,000 ktpa	85	0.717	0.339	0.051
Conveyor transfer	Conveyor Transfer 5 between Dump Station and Stockyard	CV5	20,000 ktpa	85	0.717	0.339	0.051
Conveyor transfer	Conveyor Transfer 6 between Dump Station and Stockyard	CV6	20,000 ktpa	85	0.717	0.339	0.051
Conveyor transfer	Conveyor Transfer 7 between Dump Station and Stockyard	CV7	20,000 ktpa	85	0.717	0.339	0.051
Stacker/reclaimer	Stacker Reclaimer 1	SR1	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 2	SR2	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 3	SR3	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 4	SR4	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 5	SR5	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 6	SR6	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 7	SR7	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker Reclaimer 8	SR8	27,000 ktpa	25	4.840	2.289	0.347
Stacker/reclaimer	Stacker 1	SR9	12,000 ktpa	25	2.151	1.018	0.154
Stacker/reclaimer	Stacker 2	SR10	12,000 ktpa	25	2.151	1.018	0.154
Conveyor transfer	Conveyor Transfer 8 between Stockyard and Buffer Bin	CV8	30,000 ktpa	85	1.076	0.509	0.077

FINAL

Table D16: Stage 3 Operations – Particulate Matter Emissions

Category	Sources	Source Number	Activity Rates	CE(%)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Conveyor transfer	Conveyor Transfer 9 between Stockyard and Buffer Bin	CV9	30,000 ktpa	85	1.076	0.509	0.077
Conveyor transfer	Conveyor Transfer 10 between Stockyard and Buffer Bin	CV10	30,000 ktpa	85	1.076	0.509	0.077
Conveyor transfer	Conveyor Transfer 11 between Stockyard and Buffer Bin	CV11	30,000 ktpa	85	1.076	0.509	0.077
Conveyor transfer	Conveyor Transfer 12 between Stockyard and Buffer Bin	CV12	120,000 ktpa	85	4.303	2.035	0.308
Conveyor transfer	Conveyor Transfer 13 between Stockyard and Buffer Bin	CV13	120,000 ktpa	85	4.303	2.035	0.308
Conveyor transfer	Conveyor Transfer 14 between Buffer Bins and Shiploaders	CV14	60,000 ktpa	85	2.151	1.018	0.154
Conveyor transfer	Conveyor Transfer 15 between Buffer Bins and Shiploaders	CV15	60,000 ktpa	85	2.151	1.018	0.154
Dozer	Dozer /FEL in Stockyard	DZ	730 hrs/year	0	15.546	3.881	0.342
Shiploading	Shiploader 1	SL1	30,000 ktpa	70	2.151	1.018	0.154
Shiploading	Shiploader 2	SL2	30,000 ktpa	70	2.151	1.018	0.154
Shiploading	Shiploader 3	SL3	30,000 ktpa	70	2.151	1.018	0.154
Shiploading	Shiploader 4	SL4	30,000 ktpa	70	2.151	1.018	0.154
Stockpiles	Stockpile 1	WE1	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 2	WE2	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 3	WE3	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 4	WE4	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 5	WE5	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 6	WE6	10 ha surface area	50	21.195	10.598	1.590
Stockpiles	Stockpile 7	WE7	10 ha surface area	50	21.195	10.598	1.590
Rail	Trains idling on inbound (4 trains)	RL1	54 trains (6,100 t capacity) accessing the site per day	0	3.211	3.134	3.040
Rail	Train entering dump station (wagons full)	RL2		0	0.803	0.783	0.760

Table D16: Stage 3 Operations – Particulate Matter Emissions

Category	Sources	Source Number	Activity Rates	CE(%)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Rail	Train in dump station (half wagons unloaded)	RL3		0	0.803	0.783	0.760
Rail	Tran exiting dump station (wagons empty)	RL4		0	0.803	0.783	0.760
Rail	Train departed dump station (wagons empty)	RL5		0	0.803	0.783	0.760
Rail	Train idling on outbound (wagons empty)	RL6		0	0.803	0.783	0.760
Ships	Berth 1	BT1	2 to 3 ships at berth at any given time	0	4.883	4.883	4.193
Ships	Berth 2	BT2		0	4.883	4.883	4.193
Ships	Berth 3	BT3		0	4.883	4.883	4.193
Ships	Berth 4	BT4		0	4.883	4.883	4.193
Ships	Berth 5	BT5		0	4.883	4.883	4.193
Total					**281.603**	**150.231**	**45.439**

Summary by Activity	Dump Station	70	8.605	4.070	0.616
	Conveyor Transfers	85	25.816	12.210	1.849
	Stacker/Reclaimers	25	43.026	20.350	3.082
	Stockpiles (wind erosion)	50	148.366	74.183	11.127
	Dozer/FEL in Stockyard	0	15.546	3.881	0.342
	Ship Loaders	70	8.605	4.070	0.616
	Locomotives (combustion emissions)	0	7.224	7.050	6.839
	Vessels at Berth (combustion emissions)	0	24.416	24.416	20.967
Total			**281.603**	**150.231**	**45.439**

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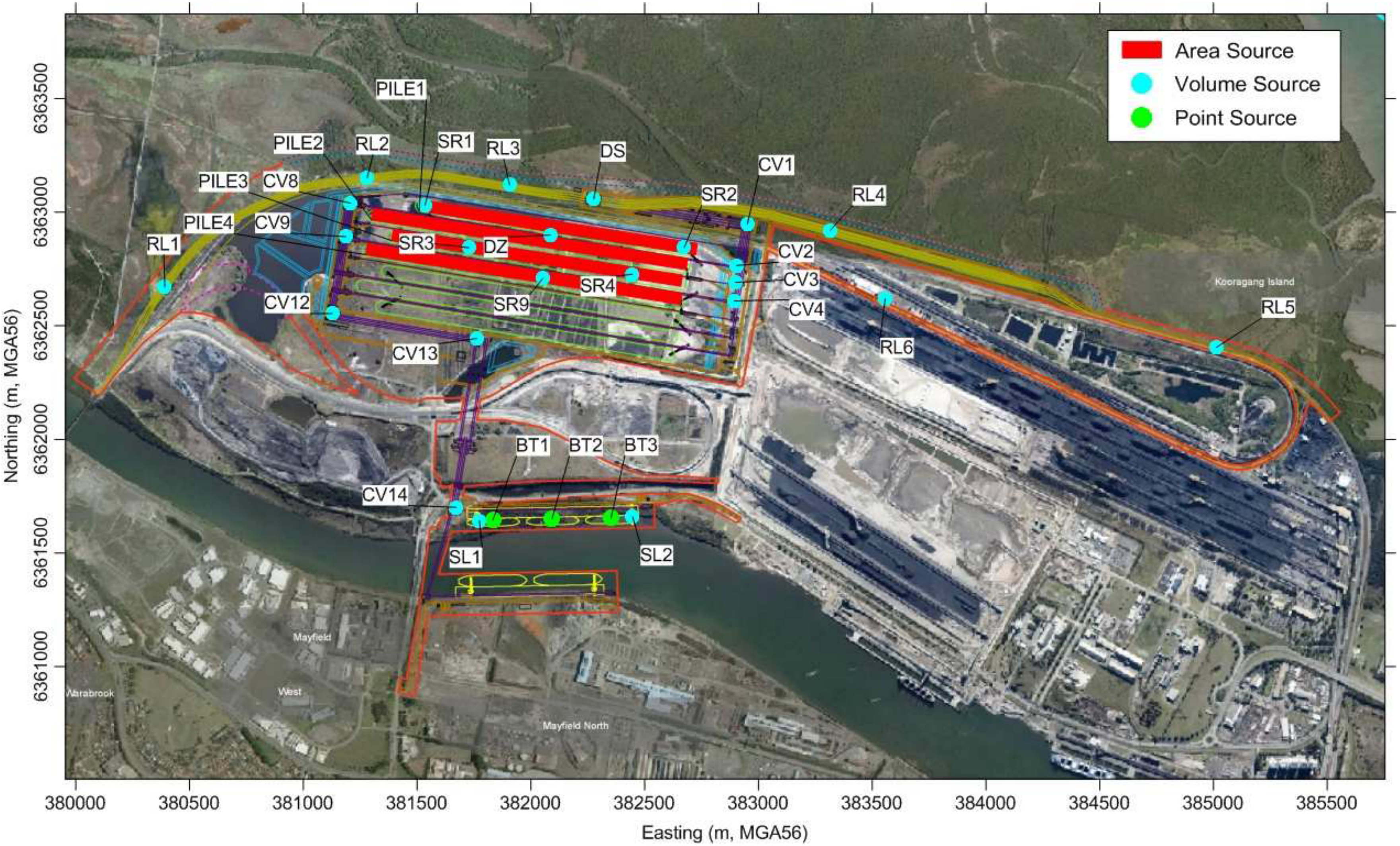

Figure D3 – Spatial allocation of Stage 1 Operation Emissions

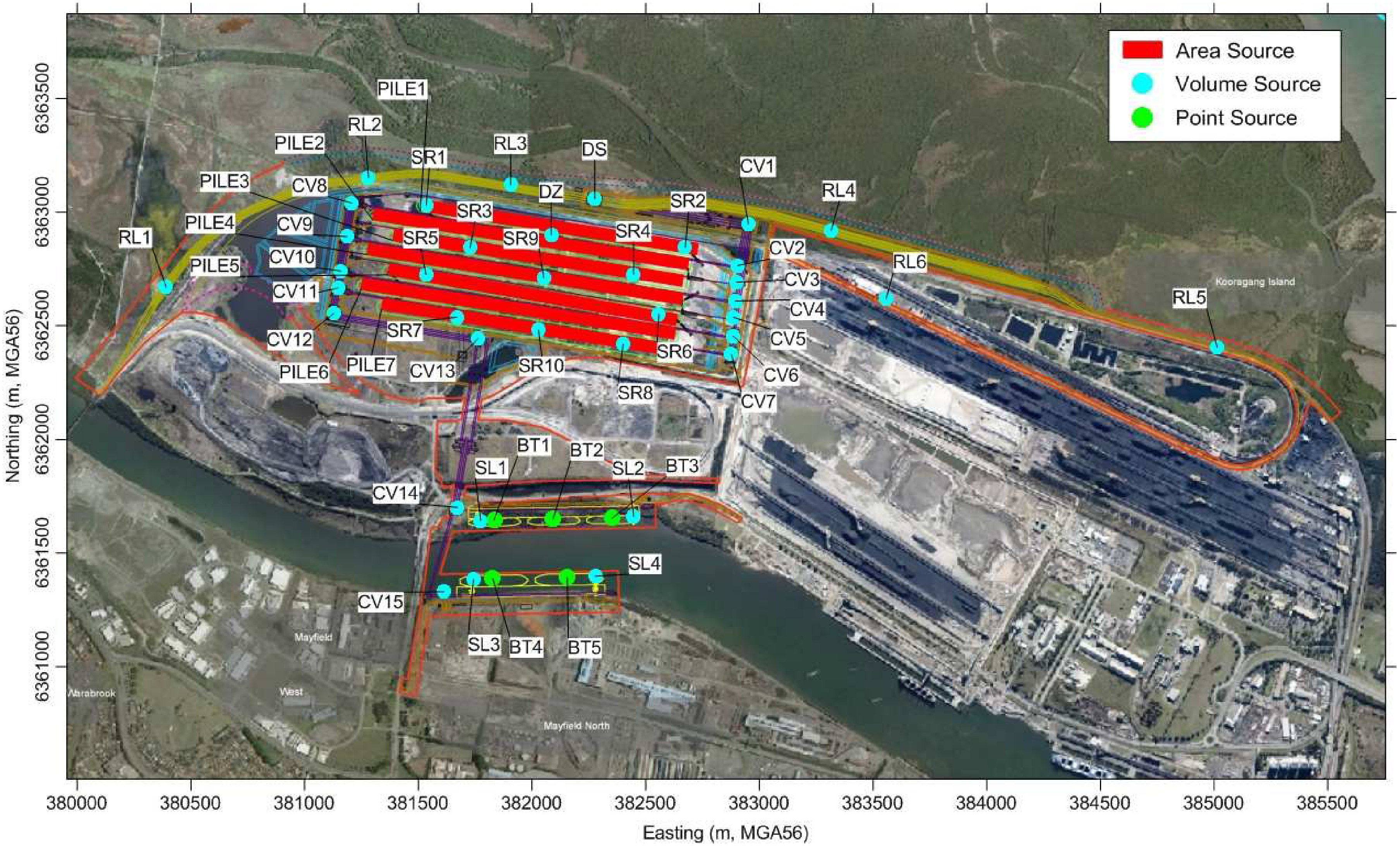

Figure D4 – Spatial allocation of Stage 3 Operation Emissions

Appendix E
Incremental Air Pollutant Isopleths

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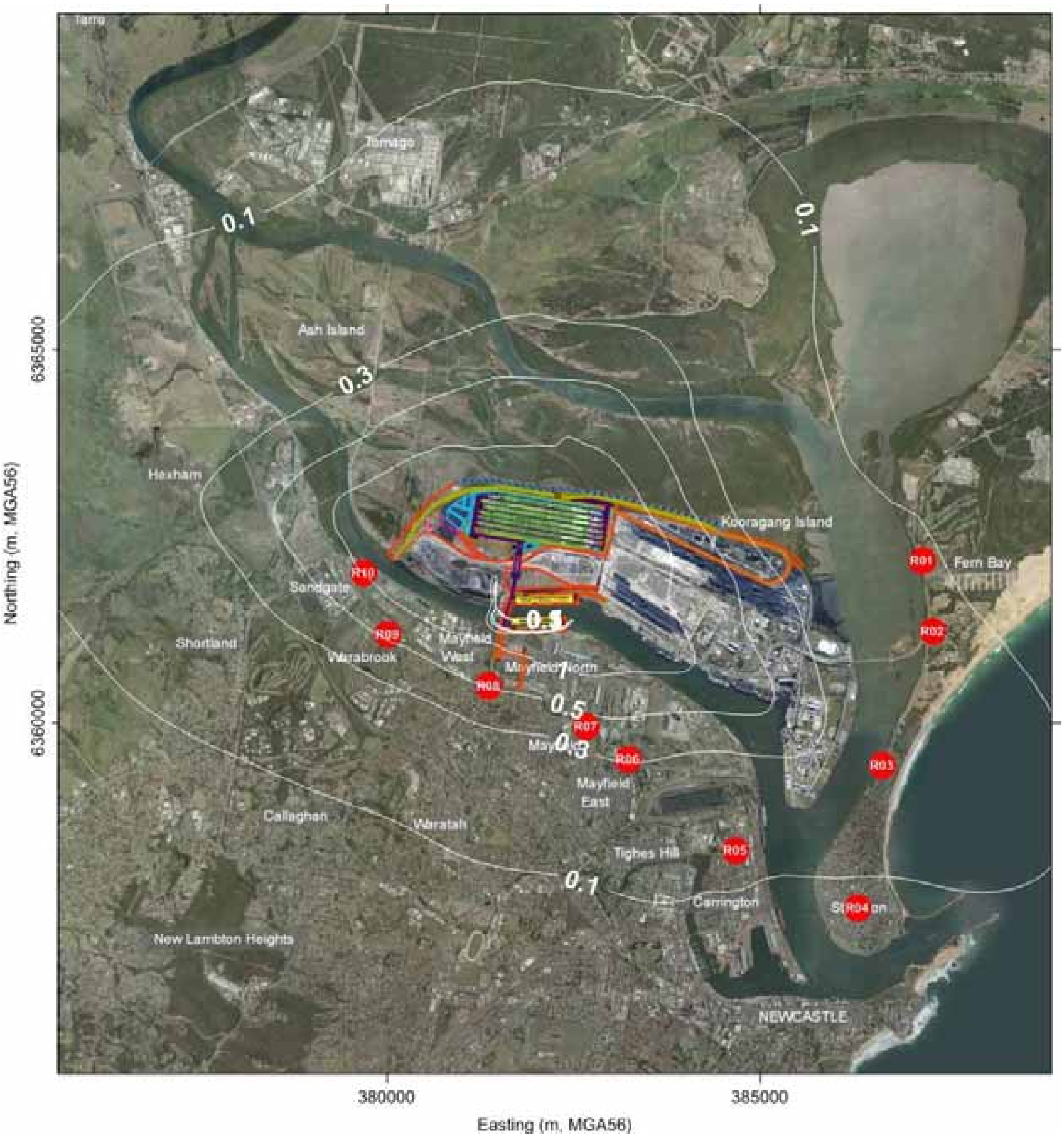

Figure E1: Incremental Annual Average TSP Concentrations (µg/m³) – Construction Stage 1

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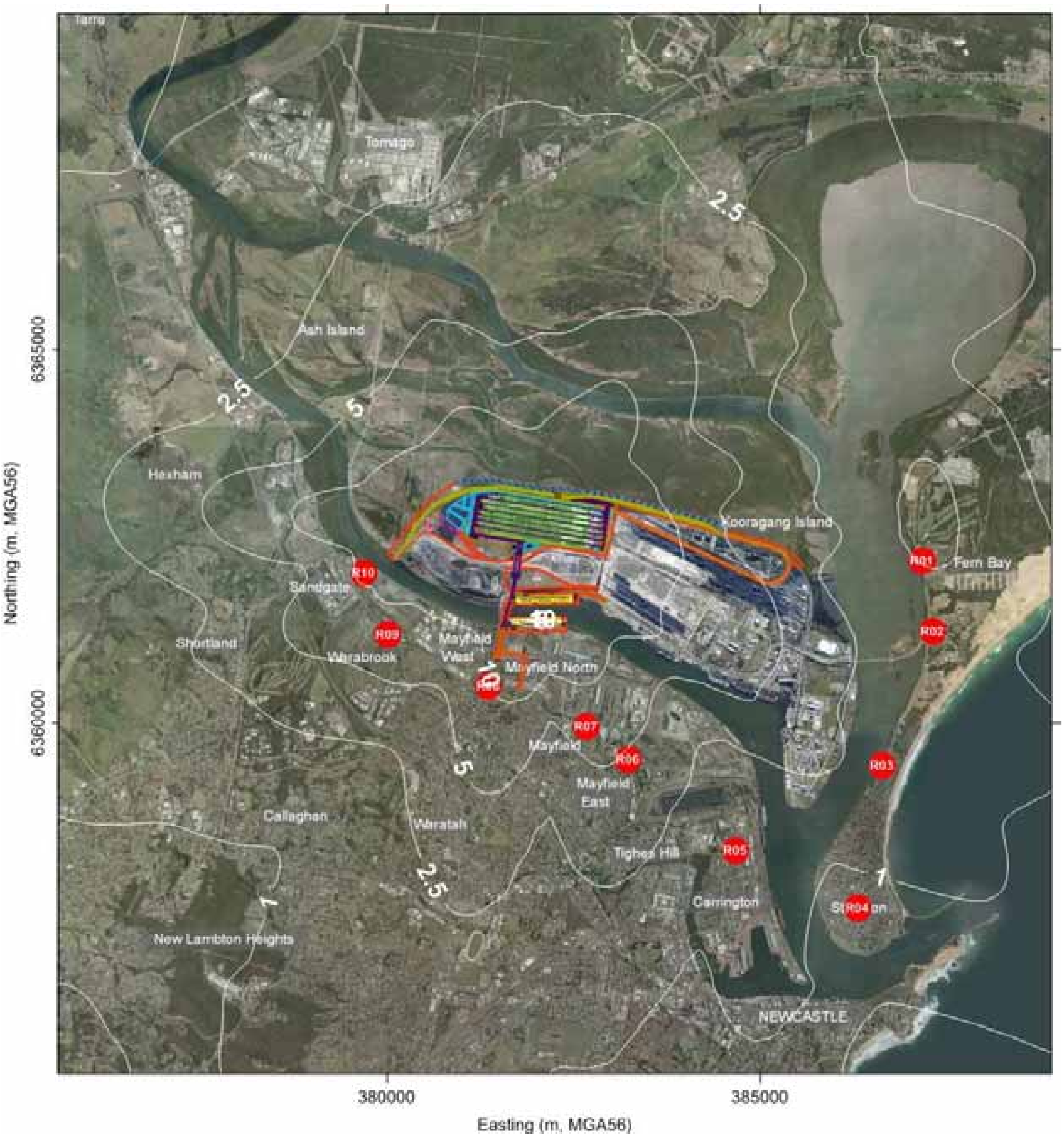

Figure E2: Incremental Maximum 24-hour Average PM_{10} Concentrations (µg/m³) – Construction Stage 1

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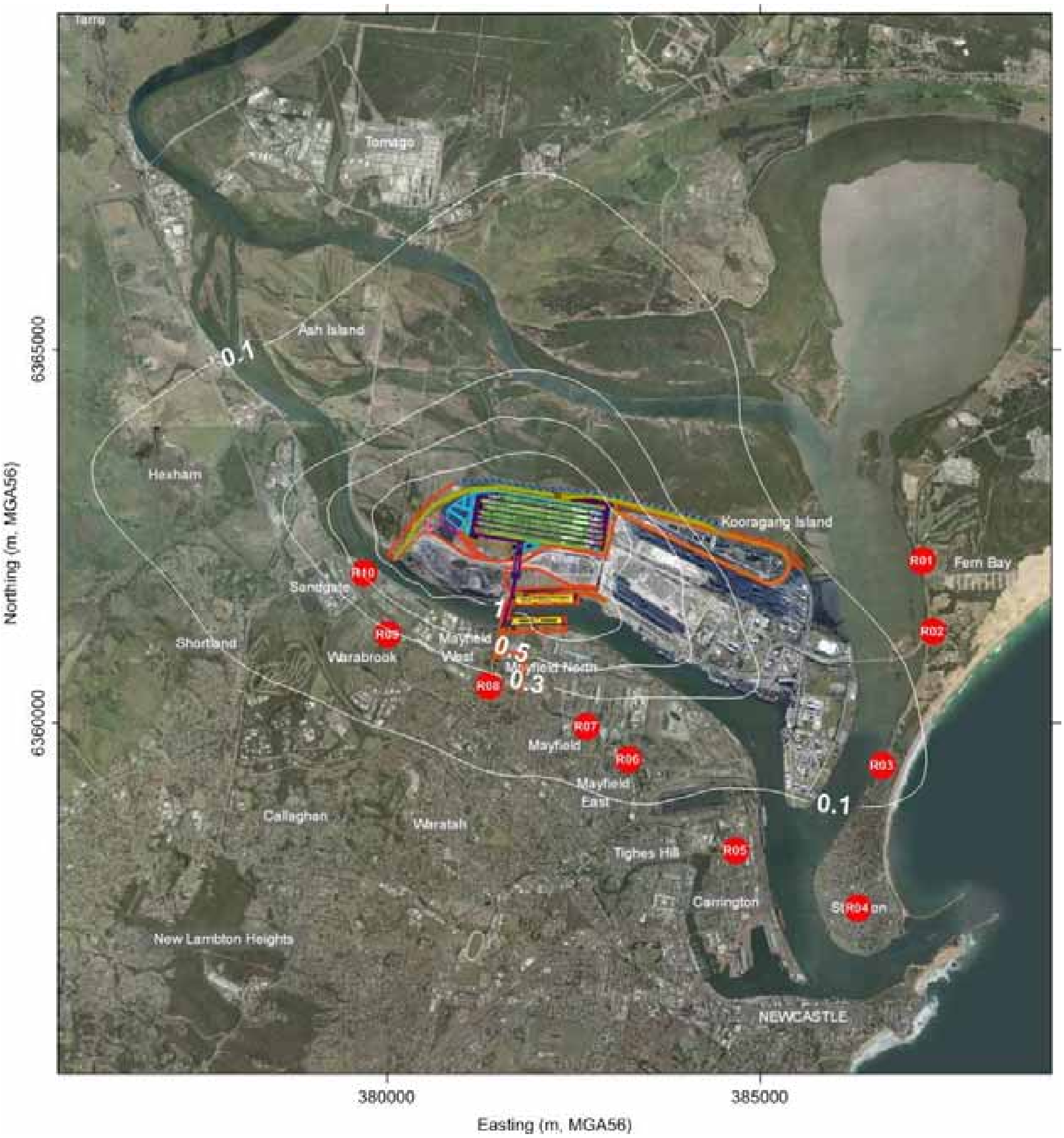

Figure E3: Incremental Annual Average PM_{10} Concentrations (µg/m³) – Construction Stage 1

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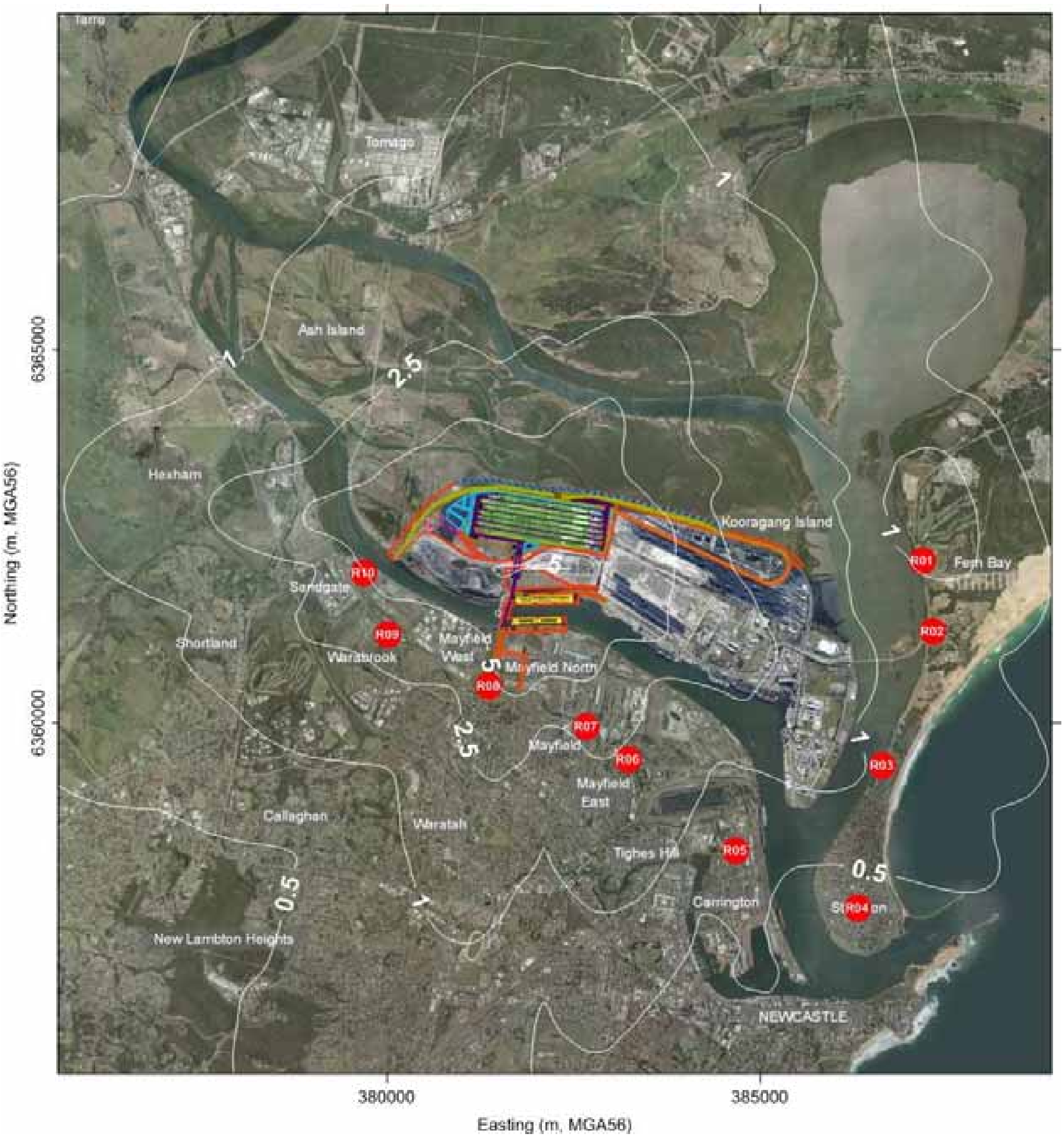

Figure E4: Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) – Construction Stage 1

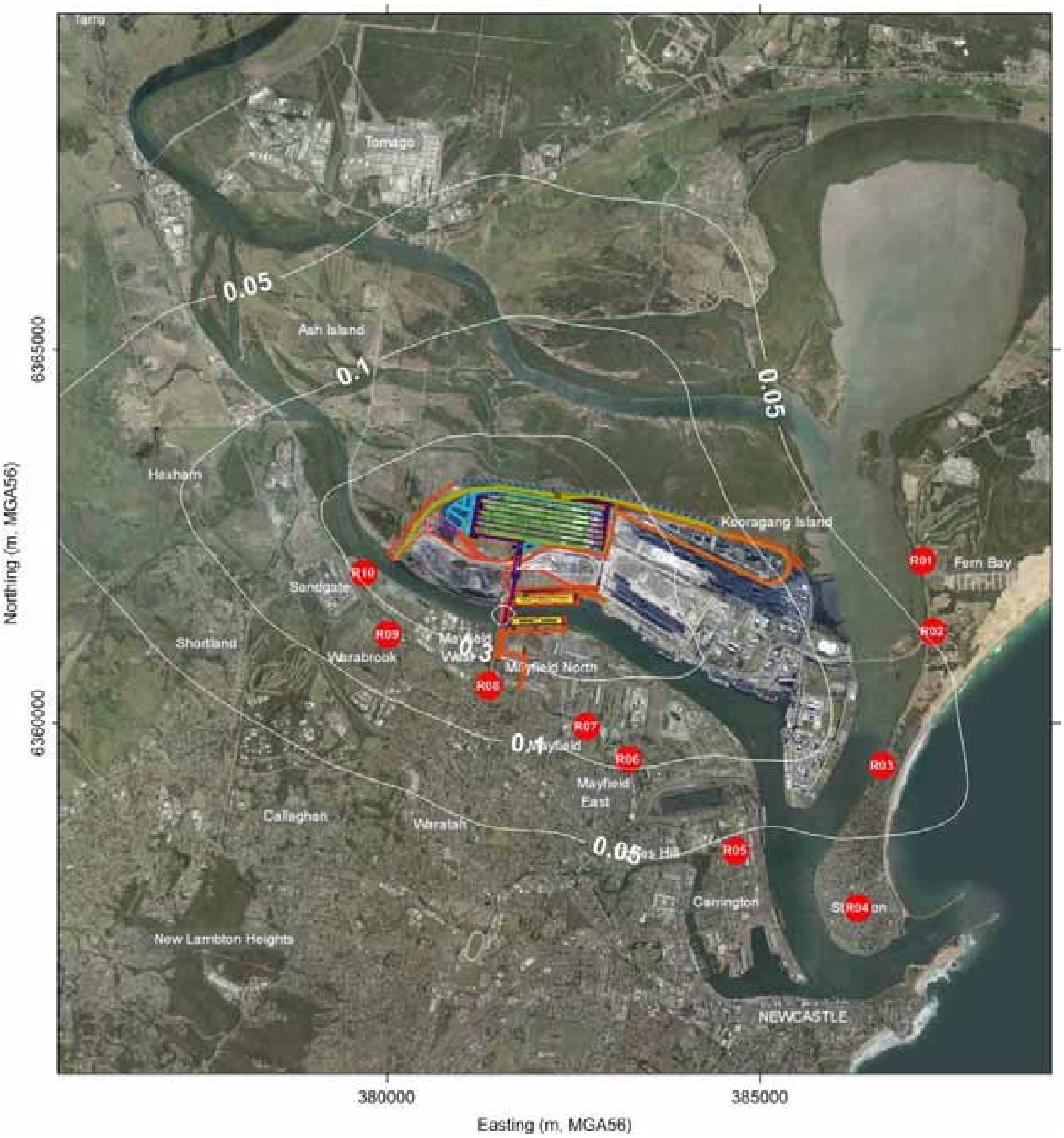

Figure E5: Incremental Annual Average $PM_{2.5}$ Concentrations (µg/m³) – Construction Stage 1

FINAL

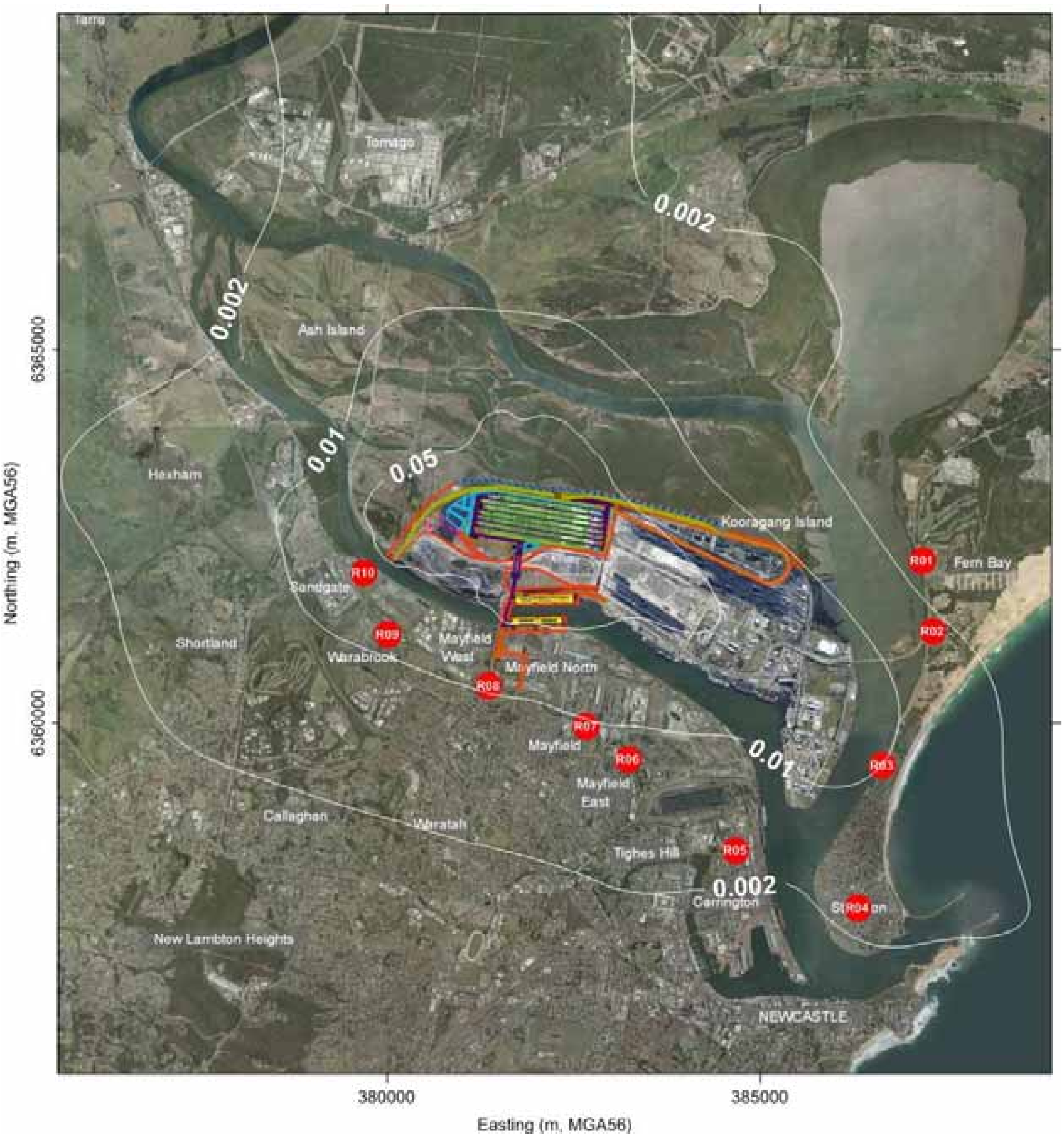

Figure E6: Incremental Annual Average Dust Deposition Rates (g/m^2/month) – Construction Stage 1

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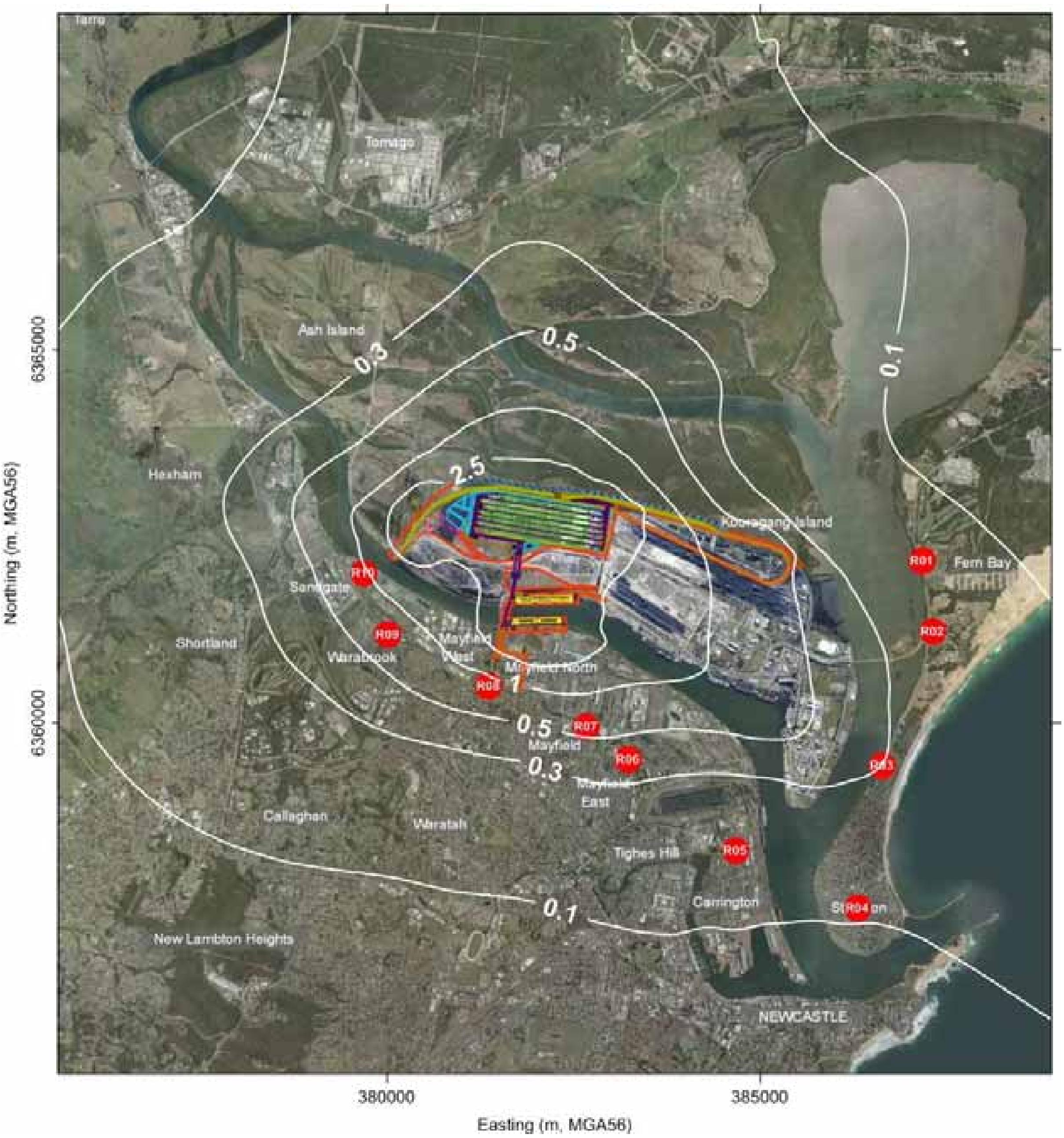

Figure E7: Incremental Annual Average TSP Concentrations (µg/m³) – Combined Operational Stage 1 and Construction Stage 2

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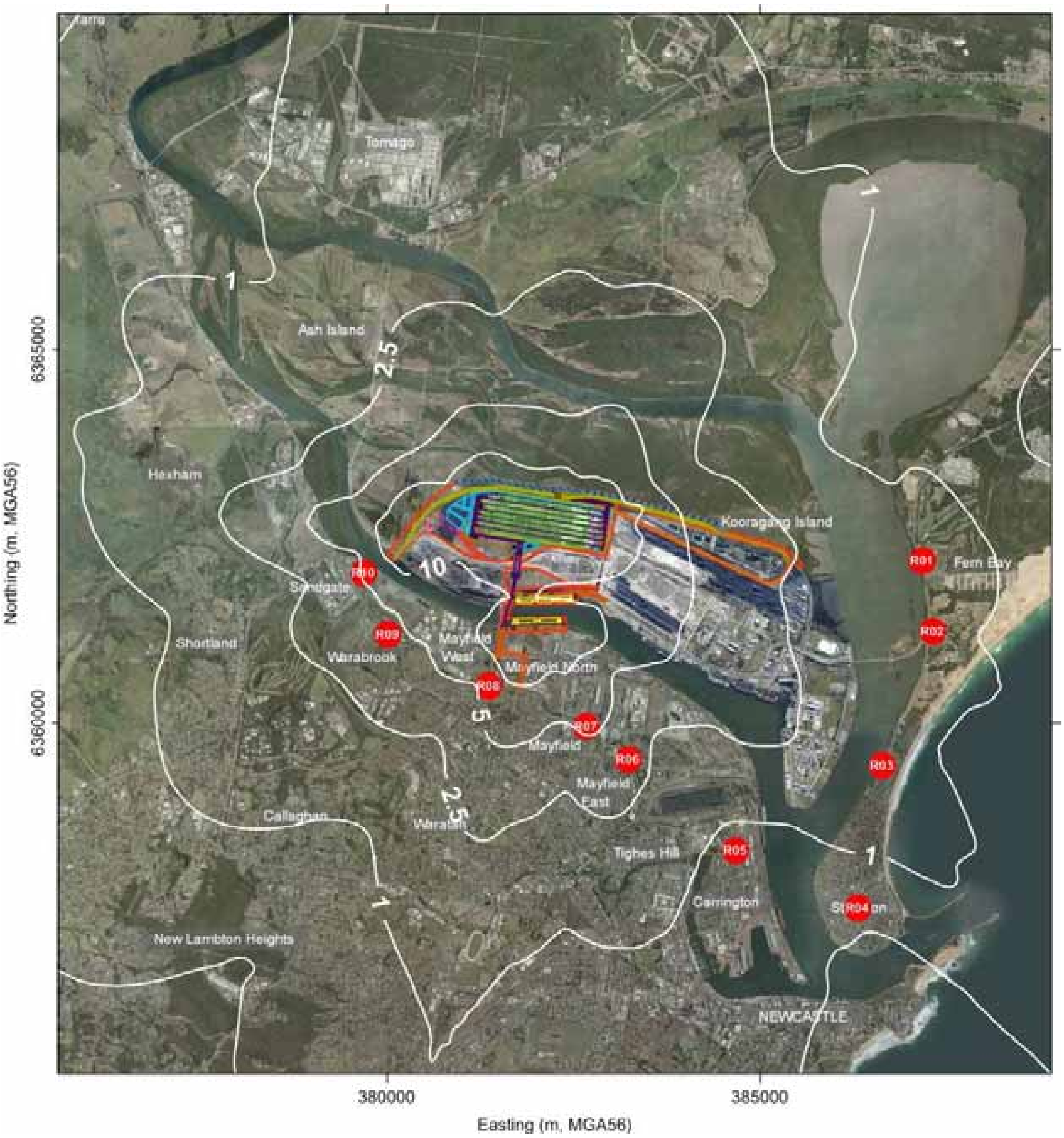

Figure E8: Incremental Maximum 24-hour Average PM_{10} Concentrations (µg/m³) – Combined Operational Stage 1 and Construction Stage 2

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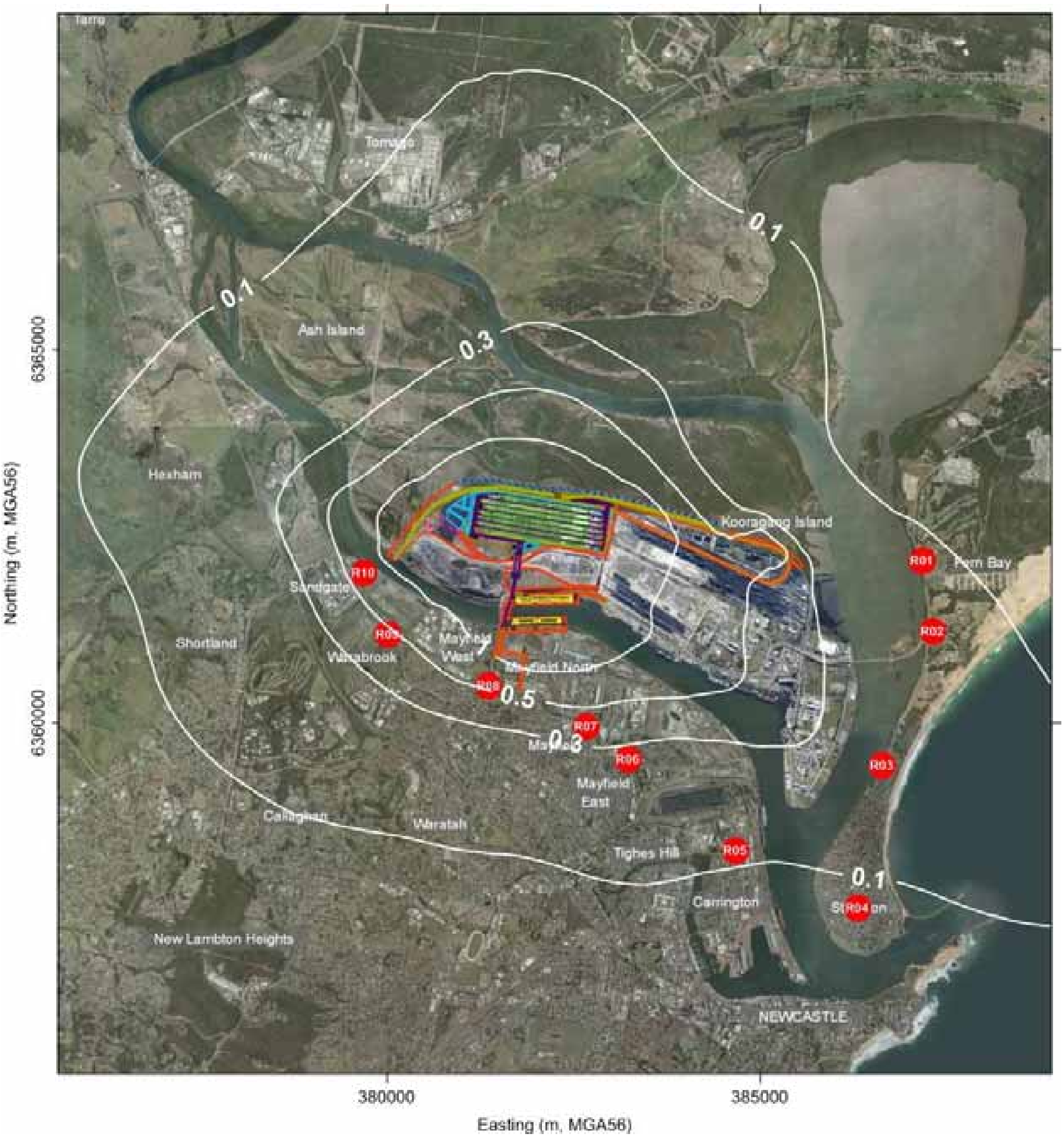

Figure E9: Incremental Annual Average PM_{10} Concentrations (µg/m³) – Combined Operational Stage 1 and Construction Stage 2

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Figure E10: Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) – Combined Operational Stage 1 and Construction Stage 2

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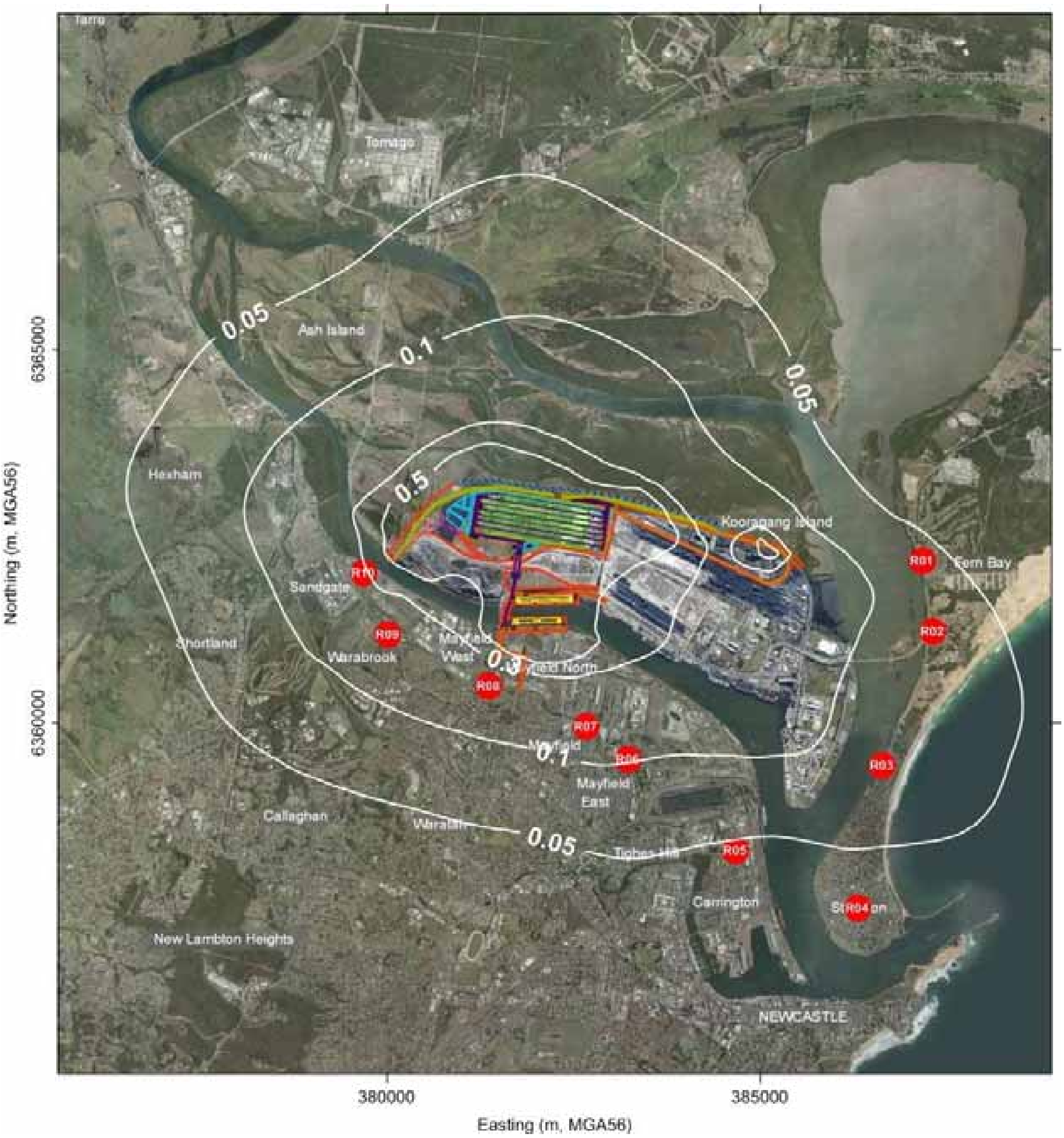

Figure E11: Incremental Annual Average $PM_{2.5}$ Concentrations (µg/m³) – Combined Operational Stage 1 and Construction Stage 2

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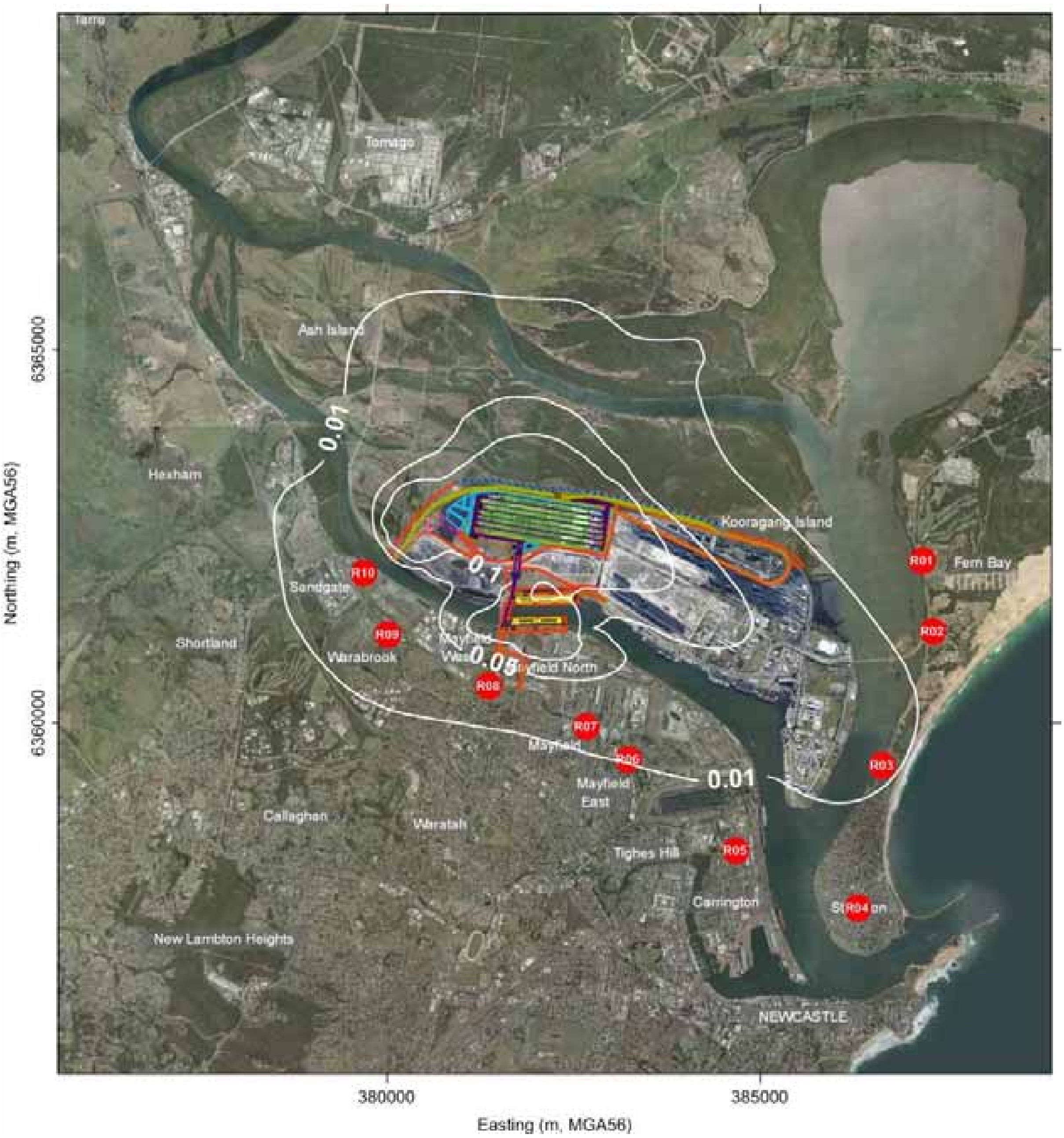

Figure E12: Incremental Annual Average Dust Deposition Rates (g/m^2/month) – Combined Operational Stage 1 and Construction Stage 2

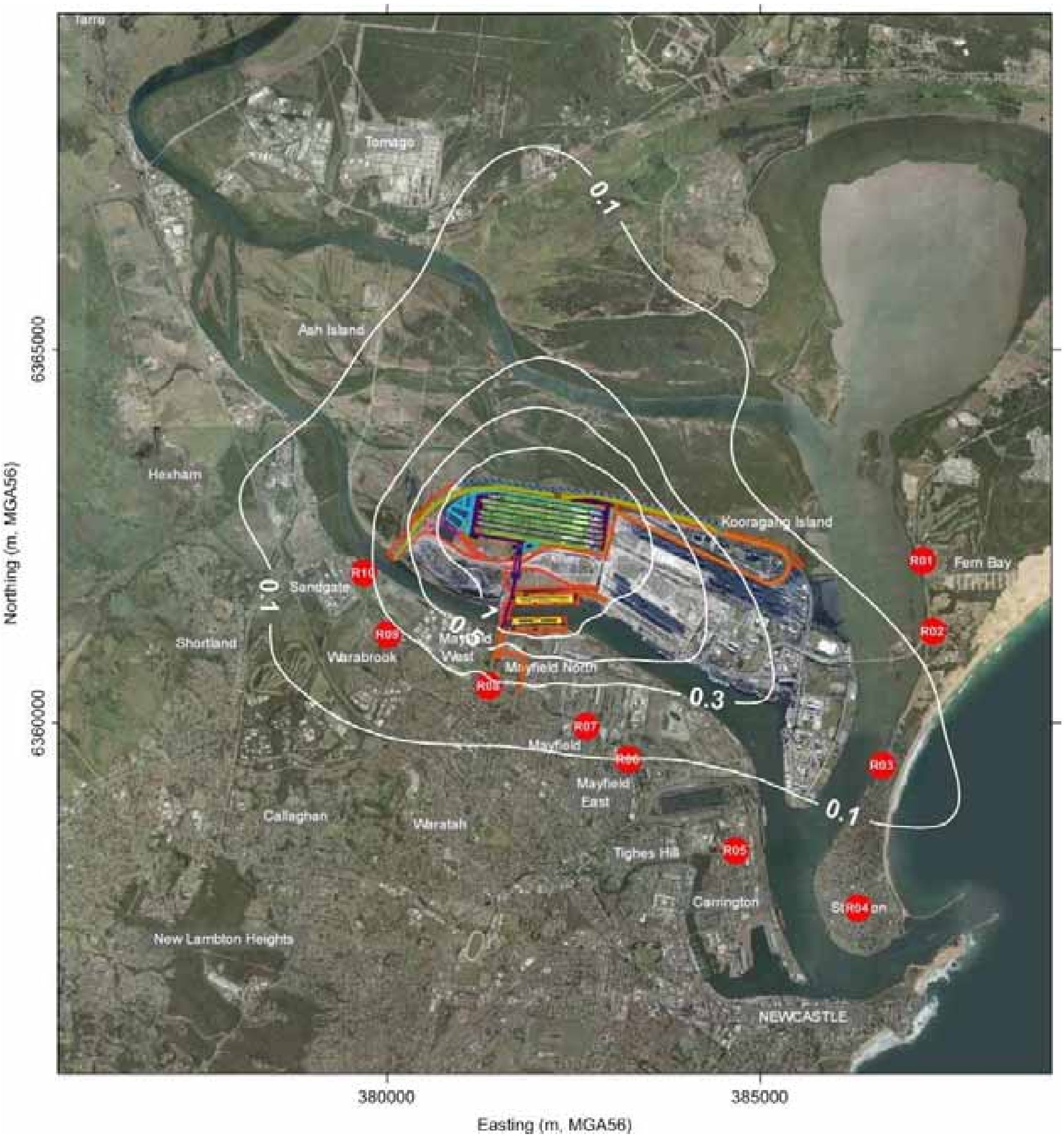

Figure E13: Incremental Annual Average TSP Concentrations (µg/m³) – Operational Stage 3

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Figure E14: Incremental Maximum 24-hour Average PM_{10} Concentrations ($\mu g/m^3$) – Operational Stage 3

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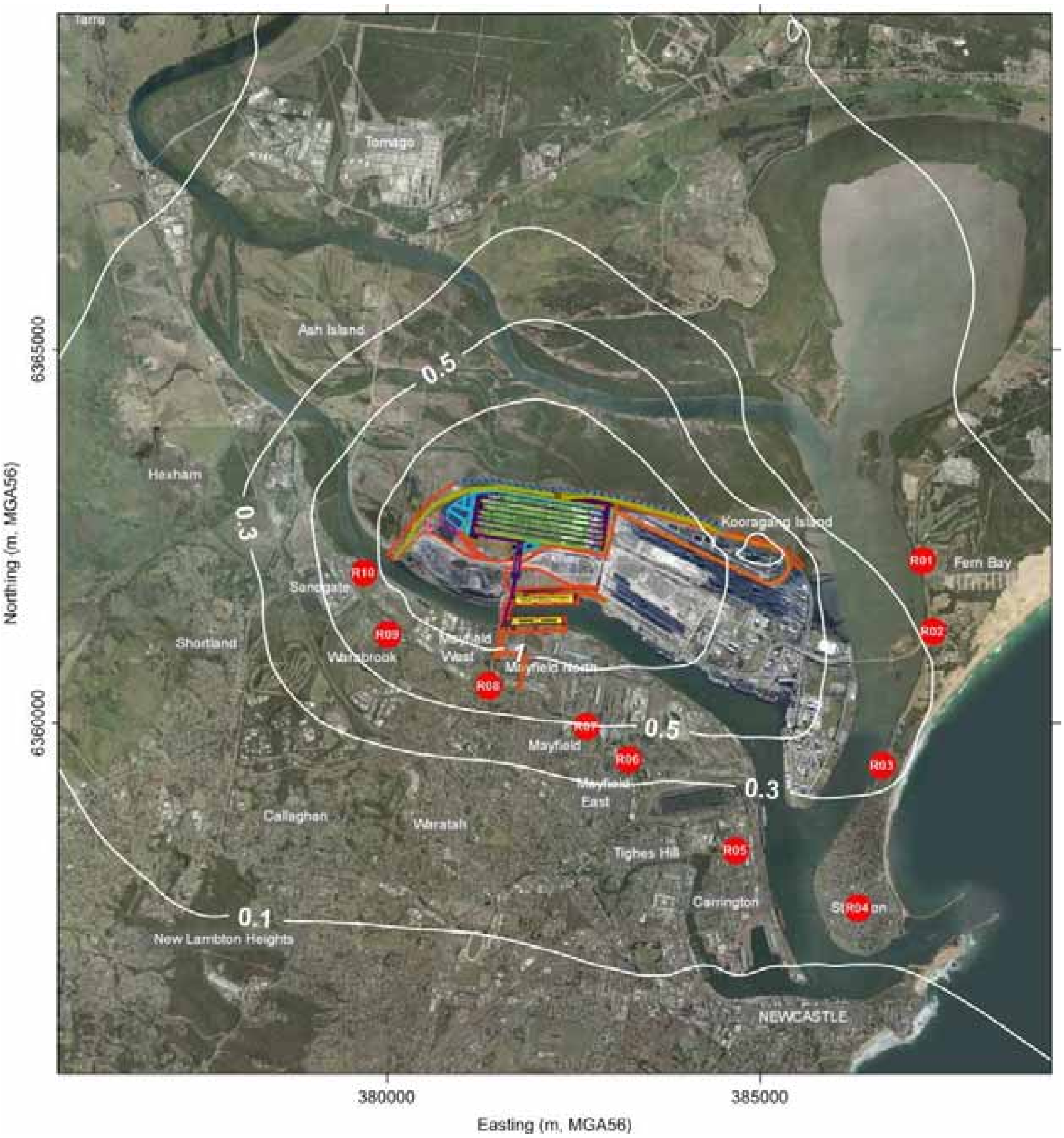

Figure E15: Incremental Annual Average PM_{10} Concentrations (µg/m³) – Operational Stage 3

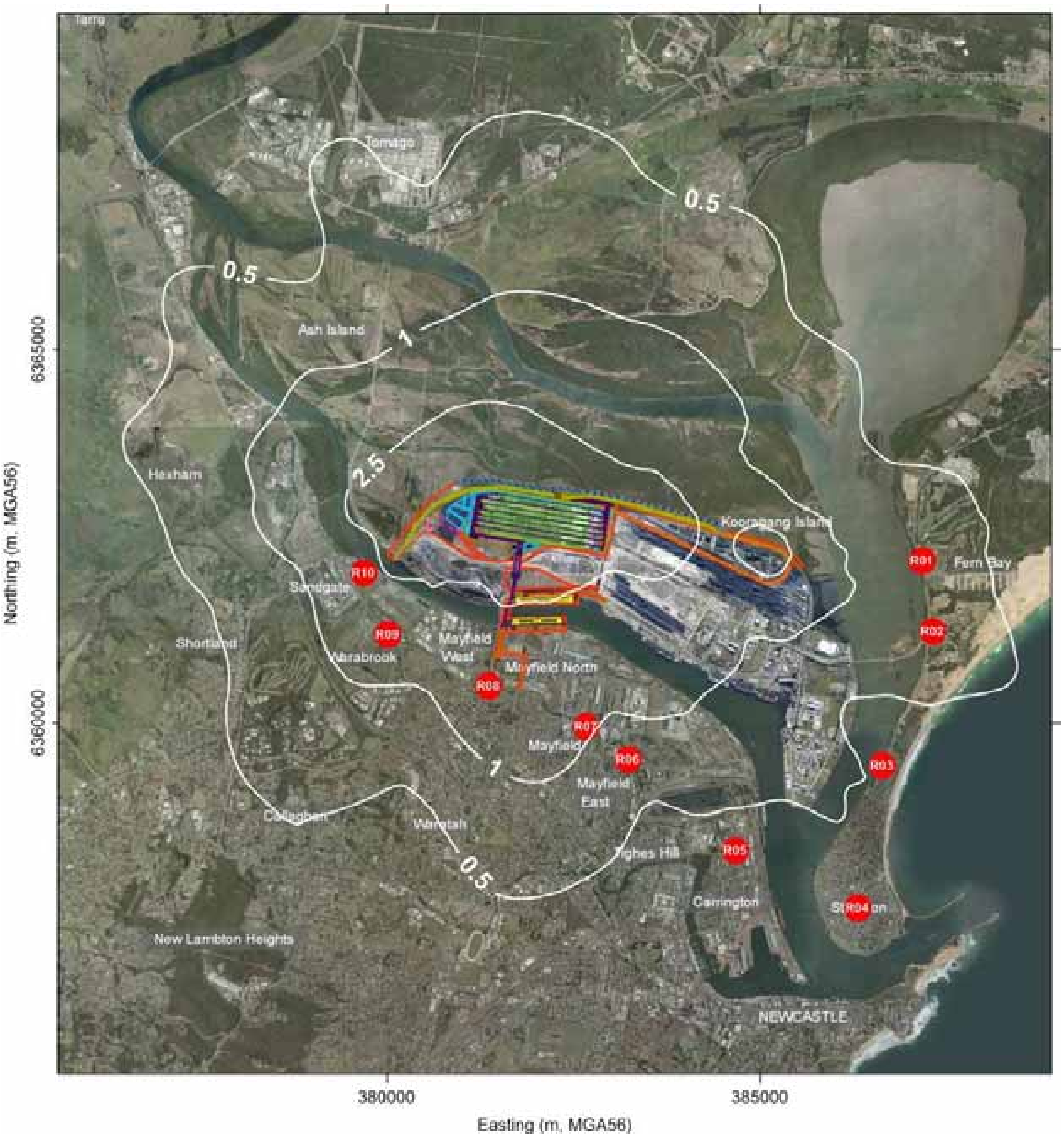

Figure E16: Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations (µg/m³) – Operational Stage 3

Figure E17: Incremental Annual Average $PM_{2.5}$ Concentrations (µg/m³) – Operational Stage 3

FINAL

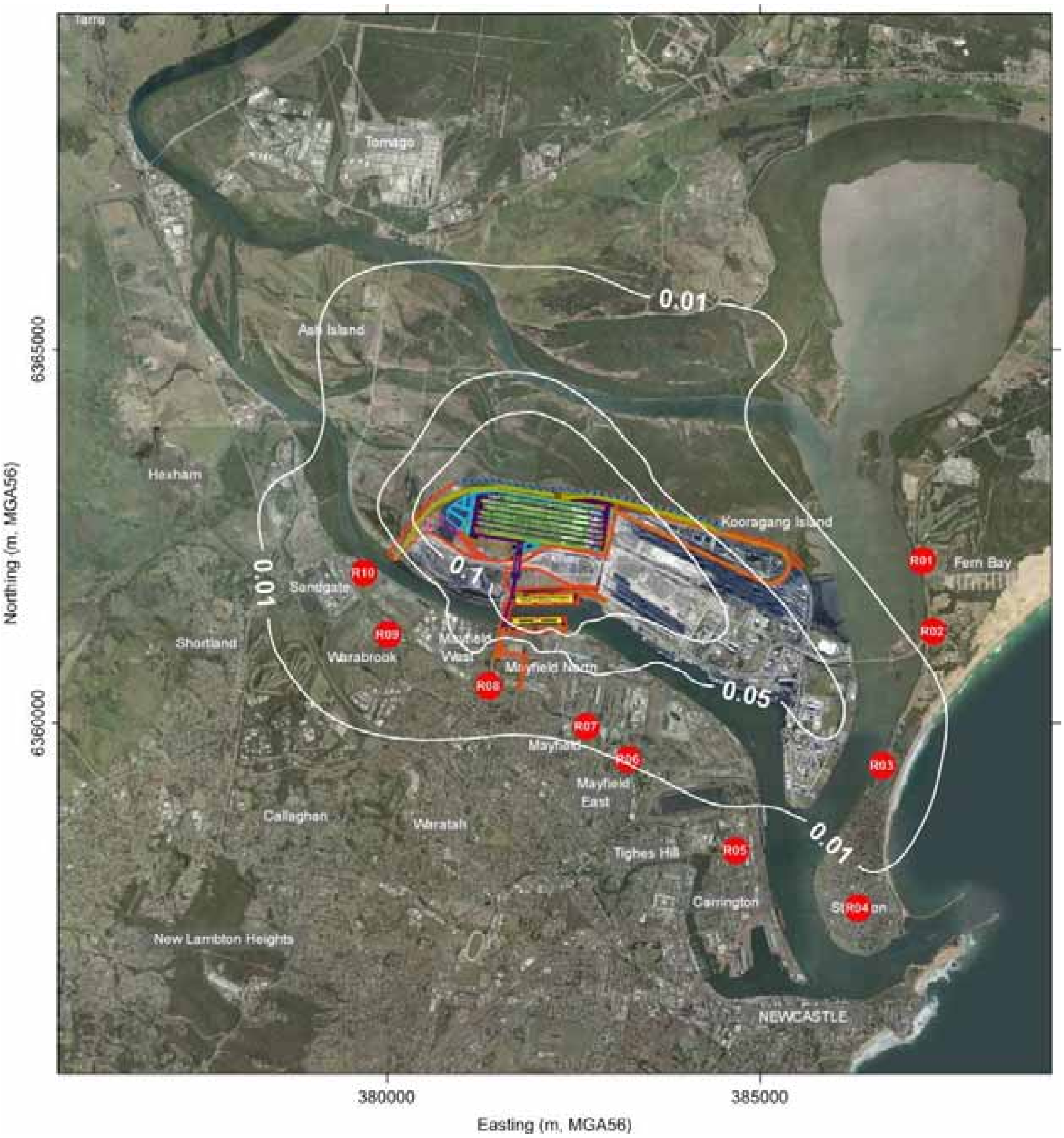

Figure E18: Incremental Annual Average Dust Deposition Rates (g/m²/month) – Operational Stage 3

FINAL

Figure E19: Incremental Maximum 1-hour Average SO_2 Concentrations (µg/m³) – Operational Stage 3

FINAL

Figure E20: Incremental Maximum 24-hour Average SO_2 Concentrations ($\mu g/m^3$) – Operational Stage 3

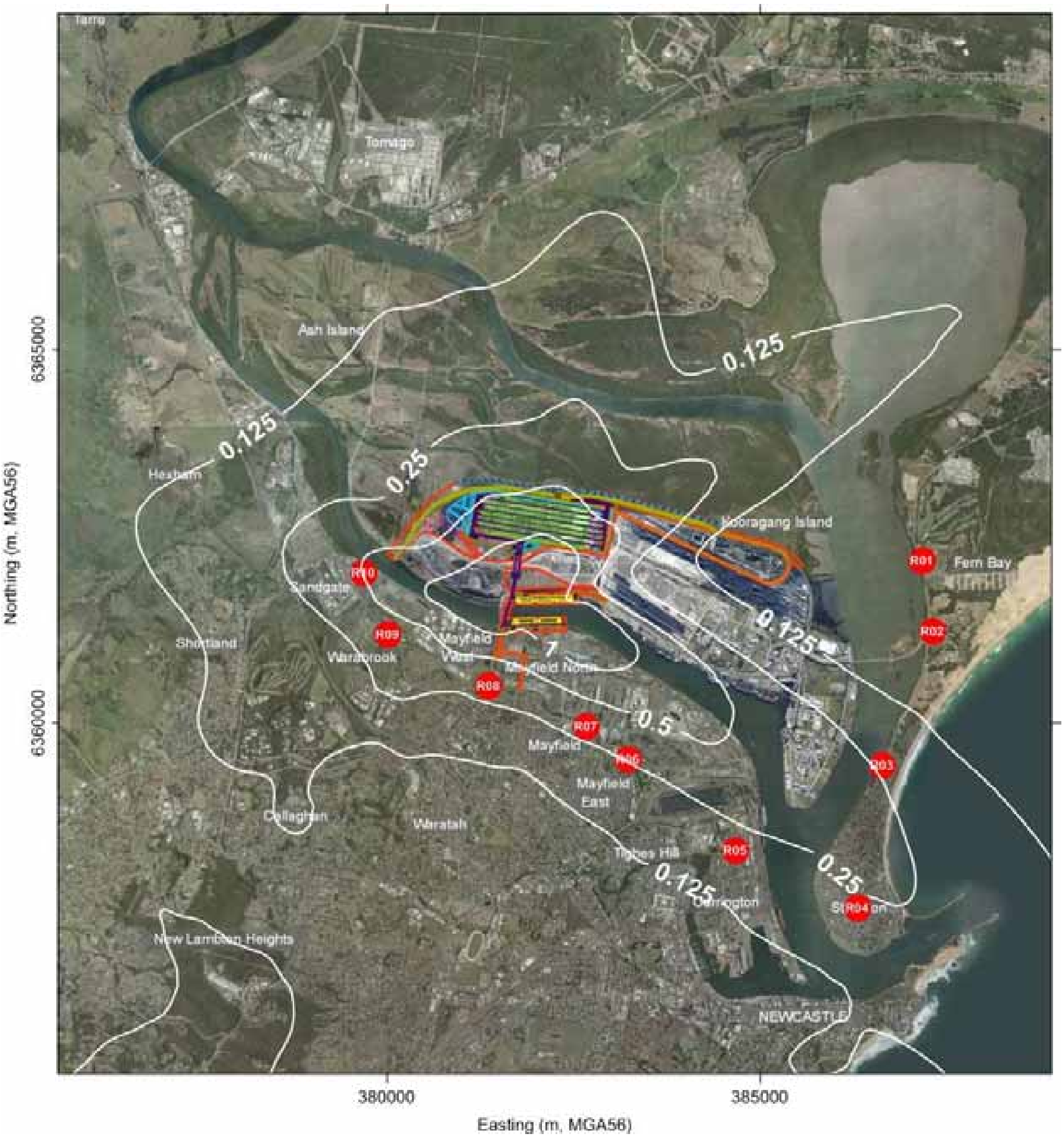

Figure E21: Incremental Annual Average SO_2 Concentrations (µg/m³) – Operational Stage 3

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Figure E22: Incremental Maximum 1-hour Average NO_2 Concentrations (µg/m³) – Operational Stage 3

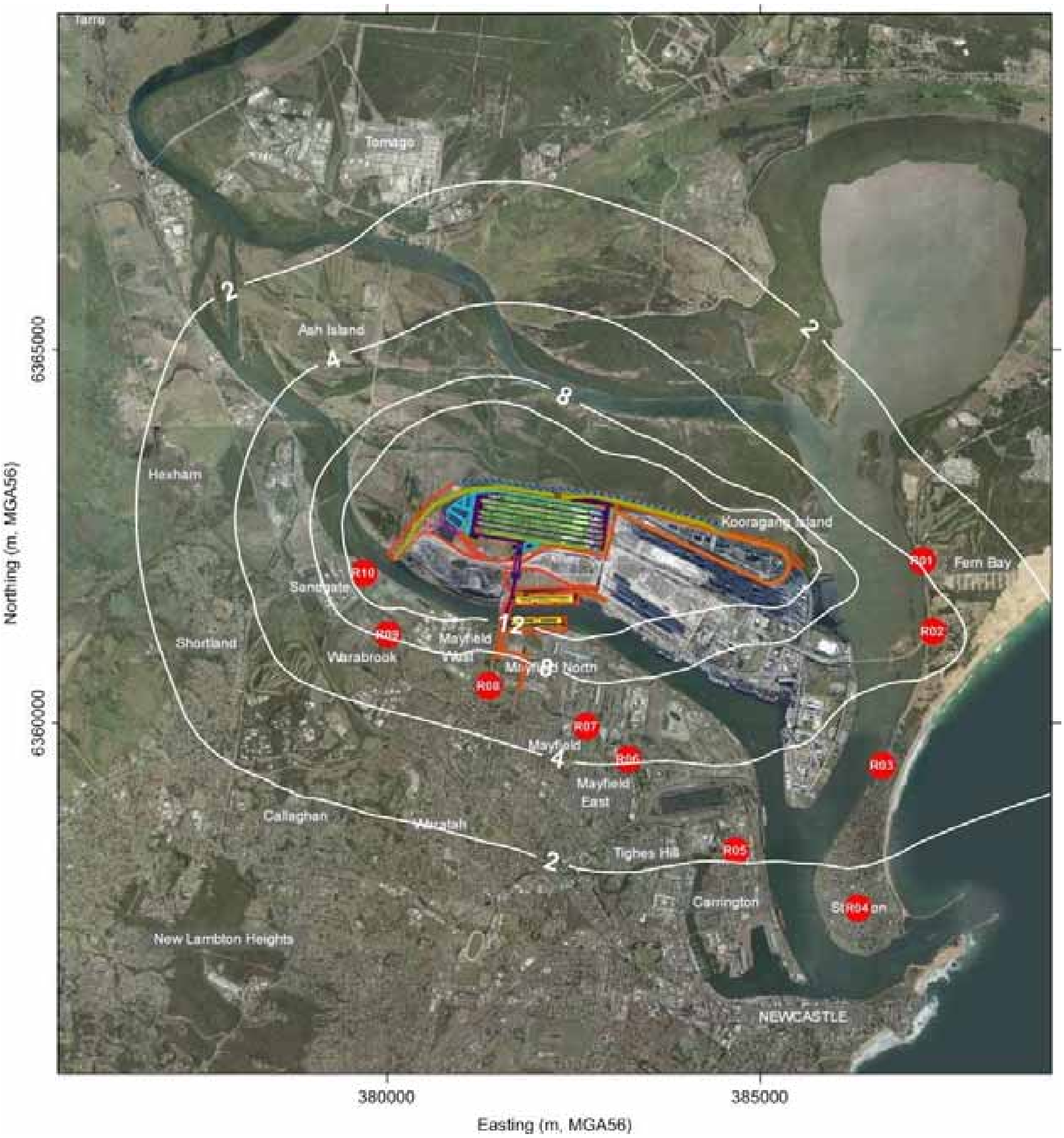

Figure E23: Incremental Annual Average NO_2 Concentrations (µg/m³) – Operational Stage 3

Appendix F
Assessment of Rail Wagon Emissions

As the delivery of coal to the T4 project area will be undertaken via rail, the potential for adverse impacts associated with fugitive dust emissions from moving rail wagons has been considered.

Connell Hatch (2008) estimated that almost 90% of coal dust emissions from rail wagons was emitted from the wagon surface with parasitic loads on sills and bodies, door leakage and residual coal in unloaded wagons representing more minor sources. It is therefore pertinent to focus on dust emissions from rail wagon surfaces in this assessment.

At peak operations, it is expected that a coal delivery rate of 120 Mtpa would be achieved. Based on information provided to ENVIRON, maximum train coal capacity would be of the order of 6,100t. The capacity of a single coal wagon is assumed to be 75t.

Queensland Rail Limited (QR) recently commissioned a comprehensive study into fugitive dust emissions from a number of their coal rail transportation systems in the Queensland coal fields. This study comprised a literature review, a network of air quality monitoring equipment and atmospheric dispersion and numerical modelling.

During this assessment, conducted by Connell Hatch (2008), reference was made to a paper by Ferreira *et al.* (2003) which focused on the release of coal dust from train wagons. The study by Ferreira *et al.* (2003) conducted measurement of TSP emissions from coal wagons over a 350km journey, and found that for such a distance, a 60t semi-covered wagon would lose approximately 0.001% of its load. (Semi-covered wagons were defined as wagons having 0.5m wide automatic doors running the length of the wagon. When in the closed position, there is a gap of about 1 m wide between the two doors.) Further testing by Ferreira *et al.* (2003) showed that if the wagon was uncovered, emissions could be increased by up to five times that of a semi-covered wagon. Based on the specifics of the study conducted by Ferreira *et al.*, emission factors of 1.71 g/km/wagon and 8.57 g/km/wagon were derived for semi-covered and uncovered wagons respectively.

The findings of Ferreira *et al.* (2003) were used to derive emission factors for the dispersion modelling assessment conducted for the QR study. The resulting predicted concentrations paired well with the track-side air quality monitoring conducted during the QR study, suggesting that the conclusions of the Ferreira *et al.* (2003) study were acceptable for estimating the fugitive coal dust emissions from rail wagons. Consequently, in the absence of site specific emissions estimation methods, the findings of Ferreira *et al.* (2003) have been adopted to estimate coal dust emissions from trains delivering coal to the T4 project area.

Rail wagons used for coal transportation in NSW are generally uncovered but have curved side walls resulting in their having a reduced exposed area compared to uncovered wagons used elsewhere (e.g. exposed area of approximately 25 m^2 is typical compared to an exposed area of approximately 30 m^2 for rail wagons used in Queensland). It is therefore appropriate to consider the aforementioned range in emission factors given for semi-covered and uncovered wagons.

To determine the potential impact along the railway servicing the T4 project area, the transportation dispersion model CAL3QHCR, developed by the United States Environmental Protection Agency (USEPA), was used. CAL3QHCR is based on the dispersion algorithms contained within CALINE-3. While this model is designed to represent road emissions, with in-built algorithms to account for thermal turbulence, it is appropriate for the purpose of this assessment.

Two separate models with a generic 200m source link length (one aligned north-south and one aligned east-west, as per the rail alignment from Hunter River to the T4 project area) were developed. Calculation points were positioned at distances away from the railway corridor (at 20m, 40m, 80m and 120m from the centre of the railway path) and spaced at 40m intervals along the rail way.

A cross section of predicted maximum 24-hour average and annual average TSP concentrations of coal dust from semi-covered and uncovered rail wagons servicing the T4 project area, as predicted by CAL3QHCR, is presented in **Figure F1** and **Figure F2** respectively. TSP concentrations are predicted to decrease with distance from the railway corridor as is to be expected.

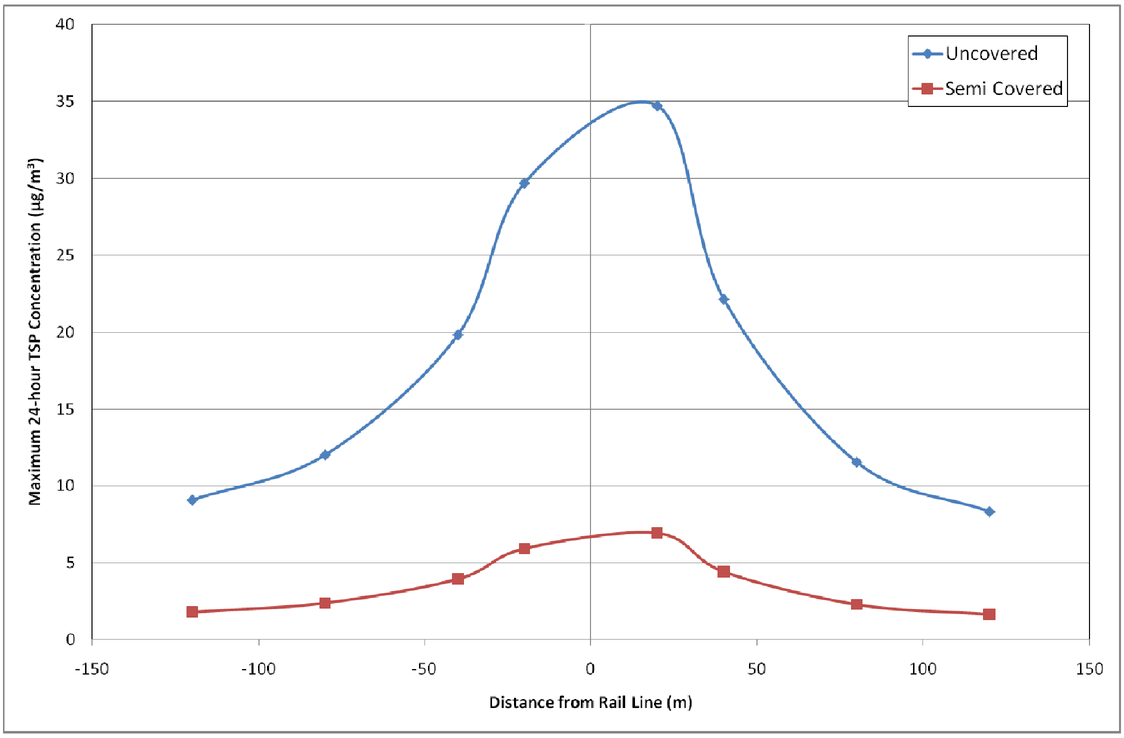

Figure F1: Cross-section of Predicted Maximum 24-hour Average TSP Concentrations due to Coal Dust Emissions from Rail Wagons On-route to the T4 project area

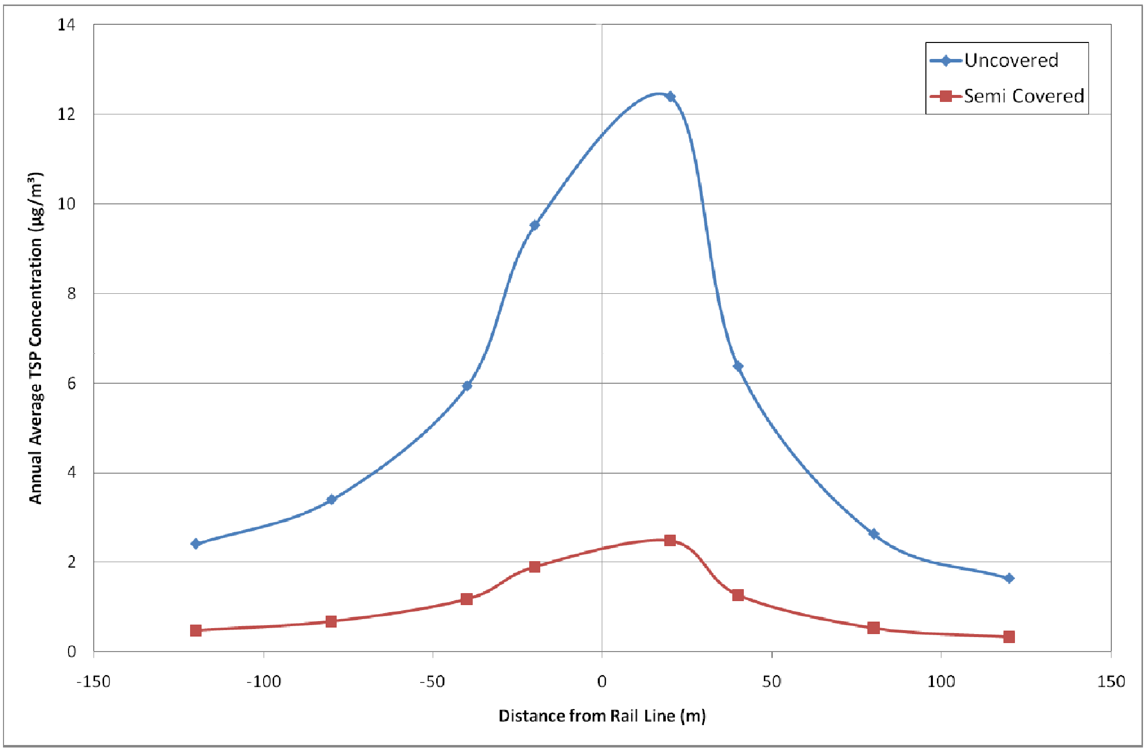

Figure F2: Cross-section of Predicted Annual Average TSP Concentrations due to Coal Dust Emissions from Rail Wagons On-route to the T4 project area

Peak 24-hour average TSP concentrations due to fugitive emissions from rail wagons on-route to the T4 project area, given a coal delivery rate of 120 Mtpa, were predicted to be in the range of 5 to 35 µg/m³ in close proximity (within 20 m) of the railway corridor.

The PM_{10} concentrations could be assumed to be 50% based on the ratio of PM_{10} to TSP emissions within the US-EPA predictive emission factor for wind entrained dust from stockpiles. Based on this assumption, maximum 24-hour PM_{10} concentrations in the range of 3 to 13 µg/m³ at distances of 20 m from the railway corridor. Whereas the lower range is considered negligible, the significance of the upper range increment will depend on the baseline air quality on-route and the potential for exposures occurring close to the railway corridor.

Appendix G
Health Risks due to Coal Dust Exposure

Overview of Review

Concern has been raised within the community regarding the possible health effects of coal dust emissions from existing coal handling facilities and the proposed T4 Project. Of relevance is whether or not mechanical attrition derived particles from coal[(17)] through handling or wind entrainment are more hazardous than particulate matter derived from other materials and process. Consequently, whether ambient air quality standards for particulate matter, intended to be protective of human health, afford equivalent protection in the case of exposures to coal dust.

In addressing concerns raised, attention was paid to the following:

- Information on the 'toxicity' of coal dust derived from occupational exposures;
- Findings from health studies investigating environmental (community) exposures in proximity to coal mining and port operations, including studies conducted for the Hunter Valley of NSW; and
- Current basis for ambient air quality standards.

The question to be addressed is not whether or not coal dust is toxic, but whether or not ambient air quality standards are sufficient to protect the community for coal dust. Based on the review of literature on the health implications of exposures to coal dust it was concluded that the air quality standards for particulate matter offer, as a minimum, equivalent protection for communities exposed to coal dust generated from mechanical attrition processes.

An overview is provided in subsequent subsections of several of the studies reviewed. Reference is made to occupational exposure studies given that coal dust related health risks has been more extensively investigated and documented for occupational exposures. Attention is paid to health risks arising due to coal dust exposures and the airborne respirable coal dust concentration levels associated with such risks.

Reference is subsequently made to environmental exposure studies conducted to assess community risks given proximity to coal mines and coal handling port operations. There are few credible studies assessing the effects of environmental exposures to coal dust. Furthermore, the studies reviewed do not address relative contributions of coal and non-coal dust, nor the mechanisms of action of coal dust specifically, but rather serve to indicate the potential for health effects associated with higher general airborne particulate matter concentrations.

Reference is made to Hunter Valley health studies, primarily due to these studies having been conducted locally and their having focussed on inhalation health risks to particulate matter emissions from coal mining operations. It is however noted that coal dust emissions comprise a minor component of the total particulate matter released from coal mining operations, with the major component comprising soil and related material (topsoil;

17 Coal refers to a diverse group of rocks of varying composition and characteristics made from carbonised plant matter. Major constituents of coal are carbon and moisture with variable concentrations of volatile matter including polycyclic aromatic hydrocarbons (PAHs), sulphur and mineral matter, including quartz.

overburden; inter-burden). Such studies also do not address coal and non-coal dust exposures, but focus on exposures to fine particulate matter concentrations..

Factors influencing the likelihood, nature and magnitude of health effects due to particulate matter exposures are considered based on widely referenced health literature. Specific attention is paid to major conclusions drawn regarding the influence of particle toxicity and size of particles. There is strong evidence to suggest that fine particles ($PM_{2.5}$) are more hazardous than coarser (2.5 to 10 µm) particles, despite health effects also being documented for coarser particles. Health outcomes are associated with fine particulate matter from numerous sources including traffic-related pollution, regional sulphate pollution, combustion sources, resuspended soil and road dust. It may be concluded that particle size may be more important than composition in determining health outcomes.

Ambient air quality limits for PM_{10}, both nationally and internationally, are typically based on health risks derived from studies of changes in the incidences of effects within large urban populations coincident with changes in airborne particulate matter (NEPM, 2010). Airborne particulate concentrations within urban areas comprise a high proportion of combustion-related primary and secondary particles and are therefore inclusive of particle compositions with greater inherent toxicities relative to particles derived from mechanical attrition processes. Furthermore, particle size may be more important than composition in determining health outcomes. As such it is concluded that ambient air quality standards issued will offer, as a minimum, equivalent protection for communities exposed to coal dust.

Summary of Studies Reviewed

Occupational Exposures to Coal Dust

Occupational exposures to coal dust have historically occurred during coal mining and processing. Exposure to coal mine dust can cause various pulmonary diseases, including coal workers' pneumoconiosis (CWP) and chronic obstructive pulmonary disease (COPD) (NIOSH, 2011). Exposure can also cause progressive massive fibrosis of the lungs due to exposure to respirable dust particles able to penetrate deeply into the lungs following inhalation. Respirable dust is defined as particulate matter with a mass median aerodynamic diameter of less than 4.25 µm (and thus falls within the PM_{10} fraction).

Risks related to coal dust are a function of the intensity of exposure (i.e. extent inhaled) and the duration of exposure, in addition to other factors such as the susceptibility of individuals to risk. Adverse health effects in workers exposed to coal dust have been associated with long-term occupational exposures to respirable coal dust at concentrations of 1,000 to 10,000 µg/m³ and higher. In a recent review NIOSH (2011) concluded that occupational exposures to respirable coal mine dust should be limited to 1,000 µg/m³ as a time-weighted average concentration for up to a 10 hour day during a 40 hour work week.

Ambient (environmental) PM_{10} concentrations are substantially lower than the levels recorded within industrial and mining sites. In Newcastle, for example, daily-average PM_{10} concentrations are recorded typically in a range between 12 and 24 µg/m³ with elevated concentrations of 30 to 40 µg/m³ occurring about 5% of the time, and infrequent peaks with magnitudes in the range of 50 to 80 µg/m³ (Refer to **Section 5**).

Furthermore, coal dust comprises a limited component of the airborne particulate matter concentrations recorded. ANSTO (2008) analysed the composition of fine particles measured at various ambient $PM_{2.5}$ monitoring sites including a site located in Mayfield, Newcastle. Based on the analysis of samples collected during the 1998 to 2008 period, ANSTO (2008) concluded that black carbon comprised 16%±6% of the $PM_{2.5}$ mass recorded at Mayfield. Sources of black carbon include primarily carbon generated from combustion processes, but also include carbon from coal dust (Nelson *et al*., 2007). The contribution of coal dust derived from mechanical attrition processes reduces for smaller particle sizes, and is likely to be insignificant for the less than 1 µm component of fine particles (Nelson *et al*., 2007).

Occupational exposures to coal dust have been found to cause health risks to exposed workers. Ambient PM_{10} concentrations recorded in Newcastle are a factor of 100 lower than the concentrations associated with such risks at industrial and mining sites. Furthermore, coal dust derived from mechanical attrition is reported to comprise a minor fraction of the fine component of PM_{10} concentrations.

According to the WHO International Agency for Research on Cancer (IARC), coal dust cannot be classified as to its carcinogenicity to humans (IARC 1997, IARC 2011). The recent National Institute for Occupational Safety and Health (NIOSH) meta study, which reviewed health studies for coal dust exposures published post 1995, supports IARC's findings (NIOSH, 2011).

Environmental Exposure Studies at Australian Ports

Gladstone Health Study, 2010

Queensland Health (2010) investigated the risk of adverse health impacts from ambient coal dust levels on the community in Gladstone. The contribution of coal dust to ambient particulate matter levels was assessed through black carbon monitoring at Auckland Point. Based on the data collected it was determined that black carbon levels, which are an indicator of coal dust exposure, are low and comprise less than 5% of the total PM_{10} and $PM_{2.5}$ levels.

The reported results for black carbon monitoring indicated that exposure to coal dust in itself was not posing a specific risk to human health over and above any risks that could be attributable to particulate matter generally. Comparison was made between the measured levels of black carbon as a surrogate for coal dust exposure, and the levels of exposure from occupational and other settings which have been associated (or not associated) with adverse health effects from coal dust (Queensland Health, 2010). It was concluded that based on black carbon measurements at Auckland Point, coal dust levels were more than a 1000 times lower compared with the exposure levels for respirable coal dust known to be associated with adverse health effects in occupational settings. Queensland Health considered that the ambient air quality standards issued for particulate matter were sufficiently protective of risks posed by coal dust.

Port Hedland Health Study, 2007

The Department of Health, Western Australia, commissioned a literature review and report on potential health impacts of exposure to crustal material in Port Hedland (Thompson *et al.,* 2007). The review was undertaken by the Lung Institute of Western Australia and the Institute of Occupational Medicine, UK. Thompson *et al.,* (2007) included a review of health studies undertaken for coal dust, such exposure being viewed as potentially analogous to exposures to iron ore related dust prevalent at Port Hedland. The purpose of the study was to assist in setting an air quality standard for Port Hedland.

Thompson *et al.,* (2007) noted that coal dust contains small quantities of crystalline silica and displays a relatively low level of toxicity (compared to quartz). The study concluded that exposure to airborne quartz carries the risk of silicosis, but only with prolonged exposure to concentrations of greater than 200 µg/m³. Exposure to airborne non-fibrous silicates, including coal mine dust, was concluded to be associated with pneumoconiosis but only at very high concentrations seen in industrial settings.

A key outcome of the study was the recommendation by Thompson *et al.* (2007) that a 24-hour maximum PM_{10} criterion of 70 µg/m^3 be adopted at Port Hedland, rather than the NEPM standard of 50 µg/m^3. The basis for this recommendation being primarily that particulate matter derived from mechanical attrition processes, as are prevalent at the port, are less hazardous than combustion-derived particulate matter prevalent in urban areas.

International Coal Mine and Port Studies

A review was undertaken of the literature documenting studies of health risks related to community exposures to “coal dust” due to their proximity to coal mines or port operations. A limited number of studies dealing with environmental exposures to “coal dust” have been published in international literature. Furthermore, it was determined by ENVIRON that such studies did not differentiate between coal and non-coal components of the dust but focused on total airborne dust concentrations.

In a recent review of health studies related to coal mining, Entec (2010) concluded that the so-called Newcastle University (England) study of 1999 remains the only acknowledged well-designed and executed epidemiology study into the alleged links between surface coal mining and respiratory health in children. Results from the Newcastle University study are reported in Pless-Mulloli *et al.* (2000, 2001).

Pless-Mulloi *et al.* (2001) investigated the incidence of asthma and other respiratory diseases in children living near and away from opencut coal mining sites. This epidemiological study concluded that there was “limited evidence of an association between residential proximity to opencast mining sites and cumulative or period prevalence or respiratory illness or asthma severity”.

Pless-Mulloli *et al.* (2000) concluded that children in opencut coal mining communities are exposed to a small but significant amount of additional PM_{10} to which opencut sites were a measureable contributor. They also concluded that “past and present respiratory health of children was similar, but GP consultations for respiratory conditions were higher in opencast communities during the core study period”. Sensitivities raised within the community during the course of the study have been conjectured by Entec (2010) to have been responsible for the additional consultations.

Hendryx and Ahern (2008) investigated incidences of diseases, including COPD, amongst populations living in counties with surface coal mining operations in West Virginia, USA. Results indicated that high levels of coal production were associated with worse adjusted health status and with higher rates of cardiopulmonary disease, COPD, lung disease and kidney disease.

A review of Hendryx and Ahern (2008) by Entech (2010) noted that there was no concomitant measurement of airborne particle concentrations over the course of the study. Furthermore, the effects of smoking and occupational exposure were not taken into account. Given that these risk factors are known to be significantly implicated in COPD, the robustness of the Hendryx and Ahern (2008) study has been questioned (Entec, 2010). Entec (2010) also noted that the association of population with proximity to coal mines was derived on a county of residence basis rather than actual proximity to mining operations. Hendryx and Ahern (2008) confirm within their publication that the study requires confirmatory studies to establish mechanisms of action, magnitude and health consequences of living in proximity to coal mines.

Brabin *et al.* (1994) conducted a cross sectional study to determine whether school children exposed to pollution from steaming coal dust have an excess of respiratory symptoms compared with children in control areas. Primary school children from primary schools situated within the Bootle dock area of Liverpool at which coal import and bulk handling and storage operations occurred. The study concluded "an increased prevalence of respiratory symptoms to primary school children exposed to coal dust is confirmed. Although the association with known coal dust pollution is suggestive, a cross sectional study cannot confirm a causal relationship and further studies are needed." Although dust deposition monitoring was considered in the study, no reference was made to suspended particulate concentration measurements or to the composition of airborne particles.

Based on the literature review conducted, ENVIRON note that there are few credible studies assessing the effects of environmental exposures to coal dust. Studies that have been undertaken do not address relative contributions of coal and non-coal dust, nor the mechanisms of action of coal dust specifically, but rather serve to indicate the potential for health effects associated with higher general airborne particulate concentrations. ENVIRON conclude on the basis of the review conducted, that it is more pertinent to consider the potential for health risks associated with particle size rather than coal and non-coal particulate matter properties.

Hunter Valley Health Studies

Community concerns regarding the potential health effects of air emissions have resulted in the Department of NSW Health engaging in a number of activities/studies including:

- Respiratory and Cardiovascular Diseases and Cancer among Residents in the Hunter New England Area Health Service (HNEAHS)
- Bettering the Evaluation and Care of Health (BEACH) Study

- Establishment of an Air Pollution Expert Advisory Committee

The Chief Health Officer established the Air Pollution Expert Advisory Committee. This committee is expected to provide expert advice on the current scientific evidence relating to air pollution and public health, which would complement the ongoing policy and research work already undertaken by the Department of NSW Health. The meeting frequency of this Expert Advisory Committee (EAC) is determined by referrals from the Chief Health Officer.

A summary of key study findings are presented below.

Respiratory and Cardovascular Diseases and Cancer Among Residents in the Hunter New England Area Health Service

This May 2010 report focuses on those diseases and causes of death that have been found to be associated with exposure to air pollutants. Analysis has also been undertaken on some diseases about which the community of the HNEAHS has expressed a concern. The report uses regularly collected health data to:

- assess the health of the residents of Hunter New England;
- to compare the health of the residents of Hunter New England to the health of residents across the state; and
- examine the variation in health within the HNEAHS in relation to the distribution of coal mining and coal-powered electrical power generation activity within this area.

Key findings and recommendations from the report are as follows:

- Compared to the rest of NSW, one or both of Upper Hunter and Lower Hunter, the geographical regions of HNEAHS most affected by open-cut coal mining and power generation activities, have higher rates of:
  - emergency department attendance for asthma and respiratory disease (but also for all other conditions, which may indicate a general tendency to greater use of emergency departments in these regions),
  - hospital admission for all respiratory conditions together and for asthma (Upper Hunter only),
  - hospital admission for cardiovascular disease, and
  - death from all causes and cardiovascular disease (lower Hunter only).
- These data may indicate an adverse health effect due to exposure to coal mining or coal-fired power generation activities or may be due to other factors (such as smoking, for example, which is higher in adults in Upper Hunter, although not statistically significantly higher).
- The data therefore do not establish that the adverse health effects are attributable to air pollution or to any other specific exposure. (Nor however does the data establish that the effects are not attributable to air pollution.)
- Further investigation is required to determine the role of pollutant exposure; other recognised disease risk factors including smoking need to be considered.

Bettering the Evaluation and Care of Health (BEACH) Study

The Air Pollution Expert Advisory Committee (EAC) examined the findings of the General Practitioner data analysis for the Upper Hunter and drew the following conclusions:

- The BEACH data suggests that conditions presenting to and medications prescribed by GPs in the Upper Hunter region are similar to those in the rest of nonmetropolitan NSW.
- There are indications, however, that asthma may be a more important issue in the Upper Hunter region. This observation is consistent with findings from the NSW Health (May 2010) report *Respiratory and Cardiovascular Diseases and Cancer among Residents in the Hunter New England Area Health Service* which noted higher rates for asthma and respiratory disease overall.
- With all findings from this and other studies considered together, further study of the health effects of the mining industry and other exposures in Singleton, Muswellbrook and Denman should focus particularly on asthma and other respiratory disease.

Factors affecting Health Effects of Particles

Factors influencing the likelihood, nature and magnitude of health effects due to particulate exposures include: toxicity and size of particles, susceptibility of persons exposed, and magnitude and duration of exposure (USEPA, 2009; Morawska *et al.* 2005; Pope and Dockery, 2006; WHO, 2007).

Although health effects have been related to different particle sizes and compositions, the toxicity of particles and particle size (which influences patterns of deposition in and removal from the respiratory tract) have been found to be important for determining health effects. There is strong evidence to suggest that fine particles ($PM_{2.5}$) are more hazardous than coarser (2.5 to 10 µm) particles in terms of mortality and cardiovascular and respiratory endpoints (CEPA, 1998; WHO, 2003, 2004, 2007; US-EPA, 2006; Pope and Dockery, 2006; US-EPA, 2009). Coarse particles can however result in inflammation and other health responses, with clinical exposure of healthy and asthmatic humans to concentrated ambient air particles comprised mostly of $PM_{10-2.5}$ showing changes in heart rate and heart rate variability measures (CARB, 2002; US-EPA, 2009).

Contributing factors to the toxicity of particulate matter have been found in epidemiological and controlled exposures studies to include metal content, presence of polycyclic aromatic hydrocarbons, other organic components, acidic sulphates, endotoxin and both small (<2.5 µm) and extremely small size (<0.1 µm) (WHO, 2003; US-EPA, 2006). Epidemiological analyses and toxicology studies have however linked health outcomes with fine particulate matter from numerous sources including traffic-related pollution, regional sulphate pollution, combustion sources, resuspended soil and road dust (US-EPA, 2006). This suggests that particle size may be more important than composition in determining health outcomes.

Overall Conclusion on Protection Offered by Air Quality Standards

Ambient air quality limits for PM_{10}, both nationally and internationally, are typically based on health risks derived from studies of changes in the incidences of effects within large urban populations coincident with changes in airborne particulate matter (NEPM, 2010).

Airborne particulate concentrations within urban areas comprise a high proportion of combustion-related primary and secondary particles and are therefore inclusive of particle compositions with greater inherent toxicities relative to particles derived from mechanical attrition processes as discussed in this appendix. Furthermore, particle size may be more important than composition in determining health outcomes. As such it is concluded that ambient air quality standards issued will offer, as a minimum, equivalent protection for communities exposed to coal dust. Similar conclusions were reached by Queensland Health (2010) in assessing coal dust exposures at Gladstone.