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Environmental Impact Statement – Chapter 7: Air quality

Warragamba Dam Raising

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7 Air quality

This chapter provides an assessment of air quality during construction and operation of the Warragamba Dam Raising. The relevant Secretary's Environmental Assessment Requirements (SEARs) are shown in Table 7-1.

Table 7-1. Secretary's Environmental Assessment Requirements (SEARS): Air quality

Desired performance outcomes	Secretary's Environmental Assessment Requirements[1]	Where addressed
5. Air Quality Desired performance outcome: The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent practicable.	1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	This chapter Section 7.4
	2. The Proponent must ensure the AQIA includes a demonstrated ability to comply with the relevant regulatory framework, specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation (2010).	Section 7.1 Section 7.3 Section 7.4 Section 7.5 Section 7.6 Section 7.7 Section 7.8

1 Note: this chapter specifically addresses SEAR 5 in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-.1.)

The air quality impact assessment (AQIA) is supported by detailed investigations which are documented in the Air Quality Assessment Report (ERM 2018, Appendix E).

The proposed management and mitigation measures in this chapter are collated in Chapter 29 (Environmental impact statement synthesis, Project justification and conclusion).

7.1 Project overview

7.1.1 Project description

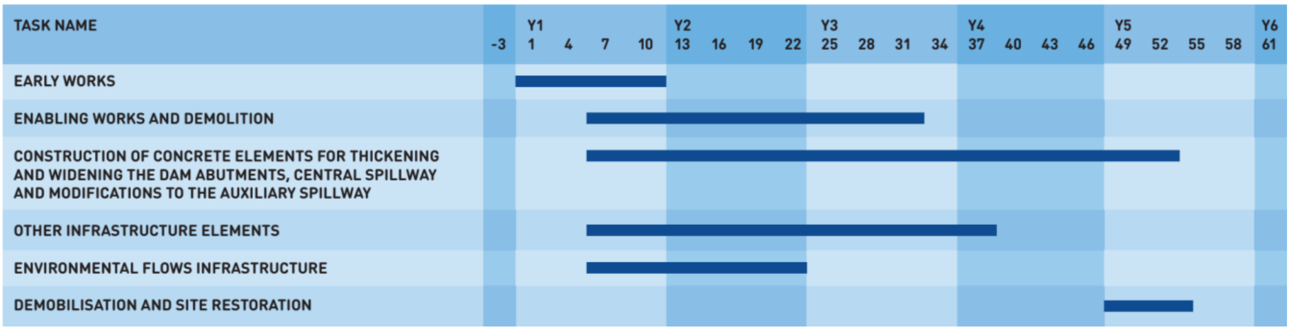
The Project is to provide additional capacity to facilitate flood mitigation by increasing the crest level of the central spillway by approximately 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water supply. The current design includes raising the dam side walls and roadway by 17 metres to enable adaptation to projected climate change.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to control discharge of water from the flood mitigation zone (FMZ)
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

A preliminary construction program is presented in Figure 7-1 with construction anticipated to be completed within four to five years.

Figure 7-1. Preliminary construction program



The Project would delay downstream flooding, which would reduce current downstream flood peaks and increase the time taken for downstream water levels to recede. The dam would be subject to the following operational regimes, depending on the water level.

Normal operation

Normal operations would apply when the reservoir level is at or lower than the full supply level (FSL), which is when the water level in the dam is at or below 116.7 mAHD.

Flood operation

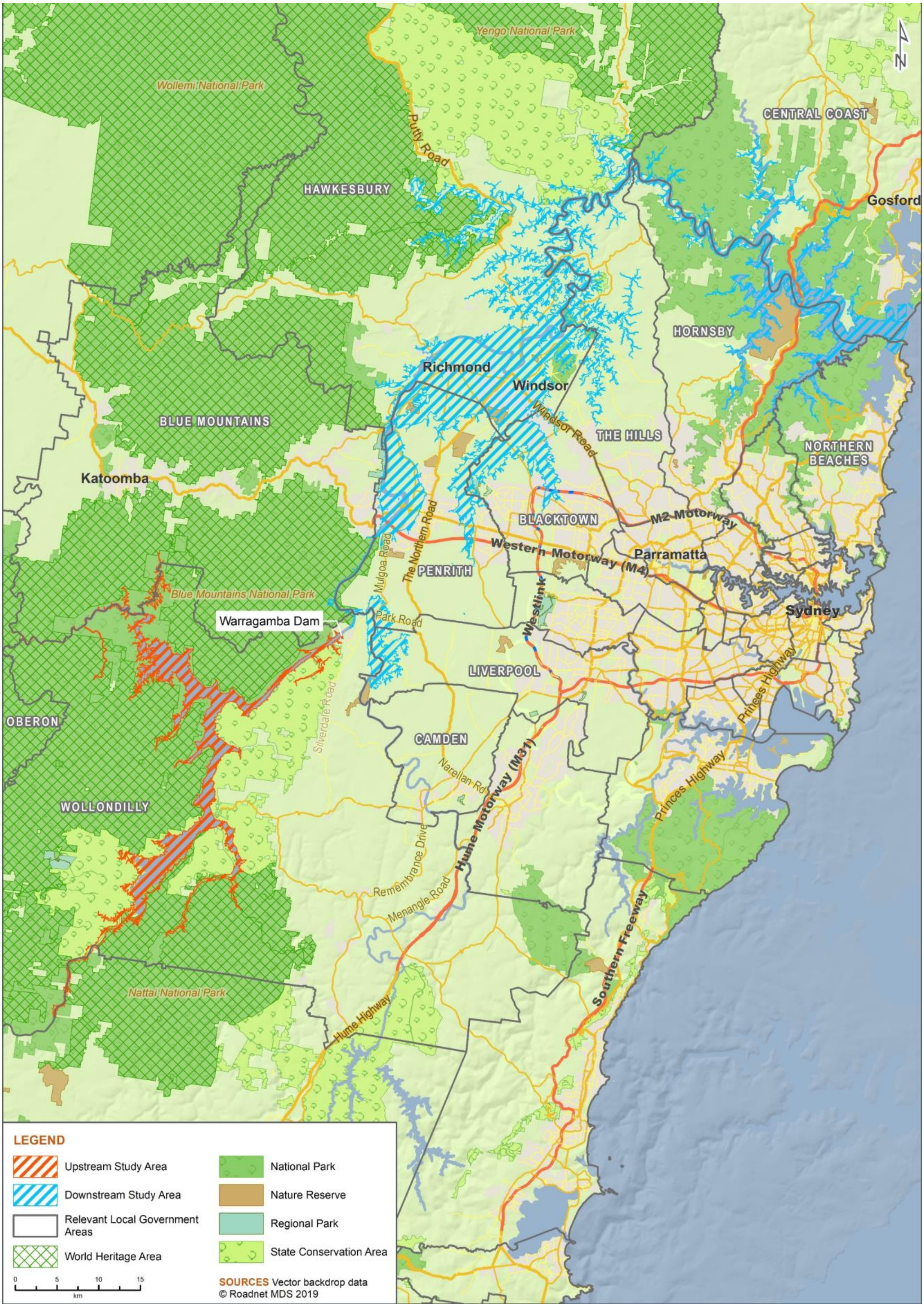
Flood operations would apply when the water level is higher than the FSL. The FMZ would have sufficient storage to accommodate up to a 1 in 40 chance in a year flood. For larger floods the FMZ would be filled and uncontrolled discharge would occur over the central spillway and, potentially, the auxiliary spillway of the dam. Operational objectives are to:

- maintain the structural integrity of the dam
- minimise risk to life
- maintain Sydney's water supply
- minimise downstream impact of flooding to properties
- minimise environmental impact
- minimise social impact.

7.1.2 Project location and study area

The Project location and study area are shown on Figure 7-2. Warragamba Dam is located approximately 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres before it joins the Nepean River. The township of Warragamba is located approximately one kilometre east of the dam wall. The upstream environment includes the reservoir formed by Warragamba Dam (Lake Burragorang) and its tributaries, and comprises approximately 5,280 hectares, broadly equating to the area between the existing FSL and the Project probable maximum (PMF) flood level. The downstream environment includes a short section of the Warragamba River, the Hawkesbury-Nepean River and its floodplain, and some of the tributaries of the Hawkesbury-Nepean River (such as South Creek) that experience backwater flooding effects.

Figure 7-2. Project location and study area



The air quality assessment addresses both construction and operational phases, however most of the assessment was focused on the the dam construction area near the township of Warragamba, which broadly covers an area of about 105 hectares. The construction study area includes the dam and the areas in and around the existing Warragamba Dam, including auxiliary access roads and site buildings. The township of Warragamba and areas immediately upstream and downstream of Warragamba Dam, as well as the immediate road network, are included in the construction study area because they are likely to be impacted during construction.

The construction footprint and surrounding areas are shown on Figure 7-3.

7.2 Methodology

7.2.1 Legislation and policy context

Legislation and guidelines relevant to the assessment and management of air quality are addressed in Chapter 2 (Statutory and planning framework) and Appendix E (Air Quality Assessment Report, Section 3). These are summarised as follows.

7.2.1.1 Protection of the Environment Operations Act 1997

This Act regulates noise, waste, soil pollution, air pollution, and water pollution in NSW. Under Chapter 3 of the Act, an environment protection licence may be issued to allow the carrying out of scheduled activities which cause pollution.

7.2.1.2 Clean Air Regulation

The Protection of the Environment Operations (Clean Air) Regulation 2010 (Clean Air Regulation) provides regulatory requirements to control emissions from wood heaters, fires, motor vehicles, fuels, and industry. The Project would be constructed and operated to ensure it complies with the Clean Air Regulation.

7.2.1.3 Air quality assessment guidelines

The AQIA has been conducted in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (Approved Methods) (DEC 2017), which specify air quality assessment criteria relevant for assessing impacts from air pollution. The air quality criteria relate to the total dust burden in the air and not just the dust from proposed activities such as land clearing and construction activities. In other words, consideration of background dust levels needs to be made when using these criteria to assess potential impacts.

Air quality monitoring was not conducted therefore the *Approved Methods for the Sampling & Analysis of Air Pollutants and 'Technical Framework – Assessment and Management of Odour from Stationary Sources in NSW* was not required.

7.2.1.4 Air NEPM

The NSW Government is a signatory to the *National Environment Protection (Ambient Air Quality) Measure 2016* (Air NEPM). The Air NEPM sets standards for six key air pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), lead, ozone, and particles (particulate matter). Particulate matter (PM) included are:

- PM_{10} – particles smaller than 10 micrometres in diameter
- $PM_{2.5}$ – particles smaller than 2.5 micrometres in diameter.

The Air NEPM has a goal for PM_{10} of 50 micrograms per cubic metre (µg/m^3) as a 24-hour average (no exceedances per year), and a $PM_{2.5}$ goal of 25 µg/m^3 as a 24-hour average. Consideration was given to these PM goals as part of the assessment.

Figure 7-3. Construction area

7.2.2 Assessment methodology

Potential air quality impacts for construction of the Project have been assessed quantitatively using the following methodology:

- desktop review of the background air quality environment based on air quality data sourced from the NSW Government's air quality monitoring stations located at Bringelly, St Marys, Oakdale and Camden (the closest stations to the construction study area)
- identify sensitive receptors, such as houses, schools, and workplaces, with the potential to be adversely affected by air quality impacts
- determine air quality assessment criteria
- reviewing the construction aspects of the Project with the potential to generate air emissions; this identified two scenarios for further assessment: site establishment works and general construction works
- quantitative assessment of the potential air quality impacts of the two scenarios by using the modelling package AERMET/AERMOD
- identify appropriate mitigation and management measures, as necessary.

Operational aspects of the Project are expected to be minimal and were assessed qualitatively.

Odour has not been assessed as there are not expected to be any odour sources during construction or operation that would require assessment of impacts. The potential for odour from decaying vegetation has not been assessed as it is likely that any odour from inundation would be upstream and there are no identified receptors within the upstream study area.

7.3 Existing environment

7.3.1 Sensitive receptors and local meteorology

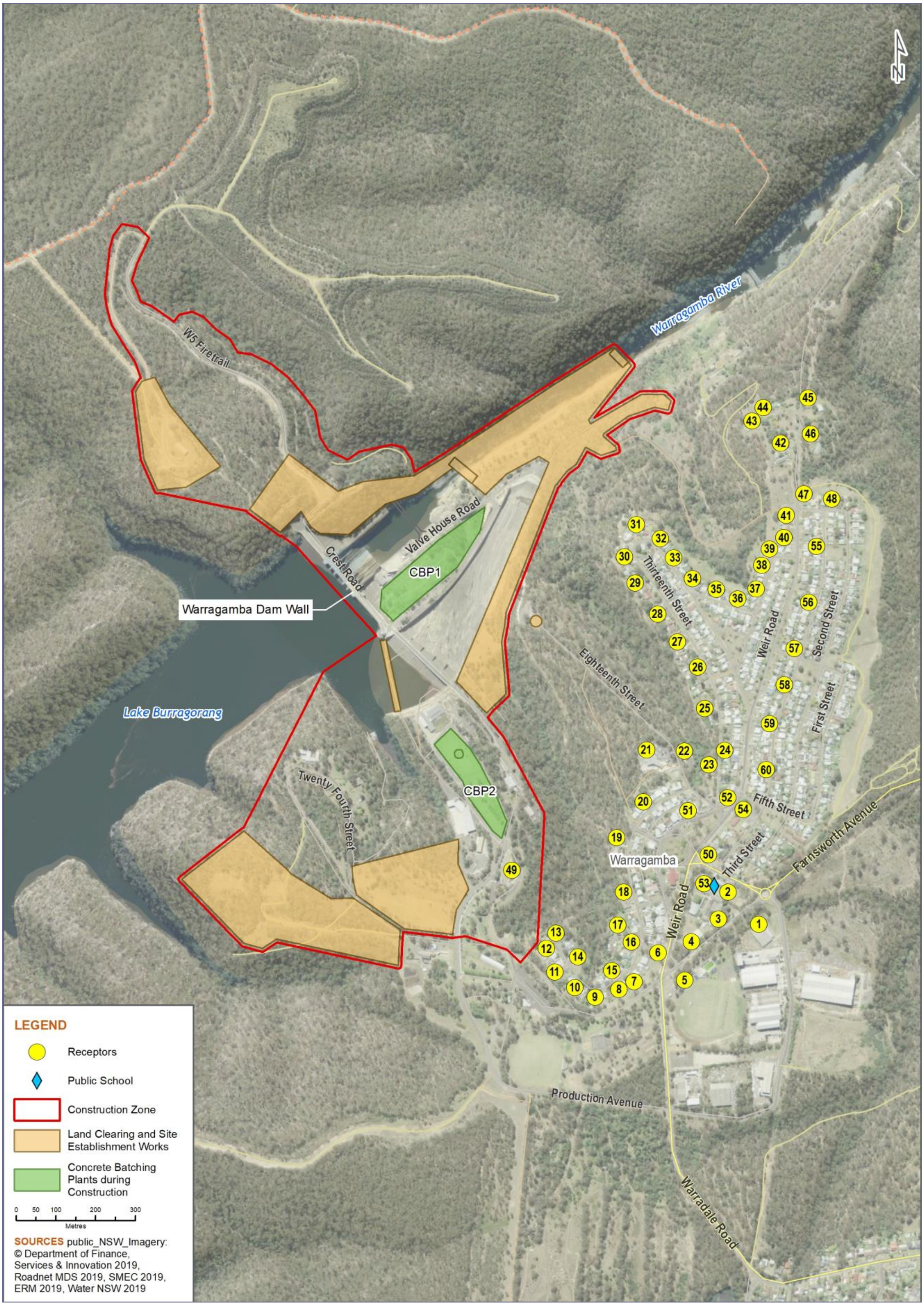
Sensitive receptors nearest to the areas of construction activity are shown in Figure 7-4. These are representative of receptors that may potentially be most impacted by dust from construction of the Project. Most of these sensitive receptors are located within a radius of one kilometre, and are mainly to the east of the Project construction areas. Many receptors are located downwind of the dominant west-southwest winds.

Dispersion models require information about the meteorology (dispersion characteristics) of a study area. Data are required on wind speed, wind direction, temperature, atmospheric stability class and mixing height. Meteorological data was obtained from the nearby Bringelly station, located approximately 15 kilometres south-east of the construction area. Five years of wind data from this station was analysed which identified 2017 as a representative year. The results are presented as a time series in Appendix E (Air Quality Assessment Report, Section 4).

The air pollution model (TAPM) was used to characterise the meteorological conditions at the Project site. TAPM is a model that generates meteorological data for each hour of the year, taking into account local terrain against a background of larger scale meteorology provided by synoptic analyses. This data was used in the assessment.

Wind roses provide a graphical summary of the occurrence of winds at a location, showing their strength, direction and frequency. Annual and seasonal wind roses for the Project site for the modelling year 2017 were used for the analysis, and which are presented in Appendix E (Air Quality Assessment Report, Section 4). The wind roses show that on an annual basis, prevailing winds are light and predominantly from the west–southwest quadrant. Winds from this quadrant are dominant throughout the year. The annual average wind speed is 1.7 metres per second (m/s) and the annual percentage of calms (winds less than 0.5 m/s) is 3.5 percent. Higher wind speeds are most often experienced during the winter months.

Figure 7-4. Sensitive receptors



7.3.2 Existing air quality and background concentrations

Existing air quality is addressed in Appendix E (Air Quality Assessment Report, Section 4). Air quality monitoring has not been undertaken specifically for the Project. However, the NSW Government monitors air quality at numerous locations around NSW with Bringelly, St Marys, Oakdale, and Camden stations are some of the closest air quality monitoring sites to the study area. All these monitoring stations, except for Oakdale, are in residential areas close to road networks and may be likely to record higher PM concentrations than the Project site given that it is less exposed to local sources such as fine particles from vehicle exhaust. The measured values are therefore likely to be conservative when applied as background levels to the Project site.

Table 7-2 and Table 7-3 summarise the annual average and 24-hour average PM_{10} and $PM_{2.5}$ concentrations respectively for the Bringelly, St. Marys, Oakdale and Camden monitoring stations. The highest annual average PM_{10} and $PM_{2.5}$ concentrations were 19.8 µg/m^3 and 7.5 µg/m^3 respectively. These concentrations are below the annual mean air quality criteria of 25 µg/m^3 for PM_{10} and 8 µg/m^3 for $PM_{2.5}$.

Table 7-2. Annual average PM_{10} and $PM_{2.5}$ concentrations

Year	Bringelly		St Marys		Oakdale		Camden	
	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
EPA criterion	**25**	**8**	**25**	**8**	**25**	**8**	**25**	**8**
2014	16.6	N/A	16.7	N/A	13.1	N/A	16.0	6.3
2015	15.8	N/A	15.0	N/A	11.4	N/A	14.0	6.2
2016	16.9	N/A	16.1	N/A	12.2	N/A	14.0	6.4
2017	19.8	7.5	16.2	7.0	12.1	6.0	15.0	6.7

N/A: no monitoring data available

Table 7-3. Maximum 24-hour average PM_{10} and $PM_{2.5}$ concentrations

Year	Bringelly		St Marys		Oakdale		Camden	
	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
EPA criterion	**50**	**25**	**50**	**25**	**50**	**25**	**50**	**25**
2014	42.6	N/A	45.0	N/A	56.3	N/A	41.4	18.5
2015	57.0	N/A	53.0	N/A	61.7	N/A	62.4	25.0
2016	61.6	21.6	100.2	93.2	75.9	12.6	43.6	36.0
2017	83.7	52.5	49.8	38.2	49.8	25.5	46.8	27.7

N/A: No monitoring data was available

In terms of the 24-hour average PM_{10} and $PM_{2.5}$ concentrations, the highest recorded concentrations are 100.2 µg/m^3 and 93.2 µg/m^3 respectively. These exceeded the 24-hour average concentration criteria of 50 µg/m^3 for PM_{10} and 25 µg/m^3 for $PM_{2.5}$.

As shown in Table 7-3, the 24-hour average PM_{10} and $PM_{2.5}$ criteria of 50 µg/m^3 and 25 µg/m^3 respectively were exceeded at least once between 2014 and 2017. Many of these exceedances are likely attributable to regional events such as bushfires or dust storms rather than emissions from specific local sources. Using the maximum monitored concentrations as background levels to which the contribution from the Project can be added is therefore considered an overly conservative and unrealistic approach, especially in the case of particulate matter.

The 24-hour average PM_{10} and $PM_{2.5}$ concentrations fluctuate considerably from day to day. To assess the cumulative impacts for short-term impacts a contemporaneous assessment was carried out using monitoring data and model predictions. As the monitoring sites were some distance from the site, the maximum at each of the four sites, for each day, was used to represent conditions at the Project location. This showed concentrations exceeded the 24-hour average criterion for PM_{10} and for $PM_{2.5}$ on some occasions throughout the year.

As there were no measured total suspended particulates (TSP) or dust deposition data available, it was assumed that PM_{10} was approximately 40 percent of TSP. A conservative assumption of background dust deposition was also used, set at 2 g/m^2/month.

A summary of the background concentrations used is provided in Table 7-4.

Table 7-4. Adopted background air quality concentrations

Pollutant	Background concentration	
	Annual mean	24-hour mean
$PM_{2.5}$	7.5 µg/m^3	Daily varying
PM_{10}	19.8 µg/m^3	Daily varying
TSP	49.5 µg/m^3	N/A*
Deposited dust	2 g/m^2/month	N/A

* N/A: No monitoring data was available

7.4 Air quality assessment criteria

The Approved Methods specify air quality assessment criteria relevant for assessing impacts from air pollution. The air quality criteria relate to the total dust burden in the air and not just the dust from proposed activities such as construction earthworks. In other words, consideration of background dust levels needs to be made when using these criteria to assess potential impacts. Air quality criteria is addressed in Appendix E (Air Quality Assessment Report, Section 3) and summarised below.

7.4.1 Particulate matter

Table 7-5 presents the EPA air quality criteria for concentrations of particulate matter that are relevant to the Project. For PM_{10} and $PM_{2.5}$, these are consistent with the Ambient Air-NEPM. However, the EPA criteria include averaging periods, which are not included in the Ambient Air-NEPM, and reference other measures of air quality, namely TSP.

Table 7-5. EPA air quality criteria for particulate matter concentrations

Pollutant	Standard	Averaging period	Source
PM_{10}	50 µg/m^3 25 µg/m^3	24-Hour Annual	EPA (2016)
$PM_{2.5}$	25 µg/m^3 8 µg/m^3	24-Hour Annual	EPA (2016)
TSP	90 µg/m^3	Annual	EPA (2016)

7.4.2 Dust deposition

Airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including native vegetation and crops. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fall out relatively close to their source. Dust fallout can soil materials and generally degrade aesthetic elements of the environment and are assessed for nuisance or amenity impacts.

Table 7-6 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective, as well as the maximum total overall dust deposition. These criteria for dust fallout levels are set to protect against nuisance impacts (EPA 2016).

Table 7-6. EPA criteria for dust deposition (insoluble solids)

Pollutant	Averaging period	Maximum increase	Maximum total
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

7.4.3 Crystalline silica

Criteria for assessing the potential impacts of crystalline silica have not been set by the EPA. In the absence of a NSW criterion, the ambient assessment criterion for mining and extractive industries, adopted by the Victorian EPA, of 3 $\mu g/m^3$ (annual average as $PM_{2.5}$) (EPA Victoria 2007) has been used.

7.5 Identification of likely emission sources

The main potential impact of the Project with respect to air quality is emissions (mainly dust) during construction. Air emission sources are addressed in Appendix E (Air Quality Assessment Report, Section 5) and summarised below.

Emissions of particulate matter (TSP, PM_{10} and $PM_{2.5}$) are expected to occur as a result of site establishment works and construction stages of the Project. These may include emissions from vehicles through engine exhausts including CO, minor quantities of SO_2 and NO_2.

Activities related to the operation of the upgraded dam are not expected to contribute additional emissions to air to any significant degree. Operational emissions are likely to be limited to CO from vehicle engine exhausts and minor quantities of SO_2 and NO_2.

Sources potentially affecting air quality because of activities related to site establishment and construction may include the following:

- surface clearing
- demolition, blasting, and construction works
- operation of the two concrete batching plants.

The overall approach to the assessment is discussed in Appendix E (Air Quality Assessment Report, Section 5). It follows the Level 2 assessment methodology of the approved methods (EPA 2016), which specifies how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from projects.

AERMOD was chosen as the most suitable model due to the source types, locations of nearest receptors, and nature of local topography. AERMOD is the US EPA's recommended steady-state plume dispersion model for regulatory purposes and it is an accepted model for the EPA. Even though the terrain is relatively hilly in the Project construction area, the sources are non-buoyant and ground-based, and the receptors are in close proximity so in this case AERMOD is appropriate.

The AERMOD modelling suite includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data. Terrain data were sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data (~30 m resolution) and processed within AERMAP to create the necessary input files.

7.5.1 Scenarios

The initial site establishment works (Scenario 1) and the general construction works (Scenario 2) are likely to be the two-significant dust generating stages for the Project. Dust emissions are likely to be generated by the activities shown in Table 7-7. Figure 7-5 shows the likely locations of dust generating activities for each of these stages.

Table 7-7. Dust generating activities

Site establishment works	Construction
Land clearing	Blasting
Topsoil removal and land levelling	Concrete batching
Spoil and material excavation, loading and stockpiling	Delivery of material to concrete batching plants
Truck movements	Truck movements
Dozer activity and grading	-

7.5.2 Potential emissions to air

The main sources of particulate emissions to air and estimates of their contribution are shown in Table 7-8 and Table 7-9 for the two stages. As shown, the emission concentrations are much lower for the construction stage than the site establishment stage and are well below the criteria, as discussed further in Section 7.6.

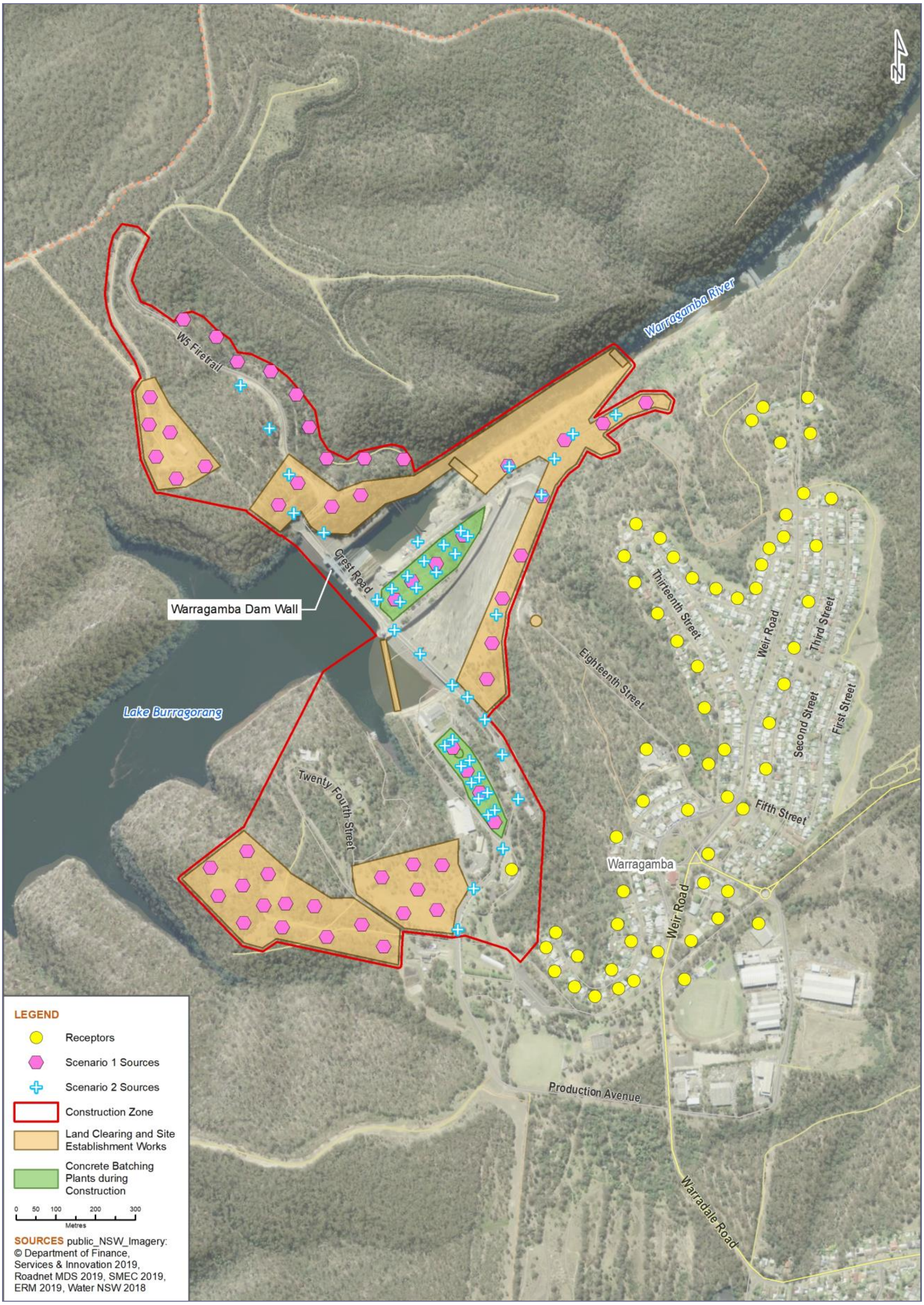
Table 7-8. Site establishment estimated emissions

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Scrapers stripping topsoil	1,001	252	25
Scraper hauling topsoil to site	1,601	403	40
Loading topsoil to stockpiles	19	9	1
Dozers pushing spoil	5,289	1,166	555
Excavators loading haul trucks	131	62	9
Hauling spoil to stockpiles	4,974	1,065	106
Unloading spoil at stockpiles	131	62	9
Grading roads	5,121	1,789	159
Wind erosion - Exposed cleared land	26,280	13,140	1,971
TOTAL	**44,547**	**17,948**	**2,875**

Table 7-9. Construction estimated emissions

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Hauling of material by aggregate and sand delivery trucks on site-sealed roads	1,384	266	94
Hauling of material by fly ash and cement delivery trucks onsite-sealed roads	162	31	11
Hauling of material by other trucks onsite-sealed roads	232	45	16
Material handling - trucks to aggregate storage bins	177	84	13
Material handling - conveying aggregate to silos	353	167	25
Residual from de-dusted air loading cement and fly-ash bag house	70	70	4
Blasting	3,703	1,926	111
TOTAL	**6,081**	**2,589**	**274**

Figure 7-5. Locations of dust-generating activities for the two main construction stages



A summary of the calculations is provided in Appendix E (Air Quality Assessment Report, Section 5).

The modelling package AERMET/AERMOD was used to develop air quality predictions for each sensitive receptor shown in Figure 7-4 and across an approximate three kilometre by three-kilometre grid.

7.5.3 Crystalline silica

Crystalline silica exposure for humans occurs most often during occupational activities that involve the working of materials containing crystalline silica products (for example: masonry, concrete, sandstone), particularly activities involving the cutting, grinding, or breaking of these materials. The potential impact of exposure to this substance has been assessed.

7.6 Assessment of potential construction impacts

This section presents modelling results showing receptors with the predicted 10 highest TSP, dust deposition, PM_{10} and $PM_{2.5}$ concentrations for both modelled stages: site establishment works, and construction. Contours for TSP, dust deposition, PM_{10} and $PM_{2.5}$ are presented for both the site establishment works and construction stages. Air quality impact assessments for site establishment and construction works are detailed in Appendix E (Air Quality Assessment Report, Section 6) and summarised below.

The dispersion modelling showed that there are predicted to be minor increases in both 24-hour and annual average concentrations for TSP, dust deposition, PM_{10} and $PM_{2.5}$. However, the magnitude of these increases is low and unlikely to result in any measurable differences in air quality or exceedances of the EPA air quality assessment criteria at the nearest receptors. Vehicle emissions were not explicitly modelled in the assessment as they are not likely to be a significant component of the total particulate emissions. In terms of total emissions, the most significant sources of dust for the Project are earthworks, blasting, land clearing, wheel-generated dust, stockpiling and windblown dust.

7.6.1 Site establishment works

The results of the modelling for the site establishment works provided the 10 highest concentrations for each pollutant as well as averaging time and corresponding receptor ID (refer Table 7-10 on next page). As shown, the predicted levels are well below the background concentrations provided in Table 7-4 and EPA air quality criteria for PM provided in Table 7-5 and deposited dust provided in Table 7-6. Predicted annual average PM_{10} concentrations of crystalline silica are well below the adopted criterion of 3 µg/m^3 (annual average as $PM_{2.5}$). Cumulative results of modelled emissions are presented as contours (annual averages) and time series (24-hour averages), discussed as follows.

7.6.1.1 Annual averages

Figure 7-6, Figure 7-7, Figure 7-8 and Figure 7-9 respectively show cumulative annual average predictions for $PM_{2.5}$, PM_{10}, TSP and dust deposition for the site establishment works. Figures show minor increases in all pollutants modelled but these increases would be well below their respective air quality assessment criteria and unlikely to cause any exceedances for the duration of the works.

7.6.1.2 Maximum 24-hour averages

Figure 7-10 and Figure 7-11 respectively show maximum 24-hour average $PM_{2.5}$ and PM_{10} levels at the nearest sensitive receptors. While the modelling showed there may be minor increases in concentrations; maximum $PM_{2.5}$ levels are predicted to be below 2 µg/m^3 and maximum PM_{10} levels below 5 µg/m^3. These are both well below their respective assessment criteria. Therefore, exceedances attributable to the Project are unlikely to occur.

The modelling predicted that the most affected receptor was likely to be R49. Further analysis of maximum 24-hour $PM_{2.5}$ and PM_{10} concentrations was conducted to determine the cumulative impacts at this receptor, with the results shown in Appendix E (Air Quality Assessment Report, Section 6). There are five measured exceedances of the 24-hour average $PM_{2.5}$ criterion in the measured background, however, there are no additional exceedances predicted due to emissions from the Project at the most affected receptors. For PM_{10}, there is one additional exceedance predicted. However, it is noted that the background value was 49.9 µg/m^3 and combined with a predicted value of only 1.5 µg/m^3 this is only slightly above the criterion. The background PM_{10} levels are predominantly below 30 µg/m^3 and exceedances of the criterion are rare and usually the result of regional dust events.

Table 7-10. Site establishment modelling predictions for ten receptors showing the highest concentrations

Receptor ID	Annual average				24-hr average	
	TSP ($\mu g/m^3$)	Dust deposition (g/m^2/month)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
Criterion (EPA 2016)	**90 $\mu g/m^3$ Annual**	**2 g/m^2/month maximum increase 4 g/m^2/month maximum total**	**25 $\mu g/m^3$**	**8 $\mu g/m^3$**	**50 $\mu g/m^3$**	**25 $\mu g/m^3$**
R11	N/A*	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R12	0.3 (49.8)	0.1 (2.1)	0.4 (20.2)	0.1 (7.6)	N/A	N/A
R13	0.3 (49.8)	0.1 (2.1)	0.4 (20.2)	0.1 (7.6)	N/A	0.5
R14	N/A	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R19	0.3 (49.8)	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R28	0.3 (49.8)	0.1 (2.1)	N/A	N/A	N/A	N/A
R29	0.4 (49.9)	0.1 (2.1)	0.3 (20.1)	0.1 (7.6)	2.3	0.5
R30	0.4 (49.9)	0.2 (2.2)	0.3 (20.1)	0.1 (7.6)	2.8	0.6
R31	0.4 (49.9)	0.2 (2.2)	0.3 (20.1)	0.1 (7.6)	2.7	0.6
R32	0.3 (49.8)	0.1 (2.1)	0.3 (20.1)	0.1 (7.6)	2.3	0.6
R33	0.3 (49.8)	0.1 (2.1)	N/A	N/A	2.1	0.5
R34	N/A	0.1 (2.1)	N/A	N/A	N/A	N/A
R42	N/A	N/A	N/A	N/A	1.8	0.4
R43	N/A	0.4	N/A	N/A	2.3	0.5
R44	N/A	N/A	N/A	N/A	2.2	0.5
R45	N/A	N/A	N/A	N/A	1.7	N/A
R49	0.9 (50.4)	0.3 (2.3)	0.9 (20.7)	0.2 (7.7)	2.9	0.9

* N/A: The predicted level at the indicated receptor is outside the top ten for that pollutant and averaging time

Figure 7-6. Predicted annual average cumulative $PM_{2.5}$ concentrations (µg/m³) due to emissions from site establishment works activities

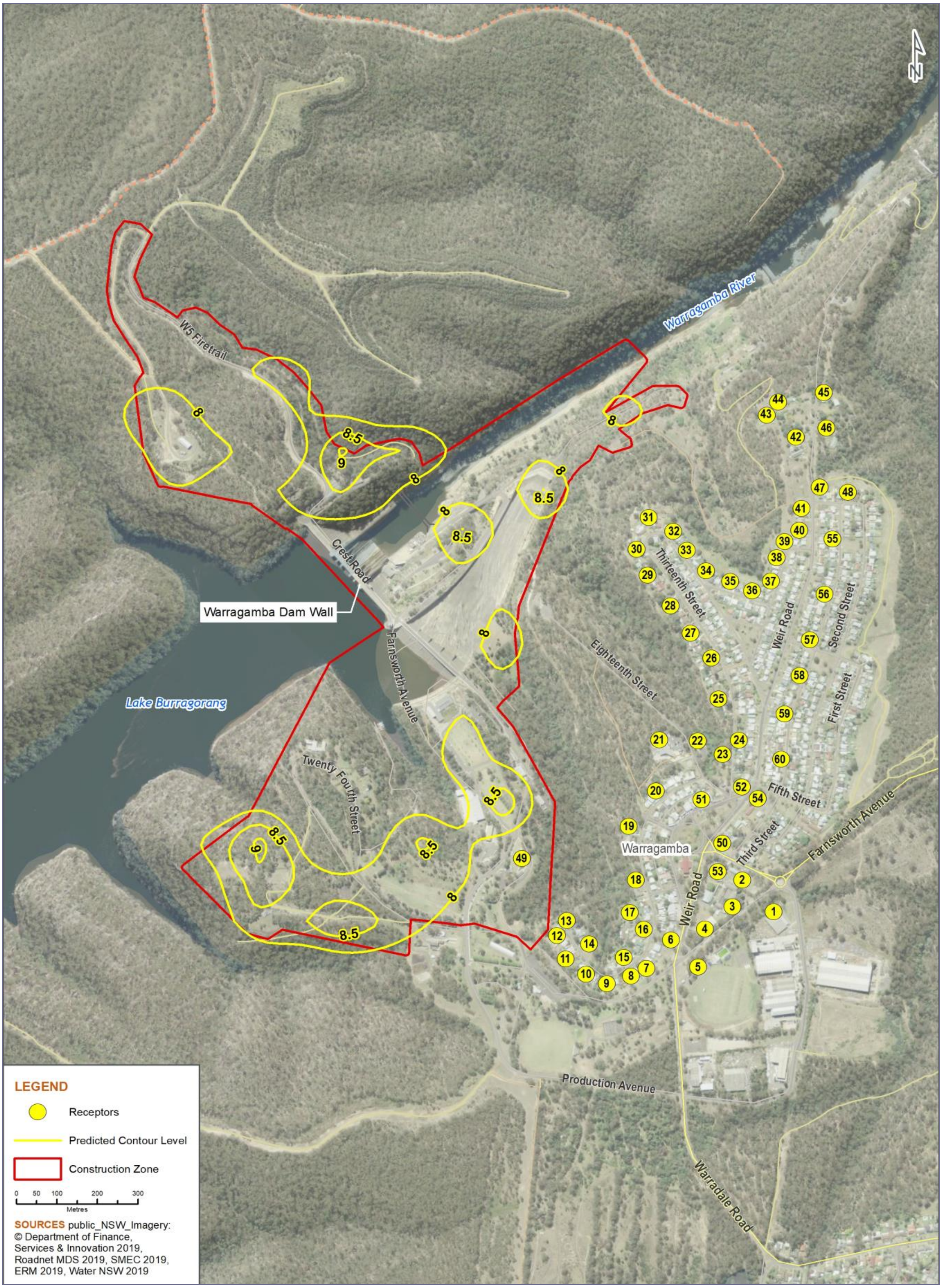


Figure 7-7. Predicted annual average cumulative PM_{10} concentrations (µg/m^3) due to emissions from site establishment works activities

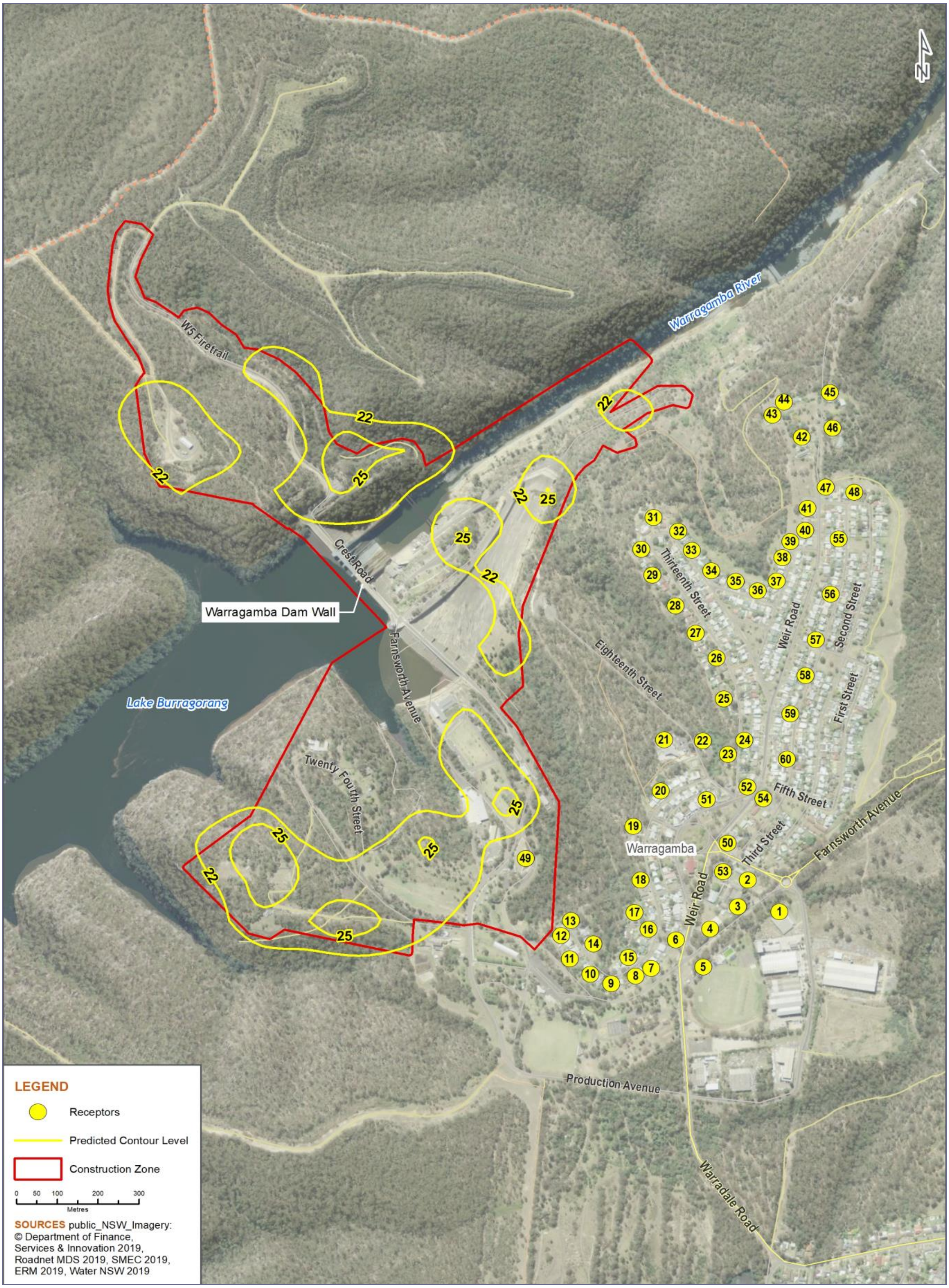


Figure 7-8. Predicted annual average cumulative TSP concentrations (µg/m³) due to emissions from site establishment works activities

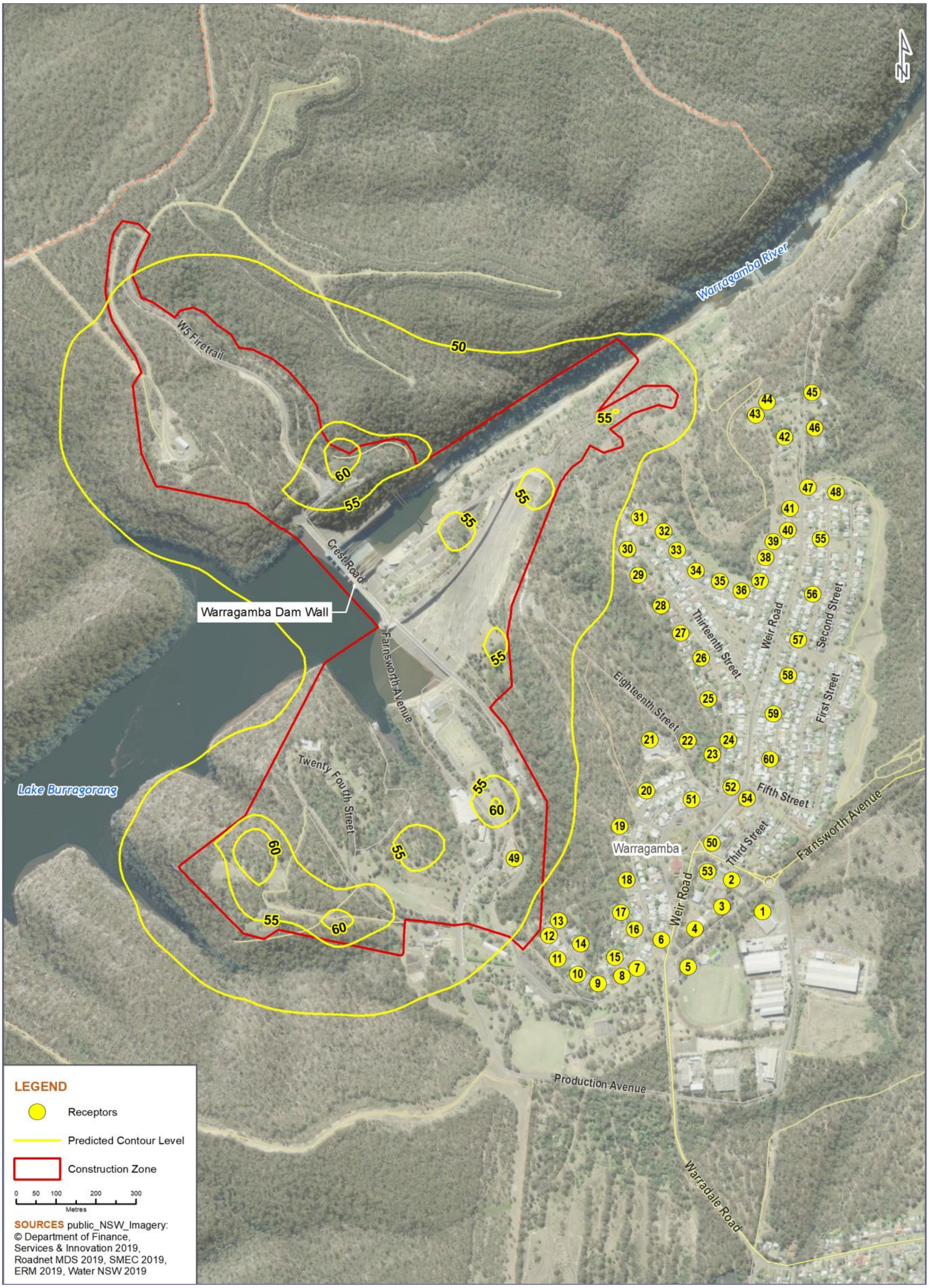


Figure 7-9. Predicted annual average cumulative dust deposition concentrations (µg/m³) due to emissions from site establishment works activities

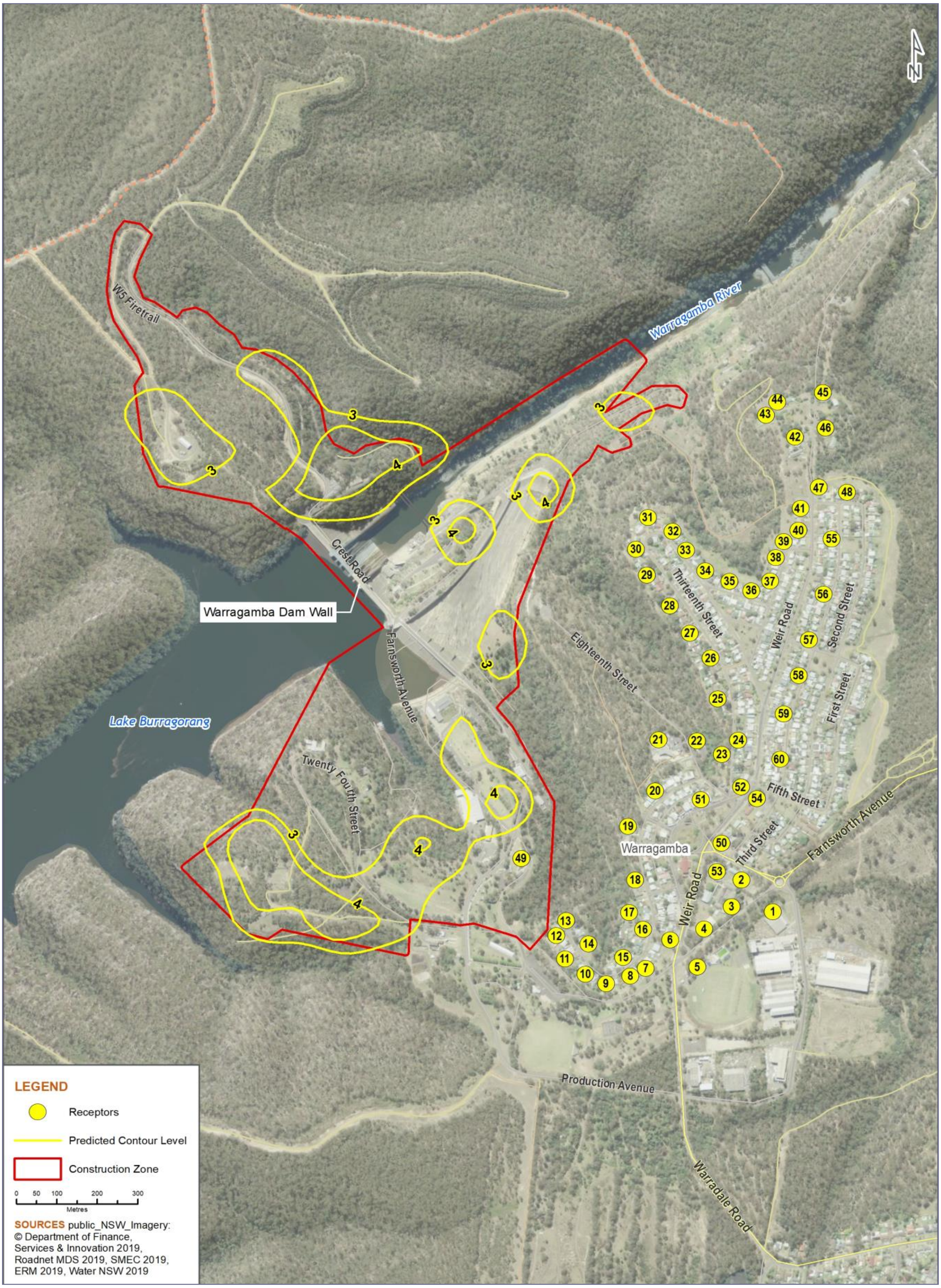


Figure 7-10. Predicted maximum 24-hour average $PM_{2.5}$ concentrations (µg/m[3]) due to emissions from site establishment works activities

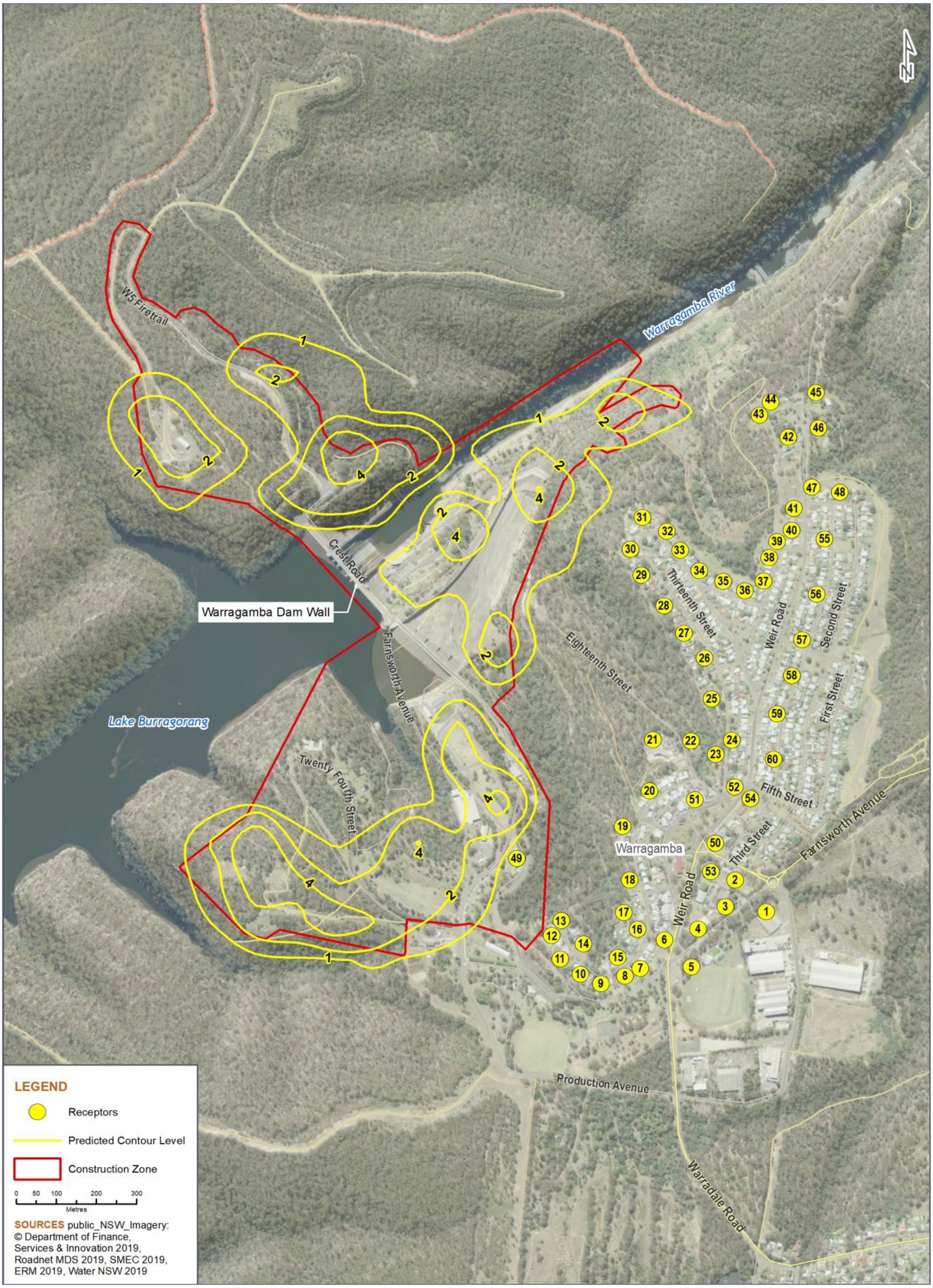
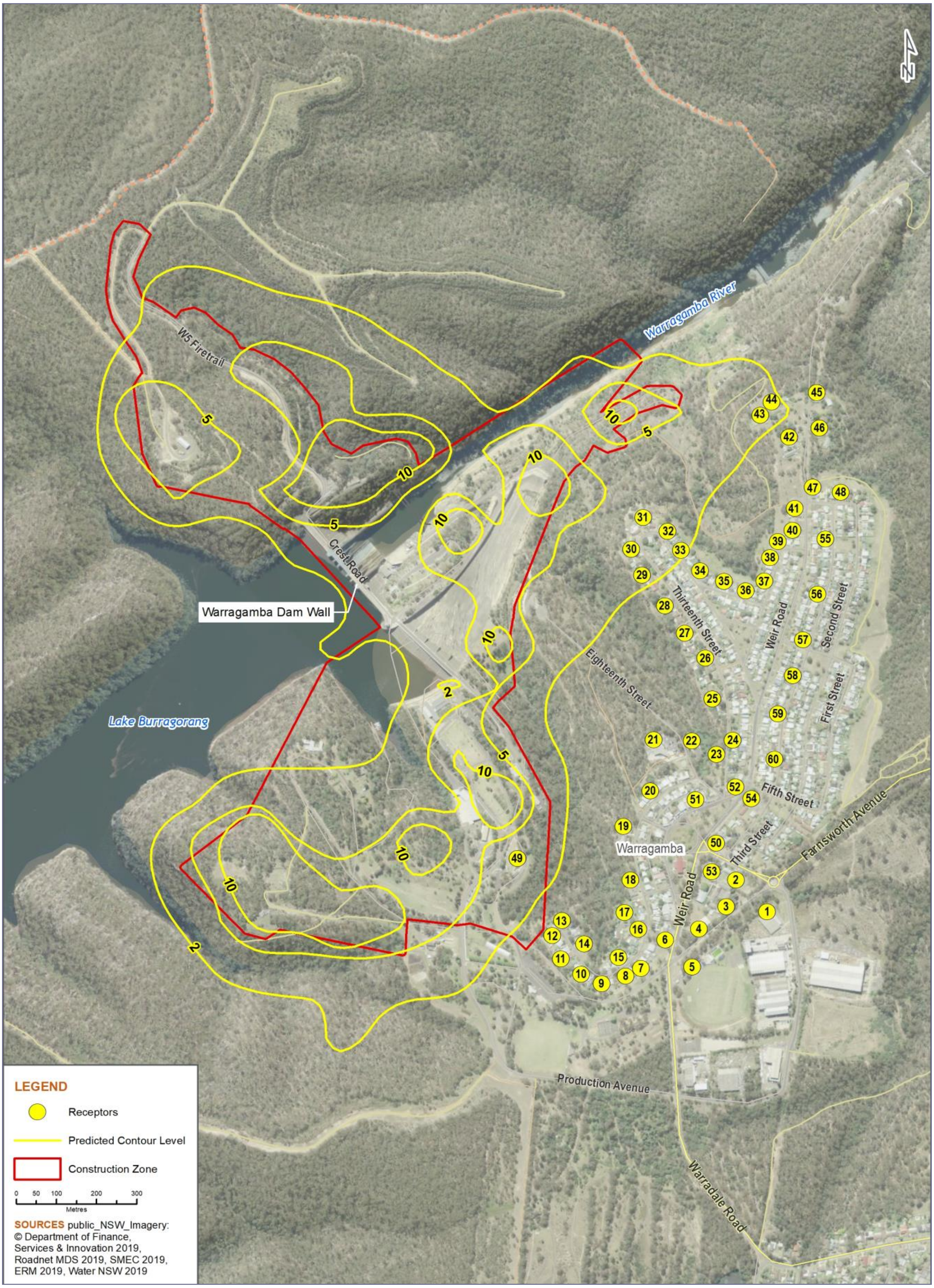


Figure 7-11. Predicted maximum 24-hour average PM_{10} concentrations (µg/m³) due to emissions from site establishment works activities



7.6.2 Construction works

The results of the modelling for the construction works stage for the 10 highest concentrations for $PM_{2.5}$ and PM_{10}, dust deposition, TSP and averaging time are presented in Table 7-11. As shown, the predicted levels are well below background concentrations, and EPA air quality criteria for PM and deposited dust.

Cumulative results are presented as contours (annual averages) and time series (24-hour averages), discussed in the next sections.

Table 7-11. Construction works modelling predictions for ten receptors showing the highest concentrations

Receptor ID	Annual average				24-hr average	
	TSP (µg/m³)	Dust deposition (g/m²/month)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³
Criteria (EPA 2016)	**90 µg/m³ Annual**	**2 g/m²/month maximum increase 4 g/m²/month maximum total**	**25 µg/m³**	**8 µg/m³**	**50 µg/m³**	**25 µg/m³**
R3	N/A*	N/A	N/A	N/A	N/A	0.1
R4	N/A	N/A	N/A	N/A	0.35	0.1
R11	N/A	N/A	N/A	N/A	N/A	0.1
R12	N/A	N/A	N/A	0 (7.5)	N/A	0.1
R13	N/A	N/A	N/A	0 (7.5)	N/A	0.1
R18	N/A	N/A	N/A	N/A	0.4	N/A
R19	0.1 (49.5)	N/A	N/A	0 (7.5)	0.4	0.1
R20	N/A	N/A	N/A	0 (7.5)	0.4	0.1
R21	N/A	N/A	N/A	0 (7.5)	N/A	N/A
R27	N/A	N/A	N/A	N/A	0.3	N/A
R28	0.1 (49.5)	0 (2.0)	0.1 (19.8)	N/A	N/A	N/A
R29	0.1 (49.6)	0 (2.0)	0.1 (19.9)	0 (7.5)	N/A	N/A
R30	0.1 (49.6)	0 (2.0)	0.1 (19.9)	0 (7.5)	0.3	N/A
R31	0.1 (49.6)	0.1 (2.0)	0.1 (19.9)	0 (7.5)	N/A	N/A
R32	0.1 (49.6)	0 (2.0)	0.1 (19.9)	0 (7.5)	0.3	N/A
R33	0.1 (49.6)	0 (2.0)	0.1 (19.9)	N/A	N/A	N/A
R42	N/A	0 (2.0)	N/A	N/A	N/A	N/A
R43	0.1 (49.6)	0 (2.0)	0.1 (19.9)	N/A	N/A	N/A
R44	0.1 (49.6)	0 (2.0)	0.1 (19.9)	N/A	0.3	N/A
R45	N/A	N/A	0 (19.9)	N/A	0.3	N/A
R49	0.3 (49.8)	0.1 (2.1)	0.2 (20.0)	0.1 (7.6)	0.8	0.3
R50	N/A	N/A	N/A	N/A	N/A	0.1
R53	N/A	N/A	N/A	N/A	N/A	0.1

* N/A: The predicted level at the indicated receptor is outside the top ten for that pollutant and averaging time

7.6.2.1 Annual averages

Figure 7-12, Figure 7-13, Figure 7-14 and Figure 7-15 respectively show that cumulative annual average predictions for $PM_{2.5}$ and $PM_{10,}$ TSP and dust deposition are significantly lower for the concrete batching and blasting during construction works than for the site establishment works scenario. There are not predicted to be any exceedances of the air quality criteria during construction of the Project based on the modelling carried out.

7.6.2.2 Maximum 24-hour averages

Figure 7-16 and Figure 7-17 show the maximum 24-hour average $PM_{2.5}$ and PM_{10} levels respectively at the nearest sensitive receptors. Maximum $PM_{2.5}$ levels are estimated to be below 0.5 µg/m^3 and PM_{10} levels below 1 µg/m^3. These are both well below their respective impact assessment criteria and are unlikely to result in any exceedances due to the Project.

The modelling predicts that the most affected receptor is likely to be R49. Further analysis of maximum 24-hour $PM_{2.5}$ and PM_{10} concentrations was therefore conducted to determine the cumulative impacts at R49. The results showed that no additional exceedances were predicted, which are shown in Appendix E (Air Quality Assessment Report, Section 6).

Figure 7-12. Predicted annual average cumulative $PM_{2.5}$ concentrations (µg/m^3) due to emissions from construction activities

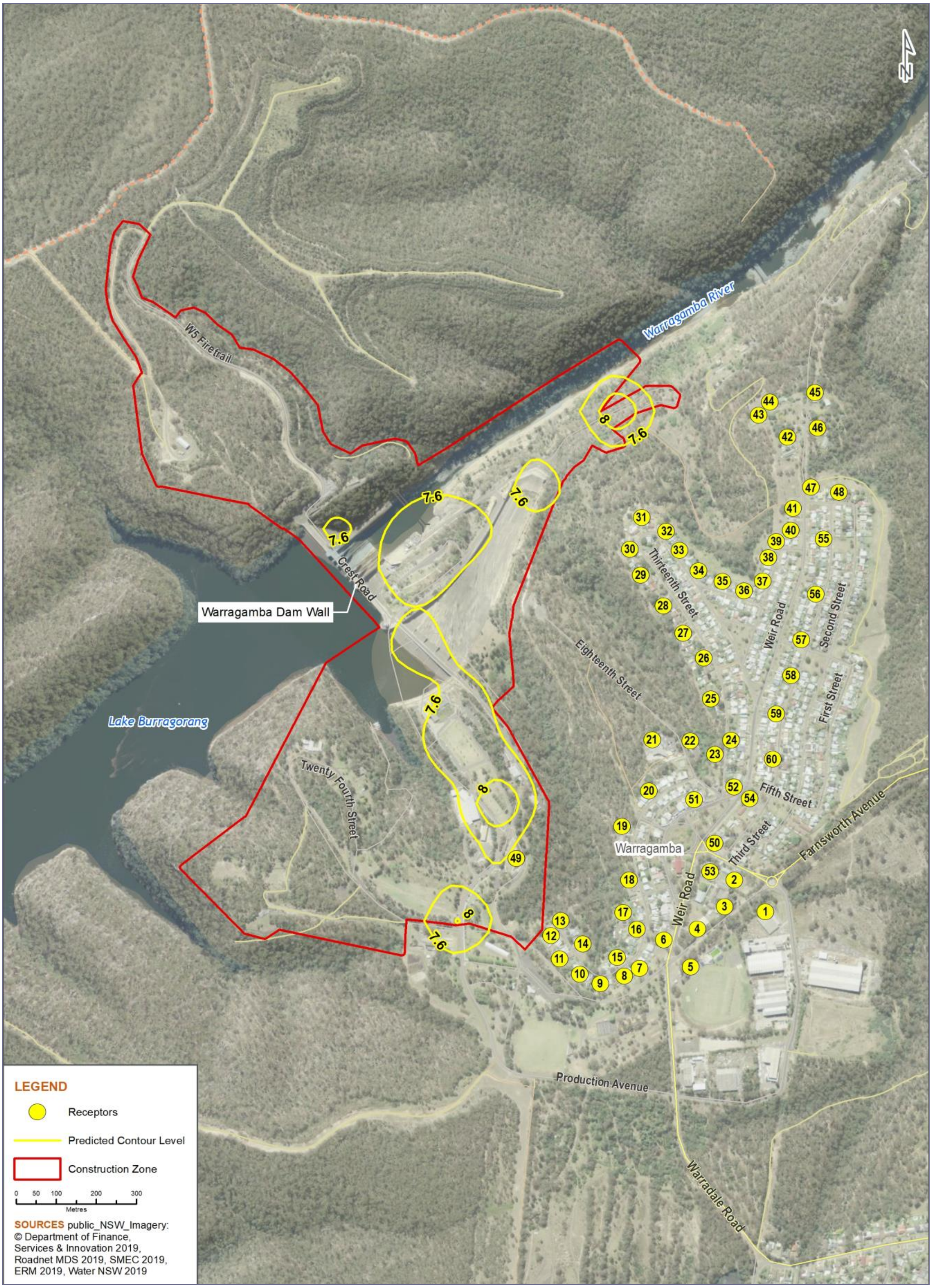


Figure 7-13. Predicted annual average cumulative PM_{10} concentrations (µg/m³) due to emissions from main construction activities

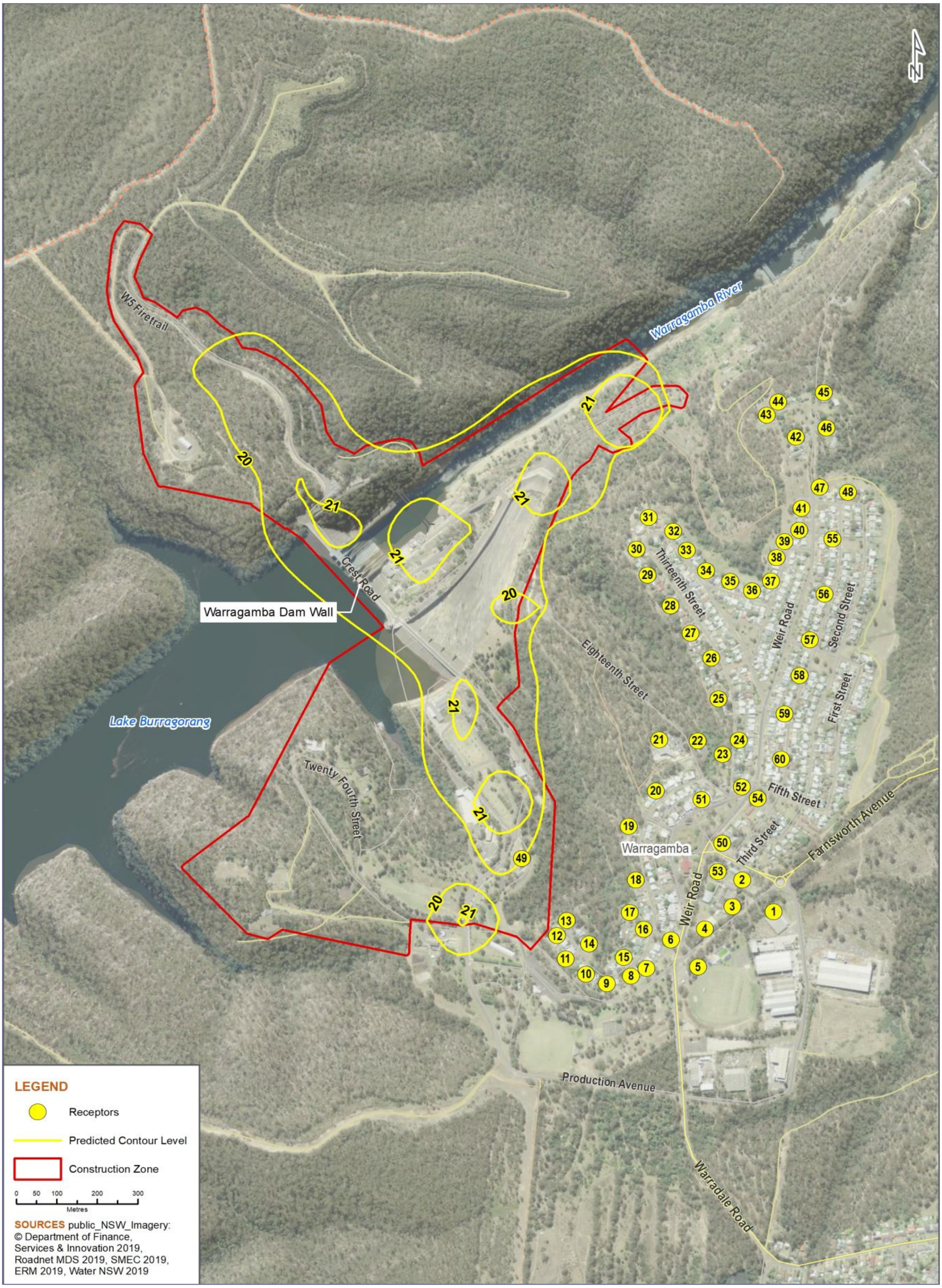


Figure 7-14. Predicted annual average TSP concentrations (µg/m³) due to emissions from main construction activities

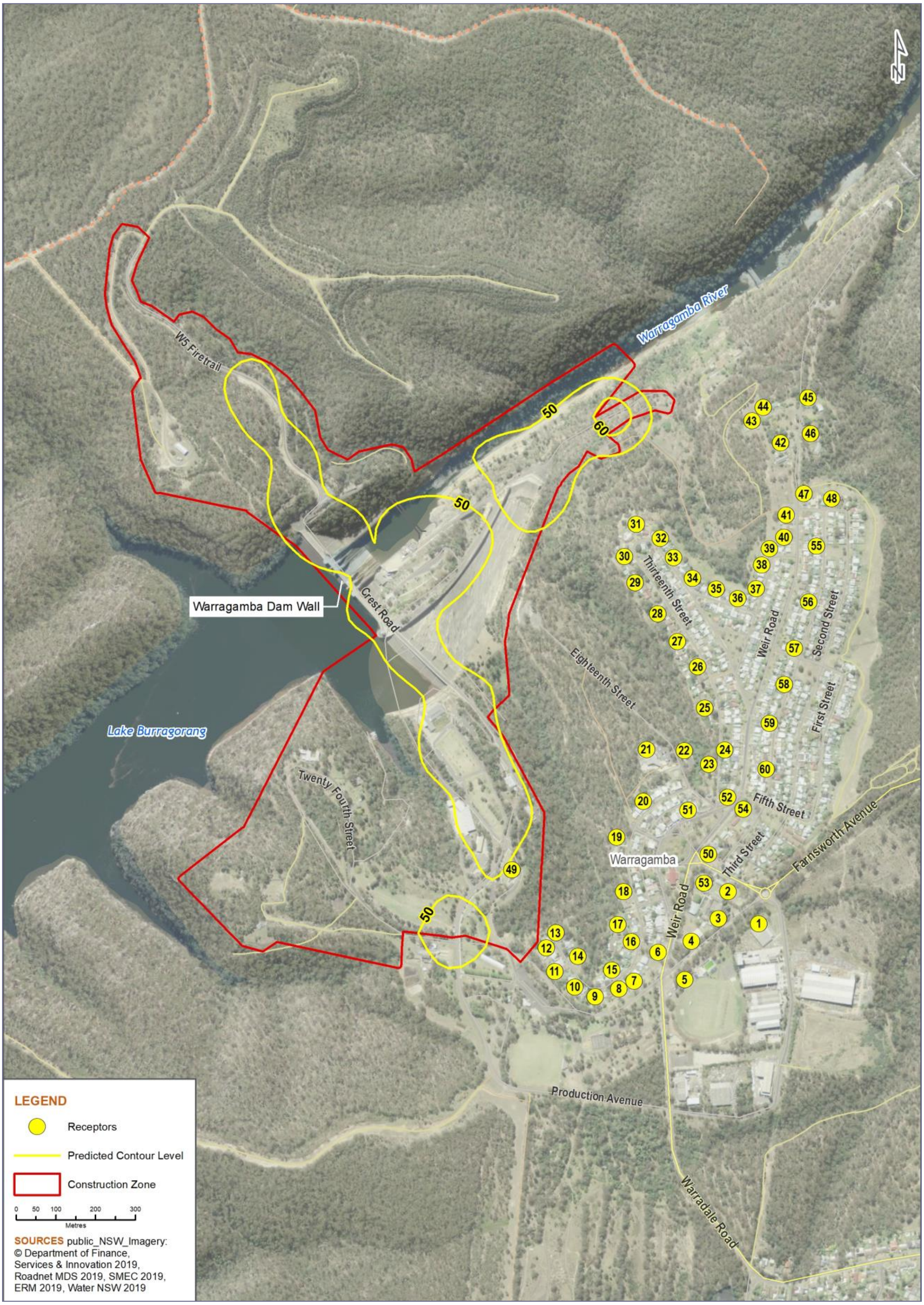


Figure 7-15. Predicted annual average cumulative dust deposition (µg/m³) due to emissions from construction activities

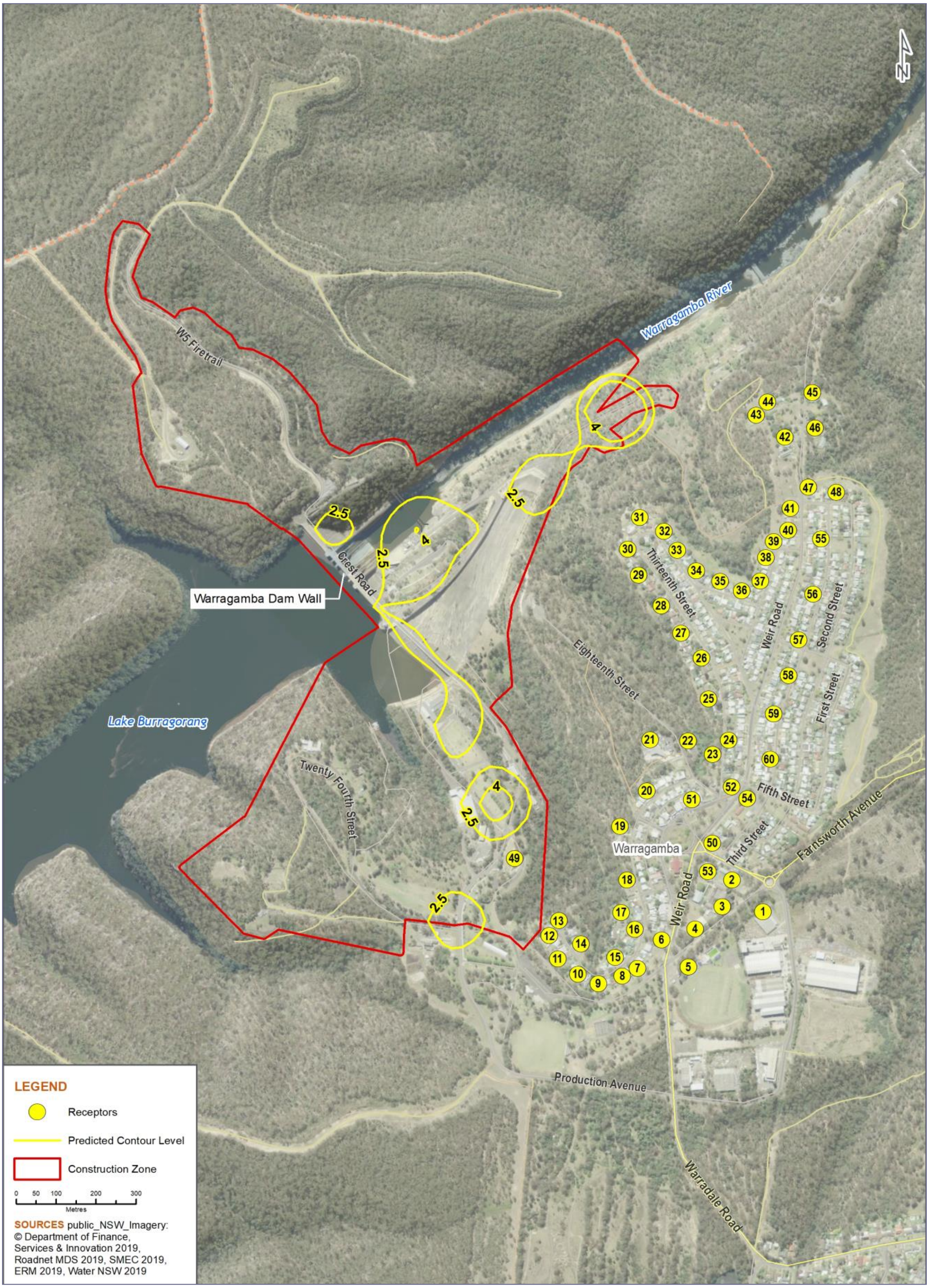


Figure 7-16. Predicted maximum 24-hour average $PM_{2.5}$ concentrations (µg/m^3) due to emissions from construction activities

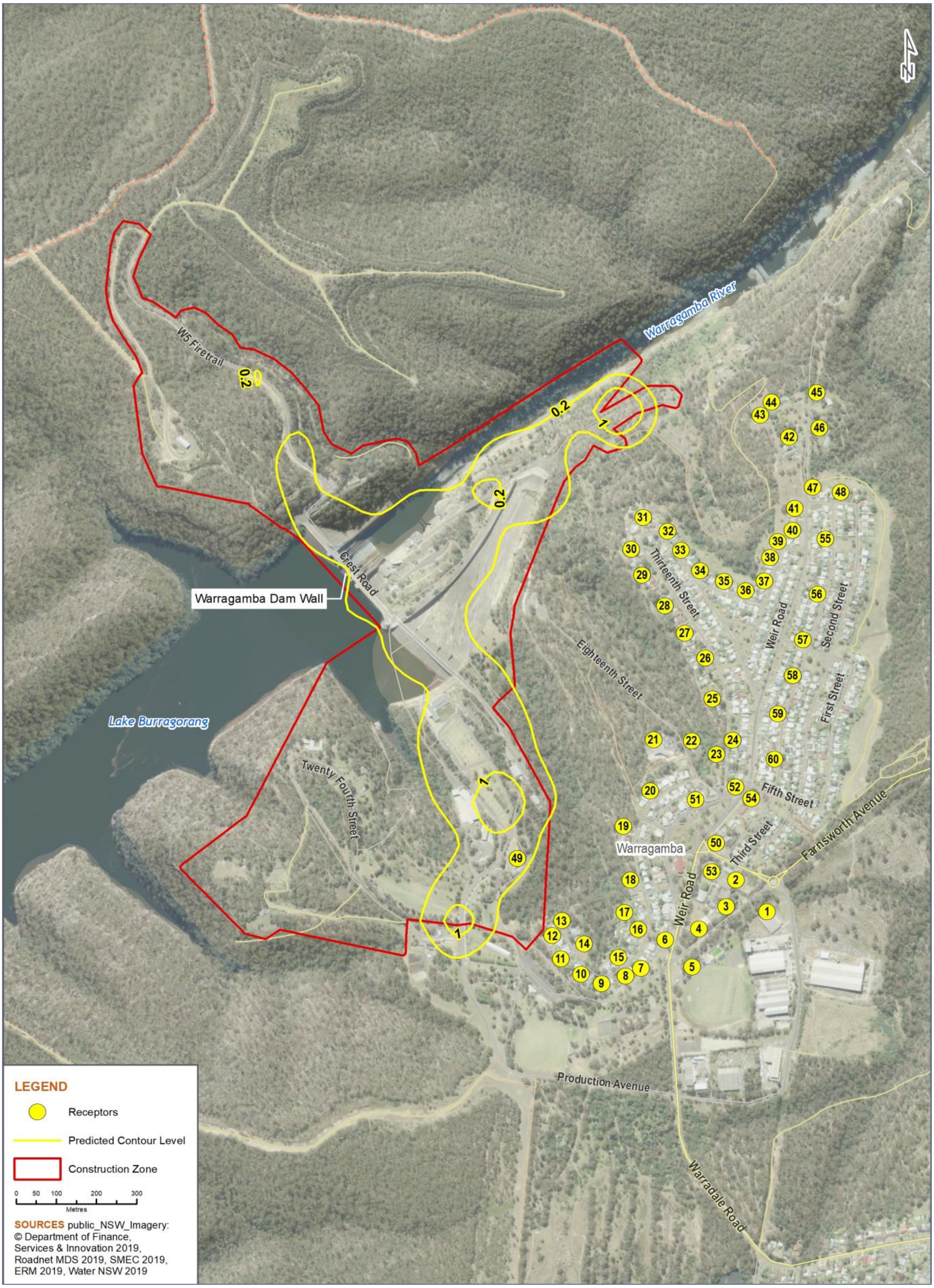
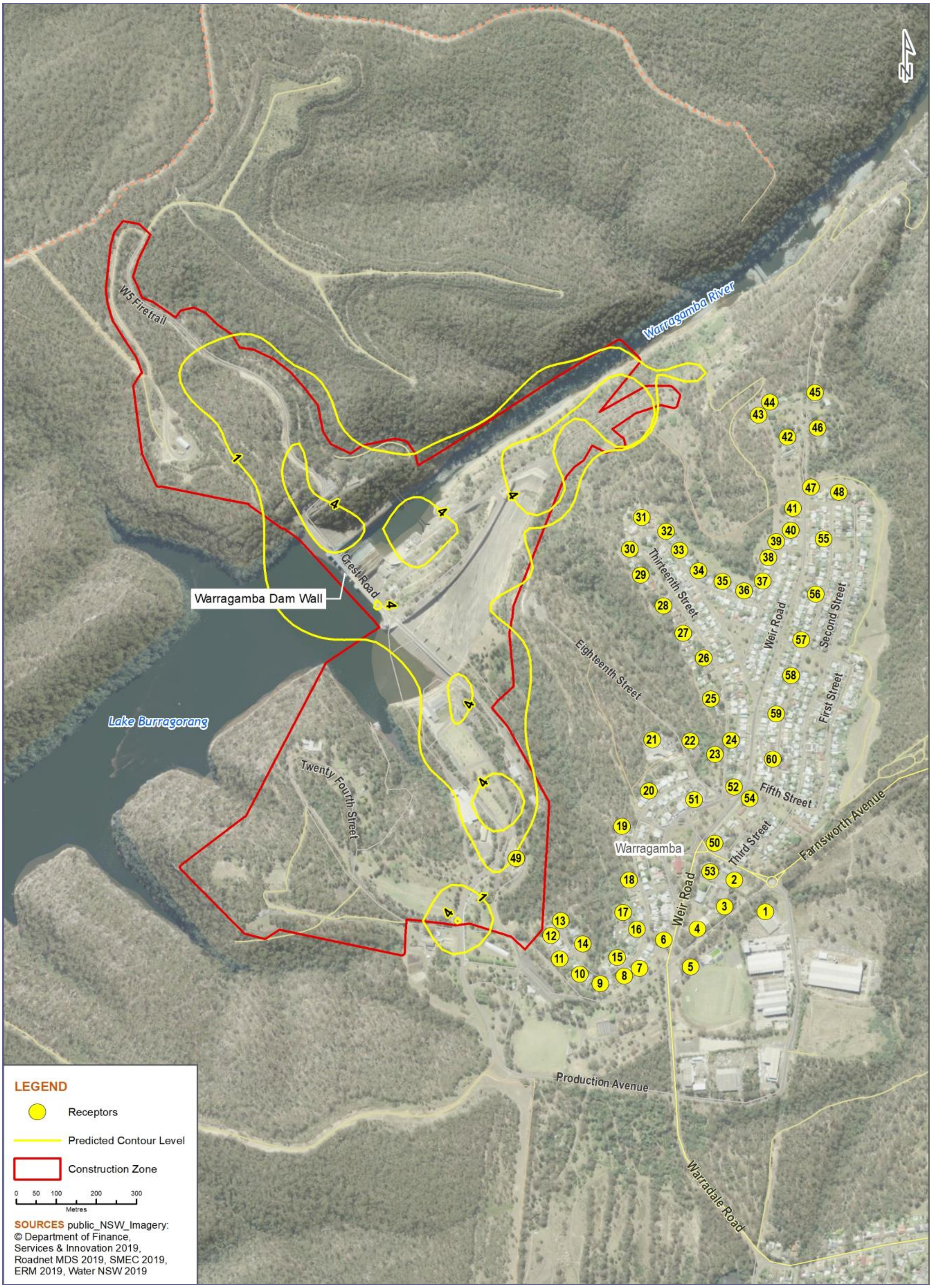


Figure 7-17. Predicted maximum 24-hour average PM_{10} concentrations (µg/m^3) due to emissions from construction activities



7.7 Assessment of potential operational impacts

The main activities associated with the operation of the raised Warragamba Dam are not expected to change from current levels. These activities are likely to be localised and would occur over short time-scales, and are therefore unlikely to pose a material risk to air quality. Sources potentially affecting air quality as a result of activities related to Project operations may include:

- wheel-generated dust from light vehicle movements on unsealed surfaces
- exhaust emissions from light vehicle movements and from fuel powered plant items such as portable generators.

Although these activities are unlikely to pose a risk to air quality, there are good practice measures that can be applied to mitigate risks to air quality as far as possible. These include:

- regular inspection of plant equipment and vehicles to ensure efficient operation and use
- complete routine servicing and maintenance of plant equipment and vehicles
- ensure that all haul routes are kept clean and clear of dust or debris
- ensure that vehicle idling is kept to a minimum.

7.8 Environmental management measures

The results of the dispersion modelling showed that minor increases in both 24-hour and annual average concentrations are predicted however, these are not anticipated to result in exceedances of the EPA air quality assessment criteria at the nearest receptors.

Safeguards and management measures have been developed to avoid, minimise, or manage potential risks identified in Section 7.5.

Table 7-12 lists the safeguards and mitigation measures to address potential air quality impacts from construction and operation. These mitigation and management measures have been incorporated in the summary measures in Chapter 29.

Additional guidance on the control of dust at construction sites in NSW is provided as part of the EPA local government air quality toolkit. Detailed guidance is also available from the UK (Greater London Authority 2006) and the United States (Countess Environmental 2006).

Table 7-12. Management measures

Impact	ID	Environmental management measure	Timing	Responsible
Impacts from ambient air quality from dust generation and deposition during construction	AQ1	A construction air quality management plan will be developed and implemented to monitor and manage potential air quality impacts associated with the construction of the Project and activities at construction ancillary facilities. The management plan will identify Project construction activities with the potential to have air quality impacts and the controls required to avoid, minimise, and mitigate these impacts. The plan will include measures to: ▪ minimise Project and cumulative dust generation from stockpiles, haulage routes, work activities, exposed ground surfaces and materials handling/storage ▪ minimise generator and vehicle emissions during construction ▪ inspect and address corrective actions ▪ modify or cease dust generating works during unfavourable weather conditions ▪ monitor dust levels ▪ respond to complaints about dust and other air quality issues. The Plan will be implemented for the duration of construction.	Pre-construction and construction	WaterNSW Construction Contractor
	AQ2	Demolition activities, including removal of hazardous materials will be planned and carried out in a manner that minimises the potential for dust generation. Removal of hazardous materials will be completed prior to the commencement of general demolition works.	Construction	WaterNSW Construction Contractor

7.9 Risk assessment

An environmental risk assessment was carried out in accordance with the SEARs, using the methodology provided in Appendix C (Risk assessment procedure). A Project risk matrix was developed and risk ranking evaluated by considering:

- the likelihood (L) of an impact occurring
- the severity or consequence (C) of the impact in a biophysical and/or socio-economic context, with consideration of:
  - whether the impact will be in breach of regulatory or policy requirements
  - the sensitivity of receptors
  - duration of impact, that is, whether the impact is permanent or temporary
  - the areal extent of the impact and/or the magnitude of the impact on receptors.

The likelihood and consequence matrix is shown on Figure 7-18.

Once the consequence and likelihood of an impact are assessed, the risk matrix provides an associated ranking of risk significance: **Low**; **Medium**; **High** or **Extreme,** as shown in Table 7-13**.** The residual risk was determined after the application of proposed mitigation measures.

The risk analysis for potential air quality impacts is provided in Figure 7-18. This includes the residual risk of the potential impact after the implementation of mitigation measures.

Table 7-13. Risk ranking definitions

Risk definitions	
Extreme 21 – 25	Widespread and diverse primary and secondary impacts with significant long-term effects on the environment, livelihood, and quality of life. Those affected will have irreparable impacts on livelihoods and quality of life.
High 15 – 20	Significant resources and/or Project modification would be required to manage potential environmental damage. These risks can be accommodated in a Project of this size, however comprehensive and effective monitoring measures would need to be employed such that Project activities are halted and/or appropriately moderated. Those impacted may be able to adapt to change and regain their livelihoods and quality of life with a degree of difficulty.
Medium 9 – 14	Risk is tolerable if mitigation measures are in place, however management procedures will need to ensure necessary actions are quickly taken in response to perceived or actual environmental damage. Those impacted will be able to adapt to changes.
Low 1 – 8	On-going monitoring is required however resources allocation and responses would have low priority compared to higher ranked risks. Those impacted will be able to adapt to change with relative ease.

Figure 7-18. Risk matrix

	Consequence				
	Negligible	**Minor**	**Medium**	**Major**	**Extreme**
LEGAL	No legal consequences	No legal consequences	Incident potentially causing breach of licence conditions	Breach of licence conditions	Breach of licence conditions resulting in shutdown of Project operations.
SOCIO-ECONOMIC	Impacts that are practically indistinguishable from the social baseline, or consist of solely localised or temporary/short-term effects with no consequences on livelihoods and quality of life.	Short-term or temporary impacts with limited consequences on livelihoods and quality of life. Those affected will be able to adapt to the changes with relative ease and regain their pre-impact livelihoods and quality of life.	Primary and secondary impacts with moderate effects on livelihoods and quality of life. Will be able to adapt to the changes with some difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with significant long-term effects on livelihoods and quality of life. Those affected may be able to adapt to changes with a degree of difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with irreparable impacts on livelihoods and quality of life and no possibility to restore livelihoods.
HEALTH	No health consequences	Accident or illness with little or no impact on ability to function. Medical treatment required is limited or unnecessary.	Accident or illness leading to mild to moderate functional impairment requiring medical treatment.	Accident or illness leading to permanent disability or requiring a high level of medical treatment or management.	Accident, serious illness or chronic exposure resulting in fatality.
ENVIRONMENT	Localised (on-site), short-term impact on habitat, species or environmental media	Localised or widespread medium-term impact to habitat, species or environmental media	Localised degradation of sensitive habitat or widespread long-term impacts on habitat, species or environmental media. Possible contribution to cumulative impacts.	Widespread and long-term changes to sensitive habitat, species diversity or abundance or environmental media. Temporary loss of ecosystem function at landscape scale. Moderate contribution to cumulative impacts.	Loss of a nationally or internationally recognised threatened species or vegetation community. Permanent loss of ecosystem function on a landscape scale. Major contribution to cumulative effects

		A - negligible	**B** - minor	**C** - medium	**D** - major	**E** - extreme
Expected to occur during the Project or beyond the Project	**a** - expected	**13**	**14**	**20**	**24**	**25**
May occur during the Project or beyond the Project	**b** - may	**8**	**12**	**19**	**22**	**23**
Possible under exceptional circumstances	**c** - possible	**6**	**7**	**11**	**18**	**21**
Unlikely to occur during the Project	**d** - unlikely	**4**	**5**	**10**	**16**	**17**
Rare or previously unknown to occur	**e** - rare	**1**	**2**	**3**	**9**	**15**

Risk Definition (see Table 7-13)	**Low**	**Medium**	**High**	**Extreme**

Table 7-14. Air quality risk assessment

Air quality								
Key impacts	**Risk before mitigation**			**Mitigation and management**	**Risk after mitigation**			**Residual risk**
	L	**C**	**R**		**L**	**C**	**R**	
Construction								
Air pollution emissions resulting in nuisance, licence breaches and health issues: *Site establishment works* ▪ land clearing ▪ stockpiling ▪ supporting infrastructure *Construction works* ▪ vehicle movements ▪ material movements and storage ▪ concrete batching	b	C	19	AQ1, AQ2	c	C	11	Modelling predicted that during Project construction air pollutants would generally be well below air quality criteria. However, for PM_{10} there is one slight exceedance predicted at one receptor (R49). However, any exceedances of the criterion would be rare and likely the result of regional dust events. Although air quality criteria at a sensitive receptor may be exceeded only rarely, if at all, a High risk was determined due to a potential breach of regulatory requirements. Following mitigation, the risk can be reduced to a Medium residual risk, however mitigation will need to ensure that necessary actions are quickly taken in response to adverse weather, such as high wind conditions.
Operation								
Air pollution emissions resulting in nuisance, licence breaches and health issues: ▪ light vehicle movements ▪ exhaust emissions.	d	C	10		d	B	5	Low residual risk not requiring significant additional mitigation measures.

Notes: L = likelihood
C = consequence
R = rating

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