APPENDIX

L

INLAND RAIL

Air Quality Technical Report

PART 1 OF 2

Main Report

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

IR_1381

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Inland Rail Calvert to Kagaru EIS

Appendix L – Air Quality Technical Report

Australian Rail Track Corporation

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Contents

Appendices

Figures

Tables

Abbreviations

Abbreviation	Explanation
µm	micrometre
AMO	Aeronautical Meteorological Office
AOI	area of influence
AQIA	air quality impact assessment
ARTC	Australian Rail Track Corporation Ltd
BCC	Brisbane City Council
BoM	Bureau of Meteorology
CALMET	A diagnostic three-dimensional meteorological model, which provides input for the CALPUFF air dispersion model
CALPUFF	CALPUFF is an advanced non-steady-state air quality modelling system developed in the US
CALPOST	A post-processing package used to process the output from CALPUFF
CEMP	Construction Environmental Management Plan
CIA	cumulative impact assessment
CO	carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DES	Queensland Government Department of Environment and Science
DSITI	Queensland Government Department of Science, Information Technology and Innovation
EEA	European Environment Agency
EIS	Environmental Impact Statement
EMEP	European Monitoring and Evaluation Project
EMP	Environmental Management Plan
ENSO	El Niño-Southern Oscillation
EPP	Environmental Protection Policy
ERA	Environmentally relevant activities
FDMS	filter dynamics measurement systems
GDA	Geocentric Datum of Australia
GRAL	GRAL is an Austrian developed three-dimensional lagrangian dispersion model which is well suited to modelling the influence of complex terrain and buildings on pollution dispersion.
GRAMM	Prognostic meso-scale wind field model used for input into GRAL
IARC	International Agency for Research on Cancer
IAQM	UK Institute of Air Quality Management
Inland Rail	Melbourne to Brisbane Inland Rail
ISCA	Infrastructure Sustainability Council of Australia
km	kilometres
kW	kilowatt
LGA	Local Government Areas
L	litres
m	metre
MEI	Multivariate ENSO Index
mg/L	milligrams per litre
NEPM	National Environment Protection Measure

Abbreviation	Explanation
NHMRC	National Health and Medical Research Council
NO	nitrogen oxide
NO_2	nitrogen dioxide
NOx	nitrogen oxides
NPI	National Pollutant Inventory
NSW	New South Wales
NSW EPA	New South Wales Environmental Protection Authority
O_3	ozone
OEMP	Operations Environmental Management Plan
OLM	ozone limiting method
ONI	Oceanic Niño Index
PAHs	polycyclic aromatic hydrocarbons
PM_{10}	particulate matter less than 10 micrometres
$PM_{2.5}$	particulate matter less than 2.5 micrometres
QLD	Queensland
QLUMP	Queensland Land Use Mapping Program
SEQ	South East Queensland
SOI	Southern Oscillation Index
SO_2	sulphur dioxide
the proponent	Australian Rail Track Corporation (ARTC)
TAPM	Prognostic meteorological model used to provide input into CALMET
TEOM	tapered element oscillation microbalance
TEQ	toxic equivalency
THC	total hydrocarbons
ToR	Terms of Reference
TSP	total suspended particulates
UQ	University of Queensland
US EPA	US Environmental Protection Agency
VIC EPA	Victorian Environmental Protection Authority
VOCs	volatile organic compounds

Executive summary

Future Freight Joint Venture (FFJV) was engaged by Australian Rail Track Corporation (ARTC) to prepare an Environmental Impact Statement (EIS) for the Calvert to Kagaru Project (the Project).

ARTC proposes to construct and operate the Project which consists of approximately 53 kilometres (km) of single track dual gauge greenfield railway with four crossing loops to accommodate double stack freight trains up to 1,800 metres (m) long. It will also involve the construction of an approximately 1,015 m tunnel through the Teviot Range to facilitate the required gradient across the undulating topography. The Project is greenfield and one of the 'missing links' within the Inland Rail Program between Melbourne and Brisbane.

Although ARTC are applying for approval to build infrastructure to accommodate trains up to 1,800 m in length, infrastructure will be designed such that the future extension of some crossing loops to accommodate 3,600 m trains is not precluded. ARTC intend to acquire the land for the future 3,600 m crossing loop extension with the initial land acquisition, however, the approval for the construction of future 3,600 m crossing loops will be subject to separate approval applications in the future. This assessment has been undertaken for 1,800 m long train sets, 3,600 m long train sets have not been considered in the assessment.

Key elements of the air quality impact assessment included:

- Review of relevant legislation, historical meteorological data and ambient air quality monitoring data
- Generation of specific meteorology for the air quality study area
- Primarily quantitative impact assessment for the operation phase to estimate potential air quality impacts, including cumulative air quality impacts
- Identification of mitigation measures
- Assessment of the residual impact with the inclusion of the identified mitigation measures.

A survey of sensitive receptors has been conducted for the air quality study area, with a total of 548 receptors considered in the assessment.

The assessment methodology used for the assessment of construction dust is the 2014 United Kingdom (UK) Institute of Air Quality Management (IAQM) Guidance on the assessment of dust from demolition and construction (UK IAQM 2014). The IAQM process is a four-step risk-based assessment of dust emissions associated with demolition, including land clearing and earth moving, and construction activities.

An air quality dispersion modelling assessment for the operational phase was completed based upon methodologies and guidance presented in the following guidelines:

- 'Application requirements for activities with impacts to air', guideline document under the *Environmental Protection Act 1994* (Qld) (EP Act) to support applications for activities with impacts to air (DES 2019b)
- 'Approved methods for the modelling and assessment of air pollutants in New South Wales', which provides statutory methods for modelling and assessing emissions of air pollutants in New South Wales (NSW) (EPA 2016)
- Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessment in New South Wales, which provides detailed guidance on selection of CALPUFF modelling variables.

Meteorological data used in the assessment was derived in accordance with the aforementioned guidance from The Air Pollution Model (TAPM) developed by CSIRO (CSIRO 2008) and supplemented with historical data from a number of Bureau of Meteorology (BoM) stations in the air quality study area. Dispersion modelling of pollutants was then completed utilising CALPUFF with meteorology refined using CALMET.

In order to quantify emissions during operation of the Project an emissions inventory was developed. The key pollutants of interest included in the emissions inventory for diesel locomotives and fugitive coal dust were oxides of nitrogen (NO_x), particulates less than 10 micrometres in diameter (PM_{10}), particulates less than 2.5 micrometres in diameter ($PM_{2.5}$), and total suspended particulates (TSP).

The assessment of operational impacts has considered both the forecast peak and typical train volumes for 2040, with potential worst case pollutant concentrations predicted across the air quality study area. The predicted air quality concentrations and deposition rates were compared to Project air quality goals that were adopted considering the EP Act, the Environmental Protection (Air) Policy 2019 (EPP (Air)), National Environment Protection (Ambient Air Quality) Measure (Air Quality NEPM) and guidelines commonly recommended by the Queensland Department of Environment and Science (DES). The environmental values which are protected by the air quality goals considered include protecting health and wellbeing, protecting the health and biodiversity of ecosystems, and protecting agriculture uses, and protecting the aesthetics of the environment.

The methodology adopted for the assessment is conservative and is considered likely to over-estimate impacts, as is typically required for air quality impact assessments. A number of assumptions been made in the assessment, including the following key assumptions:

- Emission factors for the locomotives have been adopted from the United States Environmental Protection Agency (US EPA 2009) and the European Monitoring and Evaluation Program/European Environment Agency (EMEP/EEA 2016a)
- The diesel locomotive particulate fraction for $PM_{2.5}$ was assumed to be 96 per cent of the PM_{10} emission rates as indicated in the National Pollution Inventory (NPI) Emissions Estimation Manual for Railyards (NPI 2008), which is considered the most accurate reference for particulate emissions
- Concentrations of TSP, PM_{10}, $PM_{2.5}$ and levels of deposited dust have been predicted with and without veneering to coal wagons. Application of veneer to coal wagons is expected to reduce emissions in the order of 75 to 85 per cent. It has been conservatively assumed that fugitive coal dust emissions will be reduced by 75 per cent based on field trials (Connell Hatch 2008).
- The $PM_{2.5}$ emission rate from fugitive coal dust is considered to be 15 per cent of the PM_{10} emission rates based on the particle size distributions for mechanically generated emissions from aggregate and unprocessed ores published in the US EPA AP42 Compilation of Air Pollutant Emission Factors (US EPA, 1998). Particle size distribution data is not provided for coal, but size distributions for aggregate and unprocessed ores is considered acceptable in lieu of specific data for coal.
- Coal dust emissions were calculated from an assumed average speed which resulted in an effective wind speed over the coal wagons of 80 km/hr for the entire alignment, with the exception of travel through the Teviot Range Tunnel
- Nitrogen dioxide concentrations were derived from modelled results utilising the ozone limiting method (OLM) as per Approved methods for the modelling and assessment of air pollutants in New South Wales (EPA 2016). Background NO_2 and O_3 concentrations for the air quality study area have been assumed based on measured concentrations from the DES Mutdapilly air quality monitoring station.

The qualitative assessment of air quality impacts during the construction of the Project determined that without mitigation there is an anticipated ‘Low’ risk of human health impacts, but a ‘Medium’ risk of dust deposition impacts.

The operational phase assessment determined that compliance with the adopted air quality goals is predicted for all pollutant species for both the peak and typical train volume scenarios with the inclusion of veneering. Without veneering, the annual PM_{10} and $PM_{2.5}$ goals are predicted to be exceeded for both typical and peak train volumes in 2040.

Compliance with the drinking water guideline values prescribed by the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (2018) is predicted by a significant margin at all receptors.

Mitigation measures have been recommended for the construction and operational phases of the Project based on the results of the assessment.

Mitigation measures for the construction phase have been recommended for each construction activity and include:

- Water sprays to reduce dust emissions from the excavation and disturbance of soil and materials, vehicle travel on unsealed roads, and loading and unloading of materials.
- Rehabilitation of exposed areas.
- Minimum separation distances for the location of fuel storage tanks.

For several of the mitigation measures proposed, the expected control efficiency (emission reduction percentage) has been nominated based on guidance provided in the NPI Emissions Estimation Manual for Mining (NPI 2012).

For the construction of the Project, dust sources will be variable in nature and proximity to sensitive receptors and construction mitigations need to address this variability. For a number of emission sources identified there are multiple available mitigation measures. The exact method of mitigation implemented will be determined during construction phase planning and following confirmation of the availability and suitability of water supply sources. During the detailed phase of construction planning, a Construction Environment Management Plan (CEMP) will be developed.

The assessment of the operational phase of the Project for impacts to air quality determined that compliance is predicted for all air quality goals with the inclusion of veneering to coal trains Therefore, the only mitigation measure which is required for the operation of the Project is veneering to coal trains, and no other mitigation measures are required.

In addition to mitigation measures, methods for the monitoring, reporting and auditing of compliance with the Projects air quality goals have also been recommended for both the construction and operational phases.

1 Introduction

Future Freight Joint Venture (FFJV) were engaged by Australian Rail Track Corporation (ARTC) to prepare an Environmental Impact Statement (EIS) for the Calvert to Kagaru (C2K) Project (the Project) in accordance with the Terms of Reference (ToR) for an environmental impact statement: Inland Rail – Calvert to Kagaru project December 2017 and relevant guidelines.

To supplement the EIS, an air quality impact assessment has been undertaken to determine whether construction, commissioning, operation and decommissioning of the Project will comply with the relevant ambient air quality standards and goals. This report outlines the current regulatory system relevant to air quality management, the baseline air quality and meteorological conditions in the air quality study area, and the methodology used to carry out the assessment of impacts to air quality. For the purpose of the assessment, the air quality study area is defined as the area within 2 kilometres (km) either side of the alignment, with the alignment being the rail line itself.

The Project is one of 13 projects making up the 1,700 km Inland Rail Program. The Project is a greenfield rail corridor approximately 53 km in length that will connect the Helidon to Calvert section (H2C) in the north west, and Kagaru to Acacia Ridge and Bromelton (K2ARB) section to the east, both of which are components of the Inland Rail Program.

Figure 1.1 presents the Project location and the air quality study area.

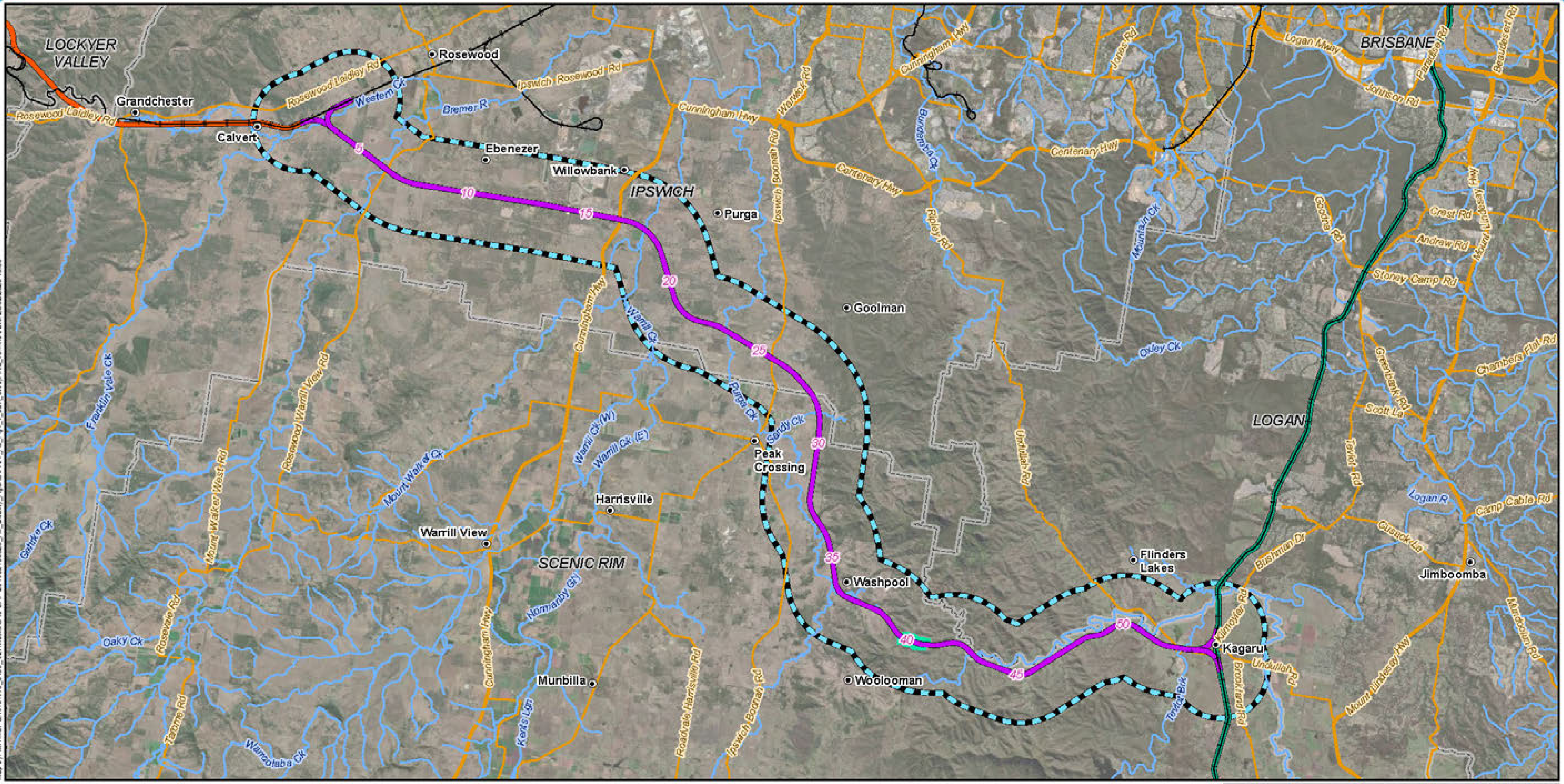
1.1 Assessment scope

The scope of the air quality impact assessment included the following:

- Review of relevant legislation and policy
- Identification of the relevant ambient air quality goals
- Discussion of local meteorology and climate conditions based on available Bureau of Meteorology (BoM) and Queensland (QLD) Department of Environment and Science (DES) monitoring data
- Discussion of existing air quality based on available DES monitoring data
- Identification of potential sources of air emissions from surrounding land uses
- A qualitative risk assessment of emissions during the construction phase
- A quantitative dispersion modelling assessment of operational phase emissions considering peak and typical train movements for the year 2040
- Identification of mitigation measures
- Assessment of the residual impact with the inclusion of the identified mitigation measures.

The air quality impact assessment has been prepared with consideration given to the following guidelines:

- ‘Application requirements for activities with impacts to air’, guideline document under the *Environmental Protection Act 1994* (Qld) (EP Act) to support applications for activities with impacts to air (DES 2019b)
- ‘Approved methods for the modelling and assessment of air pollutants in New South Wales’, which provides statutory methods for modelling and assessing emissions of air pollutants in New South Wales (NSW) (EPA 2016)
- ‘Generic guidance and optimum model settings for the CALPUFF modelling system for inclusion into the “Approved methods for the modelling and assessments of air pollutants in NSW, Australia”’ (Barclay & Scire 2011)
- ‘Guidance on the assessment of dust from demolition and construction’, UK Institute of Air Quality Management (UK IAQM) (UK IAQM 2014). This document provides a qualitative risk assessment process for the potential impact of dust generated from demolition, earthmoving, and construction activities.



Map by: MF/MEF Z:\GIS\GIS_3400_C2K\Tasks\340-EAP-201910013082_Air_Quality_figures\Fig\A3_Fig1_1_C2K_StudyArea_v5.mxd Date: 25/02/2020 13:38

Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Tunnel
- Watercourses
- Air quality study area
- Local Government Areas

A3 scale: 1:175,000

0 1 2 3 4 5km

Future Freight
Integrating Community, Environment and Engineering

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Calvert to Kagaru

Figure 1.1: C2K project overview

1.2 Assessment purpose

This technical report will accompany the EIS for the Project and focuses on the air quality impact assessment requirements of the ToR which are detailed in Table 1.1. A complete list of the ToR requirements and corresponding sections of the EIS where each of the ToR is addressed is contained Appendix B: Terms of Reference Compliance Table of the EIS.

Table 1.1 Terms of Reference compliance table for air quality

ToR section	Requirement	Report section
Existing environment		
11.128	Describe the existing air quality that may be affected by the project in the context of environmental values.	Sections 2.4 and 5
11.129	Discuss the existing local and regional air shed environment.	Section 5
11.130	Provide baseline data on local meteorology and ambient levels of pollutants for modelling of air quality. Parameters should include air temperature, wind speed and directions, atmospheric stability, mixing depth and other parameters necessary for input to the model.	Section 5
11.131	The assessment of environmental values must describe and map at a suitable scale the location of all sensitive air receptors adjacent to all project components. An estimate of typical background air quality levels should be based on surveys at representative sites where data from existing DEHP monitoring stations cannot be reliably extrapolated.	Section 4 and Appendix G
Impact assessment		
11.132	Describe the characteristics of any contaminants or materials that may be released as a result of the construction or operations of the project, including point source and fugitive emissions. Emissions (point source and fugitive) during construction, commissioning and operations are to be listed.	Section 2.4
11.133	The relevant air quality goals or objectives that will be adopted for the assessment should be clearly outlined as a basis of the assessment of impacts on air.	Section 3.6
11.134	The assessment of impacts on air will be in accordance with the EP Act, EP Regulation and EPP (Air) 2008 and reference to appropriate Australian Standards.	Sections 3 and 4
11.135	Predict the impacts of the releases from the activity on environmental values of the receiving environment using recognised quality assured methods. The description of impacts should take into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts. The impact prediction must:	Sections 6, 7, 8 and 10
	(a) address residual impacts on the environmental values (including appropriate indicators and air quality objectives) of the air receiving environment, with reference to the air environment at sensitive receptors. This should include all relevant values potentially impacted by the activity, under the EP Act, EP Regulation and EPP (Air)	Section 10
	(b) address the cumulative impact of the release with other known releases of contaminants, materials or wastes associated with existing major projects and/or developments and those which are progressing through planning and approval processes and public information is available	Section 8
	(c) include modelling of dust deposition rates and air pollutant concentrations on surfaces that lead to potable water tanks in the vicinity of the project. This modelling is to be in accordance with the Australian Drinking Water Guidelines (Australian Government 2011, updated October 2017).	Sections 4 and 7.2

ToR section	Requirement	Report section
	(d) predict the human health risk, including impacts from possible air pollutant concentrations on surfaces that may lead to potable water tanks, and amenity impacts associated with emissions from the project for all contaminants covered by the National Environmental Protection (Ambient Air Quality) Measure or the EPP (Air).	Sections 6 and 7
Mitigation measures		
11.136	Describe the proposed mitigation measures to manage impacts to air quality, including potential impacts from coal trains and the predicted level of effectiveness.	Section 9
11.137	Describe how the proposed activity will be consistent with best practice environmental management. Where a government plan is relevant to the activity or site where the activity is proposed, describe the activity's consistency with that plan.	Section 9
11.138	Describe any expected exceedances of air quality goals or criteria following the provision and/or application of mitigation measures, and how any residual impacts would be addressed.	Sections 6, 7, 9 and 10
11.139	Describe how the achievement of the objectives would be monitored, audited and reported and how corrective actions would be managed.	Section 9.4

2 Project description

2.1 Overview

The Project consists of approximately 53 km of new railway, four crossing loops, and a tunnel approximately 1,015 metres (m) long through the Teviot Range.

The key components of the Project include:

- Single track dual gauge rail line with four crossing loops to ultimately accommodate trains up to 3,600 m long based on business needs, but initially constructed for 1,800 m long train sets
- The approximately 1,015 m tunnel through the Teviot Range, and bridges to accommodate topography and crossings of waterways and other infrastructure
- Tie-ins to the existing West Moreton Railway Line at the western Project boundary near Calvert
- Allowance for a future connection to the Ebenezer Industrial Area at Willowbank
- The construction of associated rail infrastructure including maintenance sidings and signalling infrastructure to support the Advanced Train Management Systems
- Rail crossings including level crossings, grade separations/ road overbridges, occupational/private crossings, fauna crossing structures
- Tie-ins to the existing operational Sydney to Brisbane interstate railway line at Kagaru
- Significant embankments and cuttings will be required along the length of the alignment
- Ancillary works including road and public utility crossings ad realignments, signage and fencing and provision of services within the corridor (excluding those undertaken as enabling works)
- Construction workspace and access roads.

The land requirement for the Project will comprise a corridor with minimum width of 40 m, widened to accommodate earthworks, drainage structures, rail infrastructure, access tracks and fencing. The corridor will be of sufficient width to accommodate the infrastructure currently proposed for construction, as well as future expansion, including possible future requirement for 3,600 m trains.

Although ARTC are applying for approval to build infrastructure to accommodate trains up to 1,800 m in length. ARTC intend to acquire the land for the future 3,600 m crossing loop extension with the initial land acquisition. The approval for the construction of future 3,600 m crossing loops will be subject to separate approval applications in the future. This assessment has been undertaken for 1,800 m long train sets, 3,600 m long train sets have not been considered in the assessment.

Subject to approval of the Project, construction of the Project is planned to start in 2021 and operation is expected to commence in 2026.

2.2 Construction

Construction work will typically be undertaken during the following primary Project construction hours:

- Monday to Friday 6.30 am to 6.00 pm
- Saturday 6.30 am to 1.00 pm
- No work Sundays and public holidays.

Track possessions, when the construction contractor has control over an operating railway, will proceed on a 7 day/24-hour period. Track possession of Queensland Rail (QR) assets will generally be allocated over weekend periods, with extended track possession occurring over holiday periods.

Works outside of primary Project construction hours may occur throughout the duration of the construction program and will involve:

- Delivery of concrete, steel, and other construction materials delivered to site by heavy vehicles
- Movements of heavy plant and materials
- Spoil haulage
- Tunnelling activities
- Arrival and departure of construction staff during shift change-overs
- Roadworks to arterial roads
- Traffic control crews, including large truck mounted crash attenuator vehicles, medium rigid vehicles, and lighting towers
- Incident response including tow-trucks for light, medium, and heavy vehicles.

For the purposes of the air quality assessment, it has been assumed that the following activities will occur during the construction of the Project:

- Site offices, batching plants and welding
- Site preparation including site clearance, establishment of site compounds and facilities, installation of temporary and permanent fencing, installation of drainage and water management controls and construction of site access including temporary haul roads
- Civil works including bulk earthworks, construction of cuts and embankments, construction of tunnel portals and tunnel, installation of permanent drainage controls, bridge and watercourse crossing construction
- Track works including the installation of ballast, sleepers, rails and flash butt welding
- Rail systems infrastructure and wayside equipment including signals, turnouts and asset monitoring infrastructure
- Commissioning, integration testing and handover process to achieve operational readiness
- Tunnel excavation by roadheader or drill and blast method.

2.3 Operation

The train and wagon information presented in this section has been used as the basis for the impact assessment.

It is estimated that in 2026 typical operation of the Project will involve approximately 226 trains per week (33 trains per day) with volumes increasing in future years. The assessment of operational impacts (including commissioning activities) has considered both peak and typical train volumes for the year 2040. The forecast peak train volume for 2040 is 418 trains per week (60 trains per day), as shown in Table 2.1. The forecast typical train volume for 2040 is anticipated to 78.4 per cent of the peak volume, with an equal reduction (21.6 per cent reduction) across each train type, resulting in approximately 328 trains per week (47 trains per day) for the typical scenario.

Table 2.1 Weekly train movements by service

Train type/description	Volume of trains/week		Locomotive type				End destination	
	Peak	Typical[a]	NR Class	SCT Class	Class 82	PR22L	Acacia Ridge	Bromelton
MB Express (Bromelton)	14	12	x	-	-	-	-	O
MB Express (Acacia Ridge)	14	11	x	-	-	-	O	-
MB Superfreighter (Bromelton)	40	31	-	x	-	-	-	O

Train type/description	Volume of trains/week		Locomotive type				End destination	
	Peak	Typical[a]	NR Class	SCT Class	Class 82	PR22L	Acacia Ridge	Bromelton
MB Superfreighter (Acacia Ridge)	8	6	-	x	-	-	O	-
GB Superfreighter (Bromelton)	22	17	-	x	-	-	-	O
GB Superfreighter (Acacia Ridge)	10	8	-	x	-	-	O	-
New Acland Coal[b]	56	44	-	-	-	x	O	-
Cameby Downs/Rywung Coal[b]	56	44	-	-	-	x	O	-
Kogan Creek Coal[b]	42	33	-	-	-	x	O	-
Wilkie Creek Coal[b]	28	22	-	-	-	x	O	-
Ipswich Coal[b]	14	11	-	-	-	x	O	-
Narrabri – PoB Grain	24	19	-	-	x	-	O	-
Yelarbon – PoB Grain	24	19	-	-	x	-	O	-
Oakey – PoB Grain[b]	24	19	-	-	x	-	O	-
Narrabri – PoB Export Cont	12	9	-	-	x	-	O	-
Yelarbon – PoB Cotton	6	5	-	-	x	-	O	-
Toowoomba Export Containers[b]	12	9	-	-	-	x	O	-
Westlander[b]	0	0	-	-	-	-	-	-
Oakey – Rosewood Livestock[b]	0	0	-	-	-	-	-	-
Ebenzer IMEX	12	9	-	-	x	-	O	-
Total	418	328						

Table notes:

a Typical train traffic volumes are estimated to be 78.4 per cent of the peak values presented above, with an equal reduction across each train type.

b Indicates that this train service is an existing service which currently uses the QR rail line.

"**X**" Indicates that this locomotive operates the listed train type,

"-" Indicates that this locomotive is not on this train type.

"**O**" Indicates the end destination for each train, being either Acacia Ridge or Bromelton

Emission factors for the locomotives have been adopted from the United States Environmental Protection Agency (US EPA 2009) and the European Monitoring and Evaluation Program/European Environment Agency (EMEP/EEA 2016a).The US EPA emission factors are provided as tiers (Tier 0 to Tier 5). The tiers are based on the year of manufacture of the locomotive and the emission rate for different pollutants, with emissions decreasing as the tier increases (e.g. a Tier 1 locomotive has higher emission rates than a Tier 2 locomotive). Similarly to the USEPA tiers, the EMEP/EEA emission factors are provided as emission stages, with higher stages corresponding to newer engines and lower emissions.

The locomotives modelled in the assessment (refer Table 2.2) comply with the emission specifications for US EPA Tier 0 and Tier 1, and EEA Stage IIIa, and the emission factors for these classes have been used in the assessment. The US EPA and EEA emission factors are the most accurate source of available emissions data for the locomotives and are considered appropriate for use in the assessment.

Table 2.2 Locomotive specifications

Feature	NR Class	SCT/LDP	Class 82	EMD22L (formally PR22L)
Manufacturer	UGL/GE	Downer EDI	Downer EDI/EMD	EMD
Prime mover	7FDL16	GTA46C-ACe	12-710G3AJWC	Caterpillar 3512C-HD
US EPA or EEA Emissions Standard	Tier 0	Tier 1	Tier 0	EURO Stage IIIa
Rated maximum power (kW)	2,917	3,350	2,425	1,640

Table 2.3 presents locomotive data used in the assessment for the train types proposed in the Project.

Table 2.3 Locomotive data

Train description	Locomotives[a]	Maximum wagons length (m)	Maximum rail speed (km/hr)	Modelled average rail speed (km/hr)[b]	Locomotive height (m)	Wagon height (m)
Express freight	NR Class (3)	1,750	115	86	4.24	6.8
Super freighter	SCT Class (2)	1,750	115	86	4.24	5.925
Grain, cotton, and livestock	Class 82 & 2300 Class (2, 3)[c.]	1,750	80	60	-[d.]	-[d.]
Coal	PR22L (3)	990	100/80[e.]	75/60[e.]	3.87	3.95

Table notes:

a Number in brackets indicates the number of locomotives per train
b Calculated assuming 75 per cent of journey time at maximum speed, 25 per cent of journey time is idling.
c Locomotive configuration dependant on wagon payload
d No information was available for this item for this locomotive
e Varies depending on direction of travel

2.3.1 Tunnel infrastructure

To pass through the Teviot Range the proposed Teviot Range Tunnel will be constructed as part of the Project. The location of the tunnel is shown in Figure 1.1. For typical operations, the tunnel will be naturally ventilated with train emissions exiting the portals as no ventilation stack outlet is planned. The tunnel will have internal jet fans approximately 150 m inside the portal that will provide forced ventilation for maintenance activities only.

The following information was utilised in the assessment:

- Western tunnel entrance – chainage 39.855 km
- Eastern tunnel entrance – chainage 40.870 km
- Tunnel length – 1,015 m
- Internal tunnel cross sectional area – 100 m^2.

2.3.2 Crossing loops

Four new crossing loops are proposed for the Project. The loops are to be constructed as new sections of track parallel to the existing track. They range in length to accommodate the surrounding area and topography, and ultimately accommodate trains of up to 3,600 m in length based on business needs, but initially constructed for 1,800 m long train sets. The approval for the construction of future 3,600 m crossing loops will be subject to separate approval applications in the future.

Table 2.4 presents the crossing loop start and end chainage locations.

Table 2.4 Crossing loop chainage locations

Crossing loop	Phase	Start chainage (km)	End chainage (km)
Ebenezer	Initial	9.242	11.624
Purga Creek	Initial	22.500	24.700
Washpool Creek	Initial	35.550	37.750
Undullah	Initial	45.730	47.930

2.4 Project air emissions

Pollutants of potential concern to the Project have been identified through a review of:

- Expected activities
- Applicable National Pollution Inventory (NPI) emission estimation manuals
- International emissions estimation guidelines
- EIS literature for similar rail projects.

During the construction phase, particulate matter deposited as total suspended particulates (TSP) and airborne concentrations of particulate matter less than 10 micrometres in diameter (PM_{10}) will be of primary concern. These pollutants have the potential for nuisance impacts if not correctly managed (UK IAQM 2014).

Particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) is typically emitted in minor quantities from mechanical sources, and is more predominant from combustion sources (i.e. combustion engines). Emissions of combustion gases (e.g. oxides of nitrogen (NO_x) and carbon monoxide (CO)) and $PM_{2.5}$ from diesel construction vehicles and mobile plant will be significantly lower than particulate emissions from construction activities. Emissions of combustion gases and $PM_{2.5}$ are considered unlikely to result in exceedance of air quality goals or cause nuisance to sensitive receptors and therefore have not been assessed for the construction phase.

In addition to construction dust, odour and volatile organic compounds (VOCs) will be emitted as fugitive emissions from fuel tanks located at laydown areas.

The primary source of air pollution during the operation of the Project will be locomotive engine exhaust. The gaseous pollutants contained in the exhaust are produced as a product of diesel combustion and include NO_x, PM_{10}, $PM_{2.5}$, VOCs, and polycyclic aromatic hydrocarbons (PAHs).

In addition to diesel combustion, fugitive coal dust emissions (TSP, PM_{10}, $PM_{2.5}$ and dust deposition) are also considered to have the potential to impact sensitive receptors and have been assessed for the operation phase.

A brief discussion regarding these pollutants and their potential effects on health and the environmental values follows. Note that in addition to the pollutants assessed in this assessment, discussion of other pollutants not considered in detail (due to their low expected emissions) have also been provided in this section. The information presented in this section has been acquired from the NPI website (Department of the Environment, Water, Heritage and the Arts, Australian Government 2019) and the NSW Department of Planning, Industry and Environment website (NSW Department of Planning, Industry and Environment 2019).

2.4.1 Particulate matter

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. TSP refer to airborne particles, generally up to 100 micrometres (μm) in diameter. TSP is primarily associated with aesthetic impacts associated with coarse particles settling on surfaces, which also causes deposition and discolouration. These large particles can, however, cause some irritation of mucosal membranes, which pose a greater risk to health when ingested if they are contaminated. Particles with diameters less than or equal to 10 μm (known as PM_{10}) can be created through crushing and grinding of rocks and soil, and typically comprise soot, dirt, mould and pollen. These particles tend to remain suspended in the air for longer periods than larger particles (minutes or hours), and can penetrate into human lungs. Fine particulates (those with diameters less than or equal to 2.5 μm, known as $PM_{2.5}$) are typically generated from vehicle exhaust, bushfires, and some industrial activities and can remain suspended in the air for days or weeks. As these fine particulates can travel further into human lungs than the larger particulates and are often made up of heavy metals and carcinogens, fine particulates are considered to pose a greater risk to health.

Exposure to particulate matter has been linked to a variety of adverse health effects, with epidemiological research suggesting that there is no threshold at which health effects do not occur. Factors that influence the health effects related to exposure include the mass concentration, the size of the particles and the duration of exposure (e.g. short or long term). Short-term or acute health effects include respiratory problems such as coughing, aggravated asthma and acute bronchitis, with long term or chronic effects including lung damage and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from inhalation of the dust.

In addition to the respiratory health impacts from fine particulate matter suspended in air, dust can cause nuisance impacts by settling on surfaces and possessions. Dust deposition is the result of suspended particles settling out of suspension. Dust deposition is a common cause of complaints, particularly due to staining of clothes (hanging on washing lines) and deposition on vehicles and window sills. Deposition on surfaces that feed into water storage can also result in contamination of potable water supplies.

For large sources or intensive activities generated dust can affect visibility. There are methods to measure and assess visibility, including the Ringelmann scale developed in 1987. Plume visibility is not assessed in detail in this assessment as it is expected that industry standard mitigation measures will prevent significant visibility impacts occurring.

The nature of the emissions from the coal wagons (laden and unladen) is fugitive i.e. the emissions are not released through an easily quantifiable source, such as a vent or stack. The primary mechanism for coal dust lift-off from coal wagons is the movement of air over uncovered laden wagons. Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains (Connell Hatch 2008) explains that airflow across the wagon can move particles by three transport modes: suspension, saltation and surface creep, described as follows:

- Suspension: particles that are less than 75 µm in size (TSP, PM_{10} and $PM_{2.5}$) are small enough to become suspended in the airflow and transported off the wagon
- Saltation: particles from 75 to 500 µm in size (TSP) move and bounce in the layer close to the interface between the coal surface and the flow of air
- Surface creep: particles from 500 to 1000 µm in size move by surface creep propelled by wind and the impact of particles moving by saltation.

Connell Hatch (2008) state that PM_{10} is generally found to 50 per cent of TSP, but no composition percentage is provided for $PM_{2.5}$. Further discussion on the estimation of $PM_{2.5}$ composition is provided in Section 4.4.1.

Particulate emissions from coal trains travelling along the alignment have been included in the assessment. In comparison to train travel, fugitive particulate emissions from coal trains stopped at crossing loops will be negligible due to the reduced wind speed and have not been assessed in detail.

2.4.2 Nitrogen oxides

Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide (NO). The mixture of these two gases (and some other minor nitrogen and oxygen gas mixtures) is commonly referred to as nitrogen oxides, or NO_x. Nitrogen oxides are a product of combustion processes. In urban areas, motor vehicles and industrial combustion processes are the major sources of ambient nitrogen oxides.

Short term exposure to low levels of NO_2 can irritate the eyes, nose, throat and lungs, possibly leading to coughing, shortness of breath, tiredness and nausea. Short term exposure to high levels of NO_2 can cause rapid burning, spasms and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, and build-up of fluid in the lungs. Long-term exposure to high levels of NO_2 can cause chronic health effects including lung disease.

Sensitive populations, such as the elderly, children, and people with pre-existing health conditions are most susceptible to the adverse effects of NO_2 exposure. Long term exposure to NO_2 can also cause damage to plants, especially in the presence of other pollutants such as ozone and SO_2. Nitrogen oxides are also primary ingredients in the reactions that lead to photochemical smog formation.

2.4.3 Carbon monoxide

CO is a colourless, odourless gas produced by the incomplete combustion of fuels containing carbon (e.g. oil, gas, coal and wood). CO is absorbed through the lungs of humans, where it reacts to reduce the blood's oxygen-carrying capacity. In urban areas, motor vehicles account for up to 90 per cent of all CO emissions.

Short term inhalation of relatively low levels of CO (200 ppm for 2 to 3 hours) can cause headaches, dizziness, light-headedness and fatigue. Short term exposure to higher concentrations (400 ppm) of carbon monoxide can cause sleepiness, hallucinations, convulsions, collapse, loss of consciousness and death. Long term exposure to low levels of CO can result in heart disease and damage to the nervous system, whilst long term exposure of pregnant women to CO may result in low birth weights and other birth defects.

Concentrations of CO normally present in the atmosphere are unlikely to cause ill effects and therefore have not been considered in the assessment.

2.4.4 Sulphur dioxide

SO_2 is a colourless gas with a sharp, irritating odour. It is formed in combustion processes through burning fossil fuels containing sulphur. SO_2 may be oxidised in the atmosphere to form sulfuric acid, which contributes to acid rain.

SO_2 is also an irritant gas that can cause respiratory tract infections. People with pre-existing respiratory conditions such as asthma are most sensitive to SO_2 exposure. The simultaneous presence of airborne particulate matter can compound these effects. SO_2 and its aerosols can also damage vegetation and some materials.

SO_2 in low concentrations is a common pollutant in cities and some industrial environments. Higher exposure to SO_2 is typically limited to workplace environments where it is produced as a by-product. Short term exposure (5 to 15 minutes) to concentrations of 10 to 50 ppm causes irritation of the eyes, nose and throat, choking and coughing.

The study assumes low sulphur content fuel as per the requirements of Australian federal legislation (DEE, Fuel Quality Standards Act 2000 2000) (DEE, Fuel Standard (Automotive Diesel) Determination 2001, 2001). The regulation of low sulphur content fuel in Australia has significantly decreased the generation and concentrations of SO_2 near transport sources and concentrations are typically well below the relevant air quality goals. Due to the low likelihood of significant impact, SO_2 has not been considered in this assessment.

2.4.5 Volatile organic compounds

Organic compounds with a vapour pressure at 20°C exceeding 0.13 kilopascals are referred to as volatile organic compounds (VOCs). VOCs can be a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation, and respiratory problems. VOCs are commonly emitted from vehicle exhausts. Three primary VOCs (benzene, toluene and xylenes) are components of petroleum and diesel fuel and are typically the focus for assessments of engine combustion emissions.

2.4.5.1 Benzene

Benzene is an airborne substance that is a precursor to photochemical smog. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure result from car exhausts. Benzene is a toxic health hazard and a known carcinogen. It has high acute toxic effects on aquatic life and long-term effects on marine life. It can cause death in plants and roots and damage to the leaves of many agricultural crops, however normal environmental concentrations of benzene are unlikely to damage plants (Scottish Environment Protection Agency 2016). Human exposure to very high levels for even brief periods of time can potentially result in death, while lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, damage to the immune system, leukaemia and birth defects.

2.4.5.2 Toluene

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. Due to relatively fast degradation, toluene emissions are usually confined to the local area in which it is emitted. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions. The substance can cause membrane damage in plant leaves, and is moderately toxic to aquatic life with long-term exposure.

2.4.5.3 Xylenes

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing.

Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. High-level exposure can cause death. The substances have high acute and chronic toxicity to aquatic life and can adversely affect crops.

2.4.6 Polycyclic aromatic hydrocarbons

PAHs are a group of over 100 chemicals, which are formed through the incomplete combustion of organic materials, such as petrol. Exposure to these chemicals can cause a range of adverse reactions, including irritation of the eyes, nose and throat and skin. Exposure to very high levels can result in symptoms such as headaches, nausea, damage to the liver and kidneys, and damage to red blood cells. Some PAHs are declared to be probable or possible carcinogens to humans by the International Agency for Research on Cancer (IARC).

PAHs can vaporise or attach to dust particles and be transported through the air. The compounds commonly break down over days or weeks through chemical reactions in the atmosphere, others can persist for longer periods.

PAHs are moderately or highly acutely toxic to birds and aquatic organisms and moderately/highly chronic toxicity to aquatic life. Some of these compounds are known to cause damage and death to crops. PAHs can bioaccumulate and are moderately persistent in the environment.

2.4.7 Dioxins

Dioxins form part of a group of chemicals known as persistent organic compounds, which are of concern due to their highly toxic potential. Exposure in the long terms can cause cancer, and impairment of the endocrine, immune, and reproductive systems. Dioxins can bioaccumulate within animals in the environment and tends to accumulate in fat.

Emissions of dioxins will occur as a result of fuel combustion in trains, motor vehicles and mobile plant. An inventory of dioxin emission sources in Australia in 2002 was prepared by the Department of the Environment and Heritage (DEH 2004). The inventory determined that transport was a minor source of dioxins, contributing less than 2 per cent of total emissions.

Based on the rural location of the Project it is expected that existing background concentrations of dioxins will be low, and therefore a background concentration of zero has been assumed for the assessment. It is considered unlikely that emissions from the Project have the potential to result in significant impacts or exceedance of the relevant air quality goals for dioxins.

2.4.8 Trace metals

Heavy metals such as cadmium, lead, and mercury are common air pollutants that are typically emitted from industrial activities and fuel combustion. Exposure to heavy metals can result in a range of health impacts, including kidney and bone damage, developmental and neurobehavioral disorders, elevated blood pressure and potentially even lung cancer.

Long-term exposures to cadmium can cause anaemia, fatigue and loss of the sense of smell. Short term high exposures to cadmium can cause rapid lung damage, shortness of breath, chest pain, and a build-up of fluid in the lungs. Cadmium is a 'probable carcinogen'.

Lead can affect a wide variety of organs in the body, but mostly affects the nervous system. Exposure to lead may also cause paralysis in fingers, wrists or ankles and can cause small increases in blood pressure and may cause anaemia, malnutrition, abdominal pain and colic. High levels of lead can severely damage the brain and kidneys in adults and may cause death.

Exposure to high levels of any types of mercury can permanently damage the brain, kidneys, and developing foetus. Effects on brain functions may result in irritability, shyness, tremors, changes in vision or hearing and memory problems. High exposures of mercury vapour may cause chest pain, shortness of breath, and a build-up of fluids in the lungs that can be fatal.

Very minor emissions of trace metals will occur as a result of fuel combustion in trains, motor vehicles and mobile plant. As such, cumulative concentrations of trace metals at sensitive locations are expected to be well below relevant air quality goals and are not expected to cause a significant impact.

2.4.9 Ozone

Ozone is not emitted directly from fuel combustion, but rather is a secondary pollutant formed via chemical reaction of other pollutant species (primarily NO_X and VOCs) in the local atmosphere.

Ozone is a short-term lung irritant, affects lung function and can worsen asthma. Short term exposure to ozone can cause difficulty in breathing, coughing, and throat irritation if exercising outdoors when ozone levels are high.

Assessment of the formation of ozone and other secondary pollutants has not been considered in this assessment.

2.4.10 Odour

Odour emissions can be either a single compound or a mixture of compounds that have the potential to affect environmental amenity and cause nuisance. Potential sources of odour from the Project include wastewater odour and odour from fuel storage tanks.

Portable toilet facilities will be located along the alignment during construction for workers. A suitably qualified contractor will be engaged for the removal and transport of the sewage to an approved off-site treatment facility. Odour impacts from portable toilet facilities are not expected to be significant and have not been considered further.

Odour emissions from fuel storage tanks are discussed specifically in Section 6.2.

3 Relevant legislation

The relevant legislation and policy instruments considered in the assessment of air quality includes:

- *Environmental Protection Act* 1994 (Qld) (EP Act)
- Environmental Protection Regulation 2019 (Qld) (EP Regulation)
- Environmental Protection (Air) Policy 2019 (Qld) (EPP (Air))
- National Environment Protection (Ambient Air Quality) Measure 2016 (Air Quality NEPM)
- National Environment Protection (Air Toxics) Measure 2011 (Air Toxics NEPM)
- Australian Drinking Water Guidelines 2011 (Updated October 2017)
- Application requirements for activities with impacts to air ESR/2015/1839 (Department of Environment and Science 2019b)
- Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure Version 2 2013.

3.1 Environmental Protection Act 1994 and Environment Protection Regulation 2019

The EP Act is intended to protect QLD's environment while allowing for development that improves total quality of life, now and in the future, by encouraging ecologically sustainable development. There are several policies under the EP Act that govern the requirement for management of some environmental issues such as noise, air and water. The EP Act regulates environmentally relevant activities (ERA) under the EP Regulation, with some of these activities requiring an environmental authority to operate. The EP Act also outlines primary duties which are applicable to everyone in QLD, including general environmental duty, which states that "*a person must not carry out any activity that causes or is likely to cause environmental harm, unless measures to prevent or minimise the harm have been taken*".

There are several policies under the EP Act that govern the requirement for management of environmental issues such as noise, air and water. These policies determine goals to be achieved in various environments with reference to sensitive receptors. One of these, the EPP (Air) must be considered for the air quality impact assessment.

3.2 Environmental Protection (Air) Policy 2019

The EPP (Air) was prepared by the QLD Government with the purpose to achieve the object of the EP Act in relation to the air environment. Air quality objectives are provided in the EPP (Air) as indicators for identifying environmental values of the air environment that are enhanced or protected. It does not apply to workplaces and the air quality objectives set out in the EPP (Air) are intended to be progressively achieved over the long term. A summary of the air quality objectives relevant to the Project is provided in Table 3.1.

The EPP (Air) recommends different strategies to control emissions for different types of activities, including:

- Identifying environmental values to be enhanced or protected
- Stating indicators and air quality objectives for enhancing or protecting the environmental values
- Providing a framework for making consistent, equitable and informed decisions about the air environment.

The environmental values to be enhanced or protected under the EPP (Air) are:

- The qualities of the air environment that are conducive to protecting the **health and biodiversity of ecosystems**; and
- The qualities of the air environment that are conducive to **human health and wellbeing**; and

- The qualities of the air environment that are conducive to protecting the **aesthetics of the environment**, including the appearance of buildings, structures and other property; and
- The qualities of the air environment that are conducive to **protecting agricultural use** of the environment.

The air quality objectives from the EPP (Air) (discussed in Section 3.6) have been used to assess the impact of the Project on environmental values of the air environment.

3.3 National Environment Protection (Ambient Air Quality) Measure and National Environment Protection (Air Toxics) Measure

NEPM are broad framework-setting statutory instruments that outline agreed national objectives for protecting or managing particular aspects of the environment. The air quality of an environment is protected by the Ambient Air Quality NEPM as amended in 2015.The Ambient Air Quality NEPM provides guidance relating to air in the external environment and does not include air inside buildings or structures.

The Ambient Air Quality NEPM outlines monitoring, assessment and reporting procedures for the following pollutants:

- PM_{10}
- $PM_{2.5}$
- Nitrogen dioxide
- Carbon monoxide
- Ozone
- Sulphur dioxide.

In addition to the Ambient Air Quality NEPM, the Air Toxics NEPM provides a framework for monitoring, assessing and reporting on ambient levels of air toxics. The purpose of the this NEPM is to collect information to facilitate the development of standards for ambient air toxics.

The Air Toxics NEPM includes monitoring investigation levels for use in assessing the significance of monitored levels of air toxics with respect to human health. The monitoring investigation levels are levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short term, it does not mean that adverse health effects automatically occur; rather some form of further investigation by the relevant jurisdiction of the cause of the exceedance is required.

The Ambient Air Quality NEPM and Air Toxics NEPM standards are intended to be applied to air quality experienced by the general population in a region and not to air quality in areas in the region affected by localised air emissions, such as individual industrial sources or projects.

The goal of the Ambient Air Quality NEPM and Air Toxics NEPM is to achieve the recommended standards with the allowable exceedances, as assessed in accordance with the associated monitoring. The standards were set at a level intended to adequately protect human health and wellbeing. The standards in the Ambient Air Quality NEPM and Air Toxics NEPM relevant to the Project correspond to the EPP (Air) objectives protecting the health and wellbeing environmental values. The Ambient Air Quality NEPM standards relevant to the Project are consequently addressed in the air quality objectives in the EPP (Air).

3.4 Nuisance dust guideline

The deposition of larger dust particles can commonly cause nuisance in residential areas. Although no dust deposition objectives are prescribed in the EPP (Air), DES commonly set a guidance deposition rate of 120.0 milligrams per square metre per day (mg/m²/day) averaged over 1 month for environmental authorities based on research into community complaints for coal related projects. Although this deposition limit is not a legislative requirement, it is frequently used in QLD (DES 2019b) and is considered to be an appropriate criterion. For the purposes of the Air Quality Impact Assessment (AQIA) this recommended dust deposition goal has been adopted.

3.5 Other guidelines

Not all compounds of interest are detailed in the aforementioned legislation or guidelines. Other sources have been utilised to provide air quality criteria, which include the following:

- Brisbane City Council (BCC) Air Quality Planning Scheme Policy (AQPSP) (BCC 2014)
- NSW EPA Approved methods for the modelling and assessment of air pollutants in New South Wales (EPA 2016).

In addition to the above, the Environment Protection Authority Victoria (VIC EPA) guideline Recommended separation distances for industrial residual air emissions (2013) has been considered in the assessment.

3.6 Air quality goals

The air quality goals and guidelines values shown in Table 3.1 have been adopted as the air quality goals for the Project. Where air quality goals for identified pollutants are not listed within the EPP (Air) and NEPM legislation, criteria have been sourced from the NSW EPA Approved methods for modelling and assessment of air pollutants in New South Wales (EPA 2016) and the BCC AQPSP (BCC 2014).

The air quality goals in Table 3.1 have designated averaging periods. Some pollutants have goals expressed as annual average concentrations due to the chronic way in which they affect health or the natural environment (i.e. effects occur (long-term) after a prolonged period of exposure to elevated concentrations) and others have goals expressed as 24 hour, 1 hour or 30 minute average concentrations (short-term) due to the acute way in which they affect health or the natural environment (i.e. after a relatively short period of exposure). Some pollutants have standards expressed in terms of both long-term and short-term concentrations.

The dust deposition goal shown in Table 3.1 is a daily deposition average (120 mg/m^2/day), calculated using the deposition level predicted at a modelled receptor over an averaging period of one month.

The air quality goals presented in Table 3.1 are ambient air quality goals and require consideration of existing background air quality in addition to contributions from the Project.

The environmental values listed in Section 3.2, that are being protected by each proposed air quality goal is listed for objectives from the EPP (Air) Policy and the NEPM legislation. The environmental values protected through meeting these air quality goals include the following:

- Health and well being
- Protecting the aesthetic environment.

The EPP (Air) also includes air quality goals to protect the environmental values of the health and biodiversity of ecosystems and to protect agriculture. Pollutants which have goals to protect the health and biodiversity of ecosystems include fluoride, NO_2, ozone and SO_2. Fluoride, ozone and SO_2 also have goals to protect agriculture.

Fluoride, ozone and SO_2 are not pollutants of concern for the assessment (refer Section 2.4) and therefore the impact of these pollutants on the health and biodiversity of ecosystems and on agriculture does not require consideration. The EPP (Air) Policy does have a NO_2 air quality objective for the health and biodiversity of ecosystems. However, there are no World Heritage Areas or areas protected under the *Nature Conservation Act 1992* (Qld) or the *Marine Parks Act 2004* (Qld) located within one kilometre of the alignment, and therefore the impact of NO_2 on the health and biodiversity of ecosystems does not require consideration.

As required by the ToR for the Project (refer Section 1.2) and as typically necessary for air quality impact assessments, a cumulative impact assessment has been undertaken. Cumulative impacts have been assessed through consideration of background air quality which includes non-Project emission sources. Discussion of background air quality and non-Project emission sources is provided in Section 5.2.

Table 3.1 Project air quality goals

Pollutant	Air quality goal (µg/m^3)	Averaging period	Environmental values	Source
NO_2	250	1 hour[a]	Health and wellbeing	EPP (Air)
	62	Annual	Health and wellbeing	EPP (Air)
TSP	90	Annual	Health and wellbeing	EPP (Air)
PM_{10}	50	24 hours[b]	Health and wellbeing	EPP (Air)
	25	Annual	Health and wellbeing	EPP (Air)
$PM_{2.5}$	25	24 hours	Health and wellbeing	EPP (Air)
	8	Annual	Health and wellbeing	EPP (Air)
Arsenic and compounds (measured as the total metal content in PM_{10})	6 ng/m^3	Annual	Health and wellbeing	EPP (Air)
Cadmium and compounds (measured as the total metal content in PM_{10})	5 ng/m^3	Annual	Health and wellbeing	EPP (Air)
Lead and compounds (measured as the total metal content in TSP)	0.5	Annual	Health and wellbeing	EPP (Air)
Nickel and compounds (measured as the total metal content in PM_{10})	22 ng/m^3	Annual	Health and wellbeing	EPP (Air)
Chromium (III) compounds (as PM_{10})	9	1 hour	-	NSW EPA
Chromium (VI) compounds (as PM_{10})	0.1	1 hour	Screening health risk assessment	BCC AQPSP
	0.01	Annual	Screening health risk assessment	BCC AQPSP
1,3-butadiene	2.4	Annual	Health and wellbeing	EPP (Air)
Benzene	5.4	Annual	Health and wellbeing	EPP (Air)
Toluene	1,100	30 minutes	Protecting aesthetic environment	EPP (Air)
	4,100	24 hours	Health and wellbeing	EPP (Air)
	400	Annual	Health and wellbeing	EPP (Air)
Xylenes	1,200	24 hours	Health and wellbeing	EPP (Air)
	950	Annual	Health and wellbeing	EPP (Air)
Benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons)	0.3 ng/m^3	Annual	Health and wellbeing	EPP (Air)

Pollutant	Air quality goal ($\mu g/m^3$)	Averaging period	Environmental values	Source
Polychlorinated dioxins and furans	3.0×10^{-8}	Annual	Screening health risk assessment	BCC AQPSP
Dust deposition	120 mg/m^2/day	Monthly	Nuisance	DES Recommended

Table notes:

ppm	parts per million	$\mu g/m^3$	micrograms per cubic metre
ng/m^3	nanogram per cubic meter	mg/m^2/day	milligram per square metre per day

a Not to be exceeded more than one day per year

b The 2019 version of the EPP (Air) does not allow for any exceedances of the 24 hour goal for PM_{10}. The 2008 version of the EPP (Air) allowed for exceedances for five days per year and therefore air quality assessments previously considered the 6th highest PM_{10} 24 hour average. As there are no exceedances allowed in the 2019 version of the EPP (Air), the maximum predicted PM_{10} 24 hour concentration has been considered in the assessment rather than the 6th highest.

c Not legislative, but adopted for the Project. Referenced from DES Guideline: Application requirements for activities with impacts to air (DES 2019b), see Section 3.4.

4 Assessment methodology

The air quality impact assessment methodology for the construction and operation of the Project included the following key elements:

- Qualitative impact assessment for the construction phase to estimate potential air quality impacts
- Potential for commissioning phase impacts are discussed in Section 4.3
- Primarily quantitative impact assessment for the operational phase to estimate potential air quality cumulative impacts. Some minor emissions sources are assessed qualitatively
- Potential for decommissioning phase impacts are discussed in Section 4.7
- Identification of mitigation measures
- Assessment of the residual impact with the inclusion of the identified mitigation measures.

Early engagement on the draft ToR resulted in the EIS including assessment of potential pollutants in water tanks against drinking water guidelines. Dust generation during construction and operation have also been key matters raised by stakeholders and the community, which has helped to inform the development of mitigation measures for both construction and operation. This includes consideration of both onsite construction activities and the movement of construction vehicles and equipment to and within the works areas. The methodology used to assess construction and operation impacts is described in this section.

4.1 Air quality study area

For the purpose of the assessment, the air quality study area is defined as the area within 2 km either side of the alignment, which is the proposed rail centreline.

The air quality study area is located in south-east Queensland (SEQ), and spans across the Ipswich City Council, Scenic Rim Regional Council, and Logan City Council local government areas. SEQ generally experiences a sub-tropical climate with distinct wet and dry seasons.

The existing climate and meteorology of the study area is discussed in Section 5.1 with additional discussion of the meteorological data considered in the assessment included in Appendix A.

4.2 Construction phase air quality assessment

Construction emissions for large linear infrastructure projects are complex due to the number of construction activities, the distribution of sites across a large geographical area, and the transitory nature of many individual construction activities at particular locations. As such, the potential construction air quality impacts associated with the Project were assessed by describing the nature of proposed works, plant and equipment, potential emissions sources and levels. Potential impacts on surrounding sensitive receptors have been determined through a qualitative risk assessment.

The highest proportion of construction emissions results from mechanical activity, e.g. material movement or mobile equipment travel, which typically generate coarser particulate emissions (PM_{10} and TSP). Airborne PM_{10} and deposited dust (TSP) are the main pollutants of concern for construction activities and these pollutant species are the focus of the assessment for construction dust.

The assessment methodology used for construction assessment is the 2014 UK IAQM Guidance on the assessment of dust from demolition and construction (UK IAQM 2014). The IAQM process is a four-step risk based assessment of dust emissions associated with demolition, which include land clearing, earth moving and construction activities. The construction assessment steps are as follows:

- Step 1 – Screening assessment
- Step 2 – Dust risk assessment

- Step 3 – Management strategies
- Step 4 – Reassessment.

The methodology of the IAQM risk assessment procedure is tailored specifically to the assessment of emissions to air from construction activities. The IAQM risk assessment method considers the sensitivity of the air quality study area to air quality impacts based on separation distance and existing air quality, and the potential risk of adverse impacts based on the emissions magnitude of the construction activities. The IAQM method is considered the most appropriate risk assessment method for the assessment of construction impacts and has been used for the Project.

A breakdown of each step and the associated findings of the dust impact assessment are detailed in Section 6.1.

In addition to construction dust, odour and VOCs will be emitted as fugitive emissions from fuel tanks located at laydown areas. Impacts from fuel storage have been assessed in Section 6.2 following guidance from the BCC AQ Planning Scheme Policy and VIC EPA Recommended separation distances for industrial residual air emissions (2013).

Detailed dispersion modelling of construction is not typically undertaken as construction activity is difficult to forecast accurately due to the transient nature of construction work and variations to the spatial location and intensity of construction activities. The qualitative assessment method applied for the assessment of the construction phase impacts is considered appropriate for the Project and is consistent with industry standard methodology.

4.3 Commissioning phase air quality assessment

The commissioning phase of the project will involve testing and checking the rail line and communication and signalling systems to ensure that all systems and infrastructure are designed, installed and operating according to ARTC's operational requirements. All rail system commissioning activities will be undertaken in accordance with an approved Test and Commissioning Plan developed by the construction contractor and approved by ARTC.

Air emissions during the commissioning phase of the Project are anticipated to be minor and are expected to be limited to combustion engine emissions from transport vehicles and train locomotives and limited dust emissions from vehicle travel on unsealed roads.

In regards to train travel on the line, emissions from the commissioning phase of the Project will be significantly lower than emissions during the operational phase.

Air emissions from the commissioning phase of the Project are expected to be insignificant and are considered unlikely to generate nuisance or risk exceedance of the Projects air quality goals and therefore have not been assessed.

4.4 Operations phase air quality assessment

This section outlines the approach taken to the modelling and assessment of the operational air quality implications of the Project, including:

- Emissions inventory and assessment assumptions
- The dispersion modelling methodology, including the software packages and meteorological data used, the scenarios assessed and model inputs
- The air emission sources included in the modelling
- The source parameters used in the modelling
- The use of terrain and land use data

- The method applied for the conversion of NO_x to NO_2, and
- Limitations of the assessment.

Detailed discussion of the dispersion models used in the assessment is provided in Appendix B.

4.4.1 Emissions inventory

To quantify the emissions for diesel locomotives and coal wagons an emissions inventory was developed. The key pollutants of interest included in the emissions inventory for diesel locomotives and coal wagons are TSP, PM_{10}, $PM_{2.5}$ and NOx. The emissions inventory was developed using the engine types, rail traffic quantities (presented in Section 2.3) and locomotive speeds. The assessment has been undertaken for 1,800 m long train sets, 3,600 m long train sets have not been considered in the assessment.

4.4.1.1 Diesel locomotive emissions

The power rating (kW) and rated emission standard for each locomotive considered in the assessment has been provided by the Project Ventilation Design Team. Emission factors have been sourced from emissions testing completed on locomotives by the NSW EPA and rated emission standards published by the US EPA and EMEP/EEA as discussed in Section 2.3. The US EPA and EEA emission factors are the most accurate source of available emissions data for the locomotives and are considered appropriate for use in the assessment. Table 4.1 presents the referenced emissions factors on grams per kilowatt hour basis (g/kWhr).

Table 4.1 Locomotive emissions factors

Locomotive	NR Class		SCT/LDP	82 Class	PR22L
	Cycle weighted	Idling			
Locomotive Max Power (kW)	2,917		3,350	2,425	1,640
Rated Emission Standard	US EPA – Tier 0	-	US EPA – Tier 1	US EPA – Tier 0	EURO IIIA
Total Particulates (g/kWhr)	0.8	1.09	0.60	0.8	0.20
NO_x (g/kWhr)	12.74	43.7	9.92	12.74	6.00
Total Hydrocarbons (THC)[a] (g/kWhr)	1.34	4.66	0.74	1.34	0.50
Source	US EPA Emissions Limits – Line Haul Locomotives	Diesel Locomotive Fuel Efficiency and Emission Testing Report Nov 2016 by ABMARC for NSW EPA (NR121 & 93 Class)	US EPA Emissions Limits – Line Haul Locomotives		EU Emissions Standards – Nonroad Engines

Table notes:

VOCs are a subset of THC. For this assessment 100 per cent of THC emissions are assumed to be VOCs.

In diesel locomotive operation, engine power is determined by the notch setting, which ranges from notches one through eight (Spiryagin M, et al. 2016). During normal operation a diesel locomotive will progress through the notch settings to accelerate to the required rail line speeds. The locomotive would then operate at a certain notch setting that is dependent on the power output required to maintain the required rail speed.

The engine power at each notch setting differs greatly, for example, the power rating at notch eight is equivalent to 100 per cent of the maximum locomotive engine power. Whereas, at notch four the engine power would be closer to 35 per cent of maximum locomotive engine power (Spiryagin M, et al. 2015). Therefore it is important to know the power ratings and time speed at each notch setting to provide an accurate estimate of diesel locomotive emissions.

Power ratings for each notch setting for the proposed diesel locomotive engines were not available at the time of the assessment; therefore, a review of literature was completed and is summarised in Table 4.2.

Table 4.2 **Power ratings for locomotive notch settings or operating mode from various sources**

Notch setting or operating mode	**Percentage of maximum engine power**					
Source	**Spiryagin *et al.* (2016)[a]**	**Spiryagin *et al.* (2015)**	**StarCrest Consulting Group (2008)**	**Therma-Dynamics Rail LLC (2014)**	**Kim et al. (2017)**	**Casadei & Maggioni (2016)**
Idle	0.0 per cent	0.0 per cent (0 kW)	0.8 per cent (14 hp)	2.2 per cent (69 hp)	9.1 per cent (216 kW)	**2.3 per cent (74.6 bhp)**
Dynamic Braking	-	-	**3.6 per cent (67 hp)**	0.5 per cent (17 hp)	-	-
Notch 1	1.6 per cent	**4.8 per cent (133 kW)**	4.5 per cent (83 hp)	3.3 per cent (105 hp)	15.7 per cent (370 kW)	-
Notch 2	6.3 per cent	**10.7 per cent (294 kW)**	13.5 per cent (249 hp)	12.5 per cent (395 hp)	24.4 per cent (576 kW)	11.2 per cent (359 bhp)
Notch 3	14.1 per cent	**24.1 per cent (665 kW)**	26.4 per cent (487 hp)	21.7 per cent (686 hp)	34.3 per cent (810 kW)	-
Notch 4	25.0 per cent	**34.3 per cent (945 kW)**	39.9 per cent (735 hp)	32.7 per cent (1,034 hp)	46.0 per cent (1,086 kw)	33.0 per cent (1,057 bhp)
Notch 5	39.1 per cent	**45.4 per cent (1,253 kW)**	54.4 per cent (1,002 hp)	46.2 per cent (1,461 hp)	55.7 per cent (1,316 kW)	-
Notch 6	56.3 per cent	**66.0 per cent (1,820 kW)**	68.8 per cent (1,268 hp)	62.4 per cent (1,971 hp)	67.2 per cent (1,589 kW)	59.1 per cent (1,895 bhp)
Notch 7	76.6 per cent	**87.1 per cent (2,400 kW)**	85.2 per cent (1,570 hp)	84.2 per cent (2,661 hp)	83.9 per cent (1,983 kW)	-
Notch 8	100 per cent	**100 per cent (2,757 kW)**	100 per cent (1,843 hp)	100 per cent (3,159 hp)	100 per cent (2,363 kW)	100 per cent (3,206 bhp)

Table notes:

a Based upon the calculation method in Spiryagin et al. (2016) for notch power for diesel engine heavy haul operations - $P_n = (n^2/64) * P_{rated}$; Where P_n is the notch power; P_{rated} is the rated power in notch 8; and n is the discrete notch numbers, which takes a range from zero to eight.

Bold values represent adopted notch setting and operating mode percentages

Units: kW = kilowatts, hp = horsepower, bhp = brake horsepower

Spiryagin et al. (2016) provides a calculation method which follows a square-law relationship to estimate engine power at the eight engine notch settings. As an example, the Spiryagin et al. (2016) study uses engine power capabilities referenced from earlier work (Spiryagin et al. 2015) to estimate engine power. The Spiryagin et al. (2016) calculation method provides a procedure to estimate notch engine power in lieu of actual measured data. However, the calculated notch engine power is lower than all other referenced sources as shown in Table 4.2.

Notch power ratings cited by Kim et al. (2017) are greater than all other sources, especially for idling which is 9.1 per cent of maximum rated power, 3.9 times higher than the next highest idling power usage. However, the Kim et al. (2017) study investigated locomotives specific to Korea, and in combination with the relative high-power rating locomotives assessed, the results of this study were not considered suitable for the calculation of duty cycle power ratings for the Project.

Power ratings presented by Therma-Dynamics Rail LLC (2014) were lower than most sources at almost all notch settings.

The notch engine power values from Spiryagin et al. (2015) are higher than all other sources at notch seven and comparable at all other notches. The notch power ratings presented were for a line haul diesel locomotive with a total maximum power of 2,757 kW, which is similar to the engine power of the locomotives proposed for the Project. Due to the similarity in locomotive engine power, notch settings from Spiryagin et al. (2015) were used in calculating duty cycle power ratings for the Project for train travel.

For the literature reviewed, engine idling power ranged from zero per cent (Spiryagin et al. 2015) to 9.1 per cent (Kim et al. 2017). Cassadei and Maggioni (2016) presented the second highest idling power usage at 2.3 per cent of maximum engine power which was considered appropriate for adoption for the assessment as it was based on engine testing of diesel locomotives.

Limited information was available from literature with respect to engine power during dynamic braking. From the information available, the higher engine power percentage of 3.6 per cent (StarCrest Consulting Group 2008) was adopted for duty cycle calculations.

Table 4.3 summarises the adopted notch setting and operating mode percentages of maximum engine power utilised to calculate average duty cycle power ratings.

Table 4.3 Adopted notch setting and operating mode power rating percentages

Notch setting or operating mode	Adopted percentage of maximum engine power (per cent)	Source
Idle	2.3	Casadei & Maggioni (2016)
Dynamic Braking	3.6	StarCrest Consulting Group (2008
Notch 1	4.8	Spiryagin et al. (2015)
Notch 2	10.7	
Notch 3	24.1	
Notch 4	34.3	
Notch 5	45.4	
Notch 6	66.0	
Notch 7	87.1	
Notch 8	100	

In terms of time spent at each engine notch setting or operating mode, data from US rail operation was utilised to provide a basis for average duty cycle power ratings. Table 4.4 presents US EPA data from Ireson, Germer, and Schmid (2005), which represents duty cycle data for line haul and passenger diesel locomotives in the US.

Table 4.4 Duty-cycles for line haul and passenger locomotives in the US (percentage time in notch)

Notch setting or operating mode	Line haul (per cent)	Passenger (per cent)
Idle	38.0	47.4
Dynamic Braking	12.5	6.2
Notch 1	6.5	7.0
Notch 2	6.5	5.1
Notch 3	5.2	5.7
Notch 4	4.4	4.7
Notch 5	3.8	4.0
Notch 6	3.9	2.9
Notch 7	3.0	1.4
Notch 8	16.2	15.6

The line haul data represents analysis from 63 line-haul trains and 2,475 operational hours and the passenger train data from 20 passenger trains and 57,500 operational hours. As proposed rail traffic for Inland Rail and the Project will be exclusively freight and coal trains, the line haul duty cycle percentages are considered most applicable.

Average hourly power consumption rates were calculated for idling and operating locomotives based on the adopted notch power ratings and duty cycle information, presented in Table 4.5.

Table 4.5 Locomotive power usage

Power	NR Class	SCT/LDP	Class 82	PR22L
Maximum power (kWhr)	2,917	3,350	2,425	1,640
Calculated duty cycle (kWhr)	823	945	684	463
Idle (kWhr)	68	78	56	38

The air quality impact assessment is an assessment against potential worst-case air emissions therefore the number of trains assessed in the air quality impact assessment are potential peak daily train numbers instead of average daily train numbers. Pollutant diesel combustion emission rates were then calculated utilising the following parameters:

- For the peak scenario an average total of approximately 60 trains per day, with an average total of approximately 47 trains per day for the typical scenario (based on weekly rail traffic volumes)
- Locomotive type and configuration
- 75 per cent of journey time to include travel time, and 25 per cent of journey time where trains are stationary and idling in crossing loops (an assumption utilised for the operational modelling for the length of the Inland Rail Program).

Table 4.6 presents the maximum anticipated travel speeds along the Project. Average line speeds were estimated to be 75 per cent of the maximum line speeds for the Project.

Table 4.6 Locomotive travel speeds

Power	Direction of travel	NR Class	SCT/LDP	Class 82	PR22L
Maximum line speed (km/hr)	North	115	115	80	100
	South	115	115	80	80
Average line speed (km/hr)	North	86	86	60	60
	South	86	86	60	60

The following equation represents the calculation method used to determine the total locomotive power per hour for the entire Project alignment.

$$P_{total} = \sum^{loco} (P_{loco} \times d \times v_{loco} \times n_{loco})$$

Where:

- P_{total} is the total locomotive calculated power per hour for entire alignment (kWhr)
- P_{loco} is the calculated average duty cycle power for each locomotive type (kWhr)
- d is the rail track length of the Project alignment (km)
- v_{loco} is the average line speed of each locomotive type (km/hr)
- n_{loco} is the total number of locomotives of each train type per hour.

The following equation calculates the pollutant emissions from locomotive traffic along the entire Project alignment.

$$ER_{pollutant} = \frac{EF_{pollutant} \times P_{total}}{d}$$

Where:

- $ER_{pollutant}$ is the calculated pollutant emission rate for NO_x, TSP, PM_{10}, $PM_{2.5}$ and Total VOC's (as THC) (g/m/s)
- $EF_{pollutant}$ is the pollutant emission factor as per Table 4.1 (g/kWhr)
- P_{total} is the total locomotive calculated power per hour for entire alignment (kWhr)
- d is the rail track length of the Project alignment (m).

The following equation represents the calculation method to determine emissions from idling locomotives during normal assumed operation.

$$ER_{idle} = \left[\sum^{loco}\left(\frac{t_{loco}}{3} \times n_{loco} \times P_{loco}\right)\right] \times EF_{pollutant}$$

Where:

- ER_{idle} is the calculated pollutant emission rate for NO_x, TSP, PM_{10}, $PM_{2.5}$ and Total VOC's (as THC) (g/s)
- t_{loco} is the locomotive travel time along the alignment without stopping. Idling time is assumed to be 25 per cent of the total travel time along the alignment, i.e. 1/3 of the non-stopping travel time of a locomotive to travel the alignment.
- n_{loco} is the total number of locomotives of each train type.
- P_{total} is the total locomotive calculated power per hour for entire alignment from idling (kWhr)
- $EF_{pollutant}$ is the pollutant emission factor as per Table 4.1 (g/kWhr).

To determine continuous idling emissions from crossing loops, it was assumed that NR class locomotives would idle for periods up to or greater than 1 hour depending on the averaging period being assessed (refer Section 4.4.2.6). As such, the idling emission rates were therefore derived from the hourly idling locomotive power usage presented in Table 4.5, and the locomotive emission factors presented in Table 4.1.

Where emissions factors for specific pollutants of concern were not available, emission factors from the NPI Emissions Estimation Manual for Railyards (NPI 2008) and the EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP/EEA 2016a) were utilised. The referenced and speciated locomotive emissions factors are presented in Table 4.7.

The derived pollutant locomotive diesel emission rates are presented below in Table 4.8. The locomotive idling emissions rates for each crossing loop are also presented. An example of the calculation to estimate diesel locomotive emissions is provided in Appendix C, with additional emission inventory data presented in Appendix D. The methodology for the assessment of emissions from the crossing loops is explained in Section 4.4.2.5.

Table 4.7 Locomotive emission factors and speciation

Pollutant	Emission factor	Units	Speciation percentage	Source
Total suspended particulates				
PM_{10}	3.53	kg/kL	97.6	(NPI 2008)
$PM_{2.5}$	3.39	kg/kL	93.7	(NPI 2008)
Cadmium	0.01	g/tonne of fuel	0.00066	(EMEP/EEA 2016a)
Chromium	0.05	g/tonne of fuel	0.0033	(EMEP/EEA 2016a)
Copper	1.7	g/tonne of fuel	0.11	(EMEP/EEA 2016a)
Nickel	0.07	g/tonne of fuel	0.0046	(EMEP/EEA 2016a)

Pollutant	Emission factor	Units	Speciation percentage	Source
Selenium	0.01	g/tonne of fuel	0.00066	(EMEP/EEA 2016a)
Zinc	0.03	g/tonne of fuel	0.066	(EMEP/EEA 2016a)
Lead	0.0005	mg/kg of fuel	0.000033	(EMEP/EEA 2016b)
Arsenic	0.0001	mg/kg of fuel	0.0000066	(EMEP/EEA 2016b)
Total hydrocarbons				
Non-methane VOCs	4.65	kg/tonne of fuel	100	(EMEP/EEA 2016a)
Benzo(a)pyrene	0.03	g/tonne of fuel	0.00065	(EMEP/EEA 2016a)
Toluene	-	-	0.01	(EMEP/EEA 2016b)
m,p-xylenes	-	-	0.98	(EMEP/EEA 2016b)
o-xylenes	-	-	0.40	(EMEP/EEA 2016b)
Benzene	-	-	0.07	(EMEP/EEA 2016b)
1,3-Butadiene	0.31	kg/kL	7.3	(NPI 2008)
Polychlorinated dioxins and furans (TEQ)	8.35×10^{-11}	kg/kL	0.0000000020	(NPI 2008)

Table 4.8 **Derived pollutant diesel combustion emission rates**

Pollutant	Total C2K Emissions (g/m/s)	Long term average C2K idling emissions per crossing loop (g/s)[a]	Short term continuous C2K idling emissions per crossing loop (g/s)[a]
NO_x	1.95×10^{-4}	0.251	4.944
TSP	6.26×10^{-5}	0.0063	0.123
PM_{10}	3.61×10^{-5}	0.0061	0.120
$PM_{2.5}$	1.34×10^{-5}	0.0059	0.116
Total VOCs	2.98×10^{-5}	0.027	0.527

Table note:

a Explanation of the approach to modelling (long term and short term) for the assessment of emissions from the crossing loops is provided in Section 4.4.2.5 and 4.4.2.6

4.4.1.2 Fugitive coal dust

The nature of the emissions from the coal wagons (laden and unladen) is fugitive i.e. the emissions are not released through an easily quantifiable source, such as a vent or stack. The primary mechanism for coal dust lift-off from coal wagons is the movement of air over uncovered laden wagons; therefore, the surface area open to the wind plays a pivotal role in the amount of fugitive coal dust emitted.

It is expected that all coal trains operating along the proposed rail track will utilise veneering to control coal dust emissions. Veneering is a best practice management measure currently applied to trains which use the Bowen Basin coal rail lines and the West Moreton System.

A detailed study into the surface wind speed across loaded wagons and their associated dust emissions has been carried out in Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains (Connell Hatch 2008). The study also presents an equation to calculate the mass emission rate of coal dust from a moving laden wagon at a particular site, using the average wind speed at each modelling location, together with the train speed data for that site:

$$m = (k_1 \times v^2) + (k_2 \times v) + k_3$$

Where:

- m is the mass emission rate of coal dust (as TSP) from the wagon surface in g/km/tonne of coal transported
- k_1 is a constant with a value of 0.0000378

- k_2 is a constant with a value of -0.000126
- k_3 is a constant with a value of 0.000063
- v is the air velocity over the surface of the train in km/hr.

This veneer acts as a binding agent to reduce the amount of surface lift-off of particulates from the laden wagons. Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains (Connell Hatch 2008) suggested that a reduction in surface lift-off of up to 85 per cent was achievable through its application. Trials completed by the BNSF Railway Company and Union Pacific Railroad Company investigated the effectiveness of coal dust suppressants in the Powder River Basin. Trials looks at seven different chemical agents in suppressing coal dust emissions from 1633 loaded trains. The trials found the following: *"… coal dust reductions ranged from 75 to 93 percent depending on the topical treatment used in the test"* (BNSF & UP 2010). As such, an average reduction of 75 per cent was considered to be more realistic. Therefore, a conservative assumption of 75 per cent reduction in the coal dust emission rates has been taken into account in this study for the laden coal trains.

Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains (Connell Hatch 2008) also detailed that following unloading of the coal at the port or terminals, a small amount of residual coal typically remained in the wagon (approximately 0.13 tonnes (t) per wagon), which was transported back to the mine/s. In addition, parasitic loads were found to be located on the wagon sills, shear plates and bogies, which resulted in further fugitive emissions. As such, an additional 0.13 t of coal per wagon was added to the proposed coal train payload of 85.9 t per wagon when developing the modelled particulate emission rates.

Coal dust emission rates for the rail were calculated utilising the following input parameters:

- A travel speed of 80 km/h for a laden coal train travelling along the alignment (maximum laden coal train speed for alignment). The travel speed was used as the wind speed when calculating the mass emission rate of coal dust.
- Application of veneer to coal wagons is expected to reduce emissions from between 75-85 per cent. It has been conservatively assumed that fugitive coal dust emissions will be reduced by 75 per cent based on field trials (Connell Hatch 2008).
- An average coal payload per train of 5,592 t (inclusive of 0.13 t residual coal per wagon)
- A conversion factor of 0.5 from TSP to PM_{10} (USEPA 1998)
- A conversion factor of 0.15 from PM_{10} to $PM_{2.5}$ (USEPA 1998) based on the particle size distributions for mechanically generated emissions from aggregate and unprocessed ores published in the US EPA AP42 Compilation of Air Pollutant Emission Factors (US EPA 1998). Particle size distribution data is not provided for coal, but size distributions for aggregate and unprocessed ores (15 per cent for $PM_{2.5}$) is considered acceptable in lieu of specific data for coal.

Modelling of coal dust emissions assumes that all coal trains travel at speed (80 km/hr) along the alignment, and do not slow down or stop to access the crossing loops. Fugitive coal dust emissions from the crossing loops have not been specifically modelled. However, at lower wind speeds across the coal wagons, emissions are estimated to be considerably lower than the modelled rate for 80 km/hr. For example, fugitive emissions from a stationary coal train with an average 10 km/hr cross wind, the fugitive coal dust emissions represent 1.1 per cent of emissions from a coal train travelling at 80 km/hr. Coupled with the assumption that the coal trains travel at 80 km/hr for the entire proposed alignment results in an conservative estimate of coal dust emissions, which is expected to adequately represent fugitive coal dust emissions from the crossing loops proposed in the Project.

Table 4.9 Derived coal dust emission rates

Pollutant	Uncontrolled coal dust emissions (g/m/s) per train	Controlled coal dust emissions (g/m/s) per train	Total Project alignment controlled coal dust emissions (g/s)
TSP	2.14×10^{-6}	5.36×10^{-7}	2.9
PM_{10}	1.07×10^{-6}	2.68×10^{-7}	1.5
$PM_{2.5}$	1.61×10^{-7}	4.01×10^{-8}	0.22

4.4.1.3 Tunnel portal emissions

Emissions from the Teviot Range Tunnel portals were calculated utilising specific parameters relevant to the tunnel, and are summarised as follows:

- Total tunnel length of 1,015 m
- Laden coal trains travelling only in the west to east tunnel direction.

Table 4.10 presents the average train speeds for each group of expected locomotive type, which is a result of the locomotive number and type per train, weight of trailing wagons, and gradient of the tunnel rail track. A weighted average was calculated based on the percentage of rail traffic expected to travel through the tunnel. Also, the average speeds are broken into "stopping" and "non-stopping" speeds, based on operational modelling of rail traffic travelling directly through the tunnel without stopping and for stopping at the crossing loops at each end of the tunnel.

Table 4.10 Teviot Range Tunnel average locomotive speeds (km/hr)

Train type	Non stopping		Stopping	
	Northbound	Southbound	Northbound	Southbound
Superfreighter	58.7	36.5	36.9	36.0
Express	68.6	47.6	48.3	45.0
Coal	22.4	60.3	22.0	58.9
Agriculture-Steel-Containers	42.8	63.0	39.8	61.8
Weighted Average	38.0	55.6	31.5	54.4

Table note:

The weighted average speed has been calculated by multiplying the speed for each train by the ratio of that train type over the total number of trains travelling in that direction.

Average duty cycle calculations from operational modelling of Teviot Range Tunnel rail traffic are presented for each train type in Table 4.11.

Table 4.11 Teviot Range Tunnel average power (kW) per train

Train type	Non stopping		Stopping	
	Northbound	Southbound	Northbound	Southbound
Superfreighter	5,338.7	5,428.1	5,386.9	4,937.6
Express	7,631.8	7,699.1	7,700.1	7,694.3
Coal	4,447.5	4,410.1	4,456.0	3,824.4
Agriculture-Steel-Containers	4,284.0	3,972.6	4,395.6	4,042.6

Table 4.12 summarises the tunnel portal emissions used in the dispersion modelling, which include the cumulative sources of locomotive diesel combustion emissions and fugitive dust emissions from coal train wagons (calculated as per Section 4.4.1.2).

Table 4.12 Derived portal emissions

Pollutant	Northbound emission rate (kg/hr)		Southbound emission rate (kg/hr)	
	Non stopping	Stopping	Non stopping	Stopping
NO_x	1.56	**1.70**	0.98	**1.01**
TSP	**0.194**	0.187	0.054	**0.056**
PM_{10}	**0.223**	0.217	0.053	**0.055**
$PM_{2.5}$	**0.170**	0.166	0.051	**0.053**
THC	0.213	**0.271**	0.137	**0.141**

Table note:

The highest emission rate for each travel direction and the emission rate used for the modelling is shown in bold.

Generally, the calculated stopping emission rates are higher than the non-stopping due to the longer durations and as such, were utilised in modelling as conservative assumption. However, the emissions for the non-stopping northbound particulate fraction are higher due to the higher average speeds and consequently higher fugitive dust emissions from loaded coal trains. Where this is the case, the higher emission rates were utilised in modelling.

4.4.1.4 Adjoining Inland Rail projects

To assess the cumulative impact of the Inland Rail Program, the adjoining sections of the Inland Rail Program adjacent to the Project, namely the H2C and K2ARB sections, have been included in the dispersion modelling undertaken for the assessment of operational phase impacts.

One kilometre of the H2C rail section has been modelled at the western end of the alignment. The emission rates used for the modelling of this section were assumed to be equivalent to that calculated for the Project.

At the eastern end of the alignment, the Kagaru to Acacia Ridge (K2AR) and Kagaru to Bromelton (K2B) spurs were modelled to assess the impact of emissions from these rail segments. The emission rates used for the modelling of the spurs were assumed to be equivalent to that calculated for the Project, but separated for each spur based on the expected split of train traffic for each direction.

4.4.1.5 Existing rail network traffic

West Moreton System

For the purpose of the assessment it has been assumed that there will be no train travel along the existing QR West Moreton System. It is expected that all existing trains which currently utilise the West Moreton System will using the Inland Rail alignment. The Project has provided connectivity for future livestock and future passenger trains which may want travel between Ipswich and Calvert. However, no trips are confirmed at the time of the assessment.

It is highlighted that veneering is currently applied to coal trains which use the Bowen Basin coal rail lines and the West Moreton System. Therefore, existing coal trains which currently use the West Moreton System and are assumed for this assessment to use the Project will already implement veneering.

Interstate Line

Existing train traffic along the Interstate Line has been included in the dispersion modelling undertaken for the assessment of operational phase impacts. Existing train traffic volumes for 2018 have been assumed for the year of assessment (2040) for the assessment of both the peak and typical operation scenarios. A total of 32 trains per week were modelled for each scenario, consisting of 14 Sydney to Brisbane express trains, six SB Superfreighter trains, and 12 Bromelton IMEX trains. The emission rates for train traffic along the Interstate Line were calculated following the methodology described in Section 4.4.1.1.

Where the K2AR and K2B spurs join with the Interstate Line, emissions from these sections of the Interstate Line have been calculated considering the cumulative train volumes for the section modelled (spur plus Interstate Line train volumes).

4.4.2 Modelling methodology

The air dispersion modelling conducted for this assessment was based on a modelling approach using The Air Pollution Model (TAPM) as a meteorological pre-processor to the air dispersion models CALPUFF and GRAL. The CALPUFF model was used primarily for the modelling assessment; however, for assessment of pollutant impacts from the Teviot Range Tunnel portal sources the GRAL model was utilised.

The data that was available for this Project and a discussion of the data processing methodologies that were required in order to implement both CALPUFF and GRAL are discussed in the following sections. The models are briefly described in the following sections with further details provided in Appendix B. The modelling was undertaken in accordance with relevant guidance documents and appropriate literature (DEC 2005; Barclay & Scire 2011).

Figure 4.1 presents the modelling methodology undertaken for air quality impact assessment.

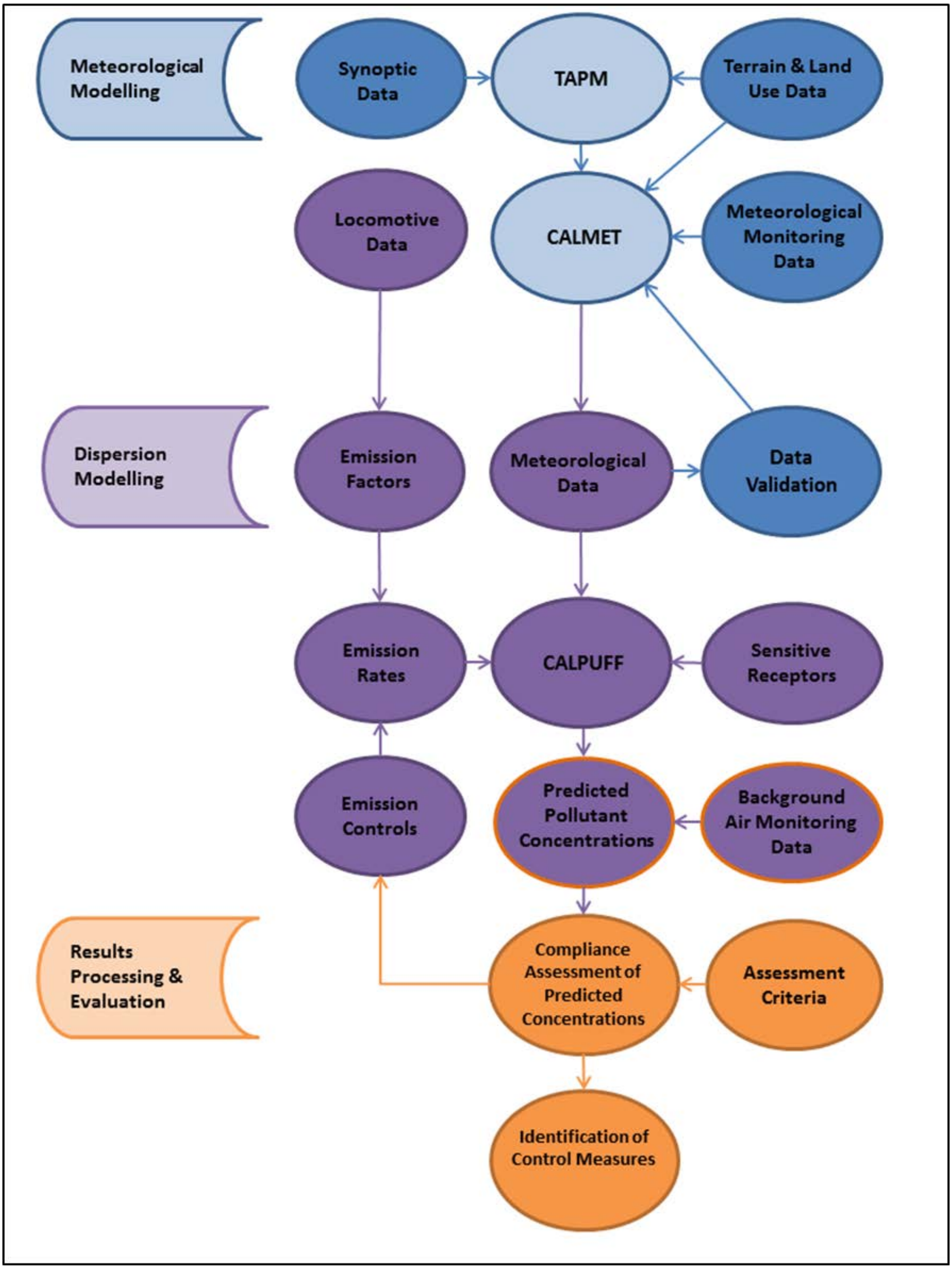


Figure 4.1 Diagrammatic representation of the CALPUFF modelling methodology

4.4.2.1 Selection of meteorological year

For Australia, the El Niño-Southern Oscillation (ENSO) has the strongest effect on year to year climate variability in Australia, mostly affecting rainfall and temperature. El Niño incidences represent periods of unusually warm Pacific Ocean conditions along the western coast of South America, which frequently presents as high rainfall events in South America and drought conditions for Australia. Conversely, La Niña periods represent cooler ocean surface temperatures along the western coast of South America and increase the likelihood of drought conditions locally and high rainfall periods in Australia.

The Southern Oscillation Index (SOI), Oceanic Niño Index (ONI), and Multivariate ENSO Index (MEI) are measures that can indicate episodes of El Niño and La Niña. Due to differences in methodology each of these aforementioned indices can have slightly differing results. However, utilising the SEI, ONI, and MEI measures for ENSO, agreeance can be seen on which years represent periods of El Niño or La Niña. The three indices show that the year 2013 was relatively neutral in terms of ENSO. The year 2013 represents an ideal candidate for selection of meteorological period that is relatively unaffected by variances in weather due to ENSO and therefore data from this year has been used for the assessment.

Further discussion regarding the selection of the meteorological year is provided in Appendix A.

4.4.2.2 TAPM and meteorological data

The meteorological data used in the dispersion model are of fundamental importance, as this data drives the predictions of the transport and dispersion of the air pollutants in the atmosphere. The most critical parameters are:

- Wind direction, which determines the initial direction of transport of pollutants from their sources
- Wind speed, which dilutes the plume in the direction of transport and determines the travel time from source to receiver
- Atmospheric turbulence, which indicates the dispersive ability of the atmosphere.

Meteorological data from BoM and DES meteorological stations in addition to prognostic meteorological data generated by TAPM has been used in the assessment. Pseudo upper air stations were generated from TAPM model runs for the air quality study area. The use of pseudo upper air stations allows the CALMET modelling to be driven primarily by surface observations.

A total of three pseudo upper air (UA) stations were generated from TAPM, with individual runs undertaken for each station. The model setup for TAPM for each of the runs undertaken is presented in Table 4.13.

Table 4.13 TAPM input parameters

Parameter	Input
TAPM Version	4.0.4
Number of grids (spacing)	5 (30 km, 10 km, 3 km, 1 km, 0.3 km)
Number of grid points	41
Number of vertical levels	25
Terrain height database	9 second digital elevation model (DEM)
Year of analysis	January to December 2013
Grid centre point	See Table 4.14 for UA1, UA2 and UA3.

BoM meteorological data was sourced from the Amberley Aeronautical Meteorological Office (AMO) and Beaudesert stations, with DES meteorological data sourced from the Mutdapilly and North Maclean stations. A summary of the meteorological stations considered, including the prognostic stations, is presented in Table 4.14. These stations are discussed further in Section 5.1.

Further information regarding meteorological data is presented in Appendix A.

Table 4.14 Meteorological stations included in modelling

Station	Coordinates (GDA zone 56 m)	Variables	Source
Amberley AMO	471,498m; 6,943,783m	Wind direction; wind speed; temperature; rainfall; pressure; relative humidity	BoM
Beaudesert Drumley Street	498,997m; 6,906,043m		
Mutdapilly	465,597m; 6,930,132m	Wind direction; wind speed	DES
North Maclean	502,956m; 6,928,187m	Wind direction; wind speed; temperature; rainfall; pressure; relative humidity	
UA1	475,832m; 6,921,235m	Upper air	TAPM
UA2	495,078m; 6,916,643m	Upper air	
UA3	455,636m; 6,935,025m	Upper air	

4.4.2.3 CALPUFF

The CALPUFF suite of programs, including meteorological (CALMET), dispersion (CALPUFF) and post processing modules (CALPOST), is an advanced non-steady state modelling system designed for meteorological and air quality modelling. DES does not require the use of any particular dispersion model (e.g. CALPUFF or AERMOD models); however, within the DES Guideline Application requirements for activities with impacts to air (DES 2019b) reference is made to the NSW EPA guidance document Approved methods and guidance for the modelling and assessment of air pollutants in NSW (2001). CALPUFF is appropriate in applications involving complex terrain, non-steady-state conditions, in areas where coastal effects may occur, and/ or when there are high frequencies of stable or calm meteorological conditions (Barclay & Scire 2011). As many of these features are present in the air quality study area, the CALPUFF model is preferred over the more commonly used Gaussian models of AERMOD or AUSPLUME, which perform poorly in the aforementioned conditions.

4.4.2.4 GRAL

In order to investigate the air quality impacts from the railway tunnel portal emissions, the GRAL dispersion model has been utilised. GRAL is a Lagrangian Particle model developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria specifically to assess the dispersion of pollutants from roadways and tunnel portals (Oettl et al. 2002; Oettl et al. 2003; Oettl et al. 2005). GRAL has been extensively evaluated against experimental data from five different existing tunnel portals both in flat and complex terrain, with high and low traffic volumes, namely the Enrei, Hitachi and Ninomiya tunnels in Japan (Oettl et al. 2003), and the Kaisermuehlen (Oettl et al. 2004) and Enrentalerberg tunnels in Austria (Oettl et al. 2002). The GRAL model was specifically utilised to assess emissions from the Teviot Range Tunnel portals.

4.4.2.5 Crossing loops

Locomotive diesel emissions from crossing loops have been modelled as follows:

- Emissions have been modelled from locomotives idling on the crossing loops. Travel around the crossing loops has not been modelled.
- Locomotives have been modelled at each end of each crossing loop as three point sources, resulting in six emission source points per loop
- Two different approaches (hereafter referred to as versions) have been assessed for crossing loops to accurately consider emissions and allow for assessment against both short and long term averaging periods:
  - Short term (1 hour average): continuous idling of NR Class locomotives assumed throughout the year

- Long term (24 hour and annual averages): idling assumed to occur 25 per cent of the travel time, e.g. 15 minutes per hour or 6 hours per day

- For the short-term version, the six point sources represent two Express trains with six NR Class locomotives. The long-term version represents emissions from a calculated composite emission of all trains travelling along the alignment
- No split of idling time has been assumed for each end of the loop to allow for the assessment of a worst-case idling for both the northbound and southbound travel directions
- The locomotive point sources have been located on the top and in the centre of "buildings" included in the model to account for the influence of downwash caused by the structure of the locomotives.

The modelled locations of the four crossing loops are discussed in Section 4.4.3.1.

4.4.2.6 Modelling scenarios

Peak and typical train volumes have been considered in the assessment. Modelling of emissions from train travel along the Project alignment has been undertaken assuming an even volume of train travel per day, e.g. daily train volumes and train emissions from travel along the alignment have been modelled based on the weekly train volumes divided by seven.

In addition to the two train volume scenarios, two different versions of each scenario (short term and long term) have been run to enable accurate assessment of emissions from the crossing loops against both short term and long term air quality goals (refer Section 3.6). The modelled scenarios and crossing loop versions assessed are summarised in Table 4.15.

The model predictions from the short term version have been used to assess compliance against the short term goals (1 hour, 24 hour, etc), with the model predictions from the long term version used to assess compliance against annual average goals.

In addition to the short and long term versions, the requirement for veneering has also been investigated by modelling particulate emissions from coal trains with and without the inclusion of veneering (75 per cent reduction to fugitive coal dust emissions). In total, eight modelling scenarios have been run to investigate the potential for air quality impacts as a result of the operation of the Project.

Table 4.15 Dispersion modelling scenarios

Scenario	Crossing loop version	Crossing loop idling description	Air quality goal averaging periods assessed
Peak train volumes 2040	Short term	Continuous idling emissions from crossing loops	30 minute, 1 hour, 24 hour and monthly dust deposition
	Long term	Idling at loops assumed to occur 25 per cent of the travel time	Annual
Typical train volumes 2040	Short term	Continuous idling emissions from crossing loops	30 minute, 1 hour, 24 hour and monthly dust deposition
	Long term	Idling at loops assumed to occur 25 per cent of the travel time	Annual

Table note:

For each of the four scenarios listed in Table 4.15 two variations have been run, one with the inclusion of veneering and one without veneering.

4.4.2.7 Consideration of climate change influence on meteorological modelling data

The meteorological modelling undertaken for the air quality study area has been undertaken using prognostic meteorological data generated by TAPM and observational data from BoM stations for the year 2013. The purpose of meteorological modelling is to develop meteorological input for dispersion modelling which is representative of typical meteorological conditions for the air quality study area based on long term historical meteorological data. Changing climatic conditions due to climate change has the potential to influence wind conditions, atmospheric stability, mixing height and other meteorological factors important to the dispersion of ground-released pollution. However, as described in NSW EPA Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) (which is the referred to guidance for air quality modelling in the QLD EP Act – Guideline: Application requirements for activities with impacts to air and is applicable for assessments in QLD) the site-representative meteorological data is to be based on long term historical meteorological data (presented in Section 5.1) therefore the potential influence of future changing climatic conditions due to climate change has not been considered in this assessment.

4.4.2.8 Conversion of NOX to NO2

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including NO and NO_2. NO will generally comprise 95 per cent of the volume of NO_X at the point of emission. The remaining NO_X will primarily consist of NO_2. The conversion of NO to NO_2 requires ozone (O_3) to be present in the air, as ozone is the catalyst for the conversion. Ultimately, however, all NO emitted into the atmosphere is oxidised to NO_2 and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) was used to predict ground-level concentrations of NO_2. The OLM assumes that approximately 10 per cent of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 per cent of the predicted NO_X concentrations, all the NO_X is assumed to be converted to NO_2, otherwise NO_2 concentrations are predicted using the equation:

$$NO_2 = 46/48 \times O_3 + 0.1 \times NO_x$$

This method assumes instant conversion of NO to NO2 in the plume, which can lead to overestimation of concentrations close to the source since conversion would usually occur over a period of hours. This method is described in detail in (EPA 2016). It should be noted that the OLM is a conservative approach as explained in Appendix E. Due to its proximity to the Project, background ozone data from the Mutdapilly monitoring station were used to convert the modelled NO2 concentrations in accordance with the OLM methodology presented in (EPA 2016) presents the variation plots of background concentrations for NO2 and O3 for Mutdapilly for the year 2013.

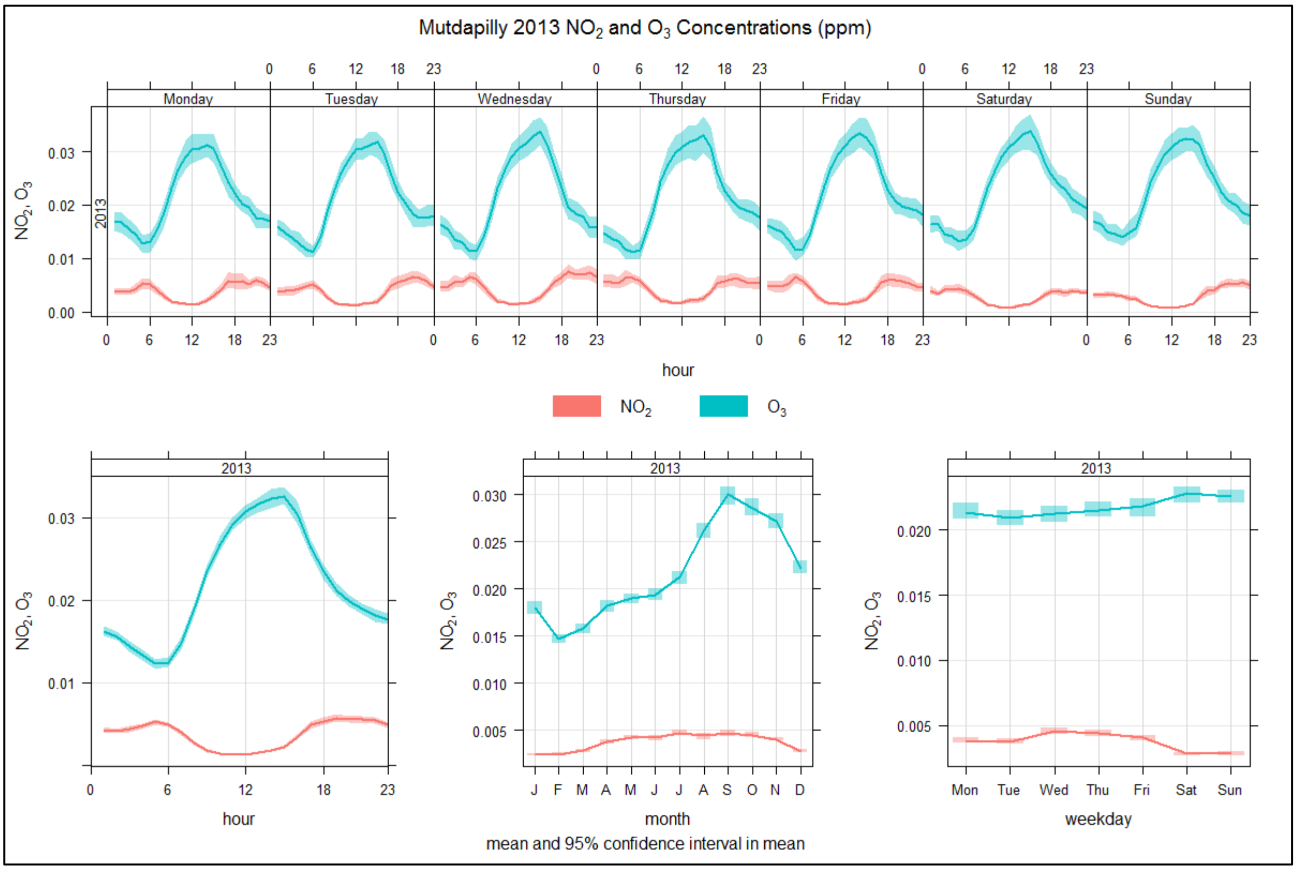


Figure 4.2 **Variation plots of concentrations for NO2 and O3 from the Mutdapilly Department of Environment and Science monitoring station for 2013**

4.4.2.9 Model input parameters

A summary of the data and parameters used as input parameters for dispersion modelling completed is shown in Table 4.16.

It is noted that the total number of sensitive receptors included in the modelling for the air quality impact assessment may be inconsistent with other technical assessments. Due to the large spatial extent required to model the Project and the significant computing resource required to run large scale models, the number of sensitive receptors included in the model was reduced to those located closest to the Project and therefore have the highest potential to be impacted.

Table 4.16 **Model input parameters**

Parameter	Input
TAPM (v4.0.4)	
Horizontal resolution	41 x 41 grid points; outer grid spacing 30,000 m x 30,000 m with an inner grid spacing of 1,000 metres.
Grid centre coordinates	152.550003; -27.7083340 (UA1) 152.750000; -27.8333340 (UA2) 152.949997; -27.8750000 (UA3)
Vertical levels	25
Land use data	Default TAPM database
Simulation length	1 January – 31 December 2013
CALMET (v6.42)	
Meteorological grid domain	60 km x 40 km
Meteorological grid resolution	200 metre resolution (300 x 200 grid cells)

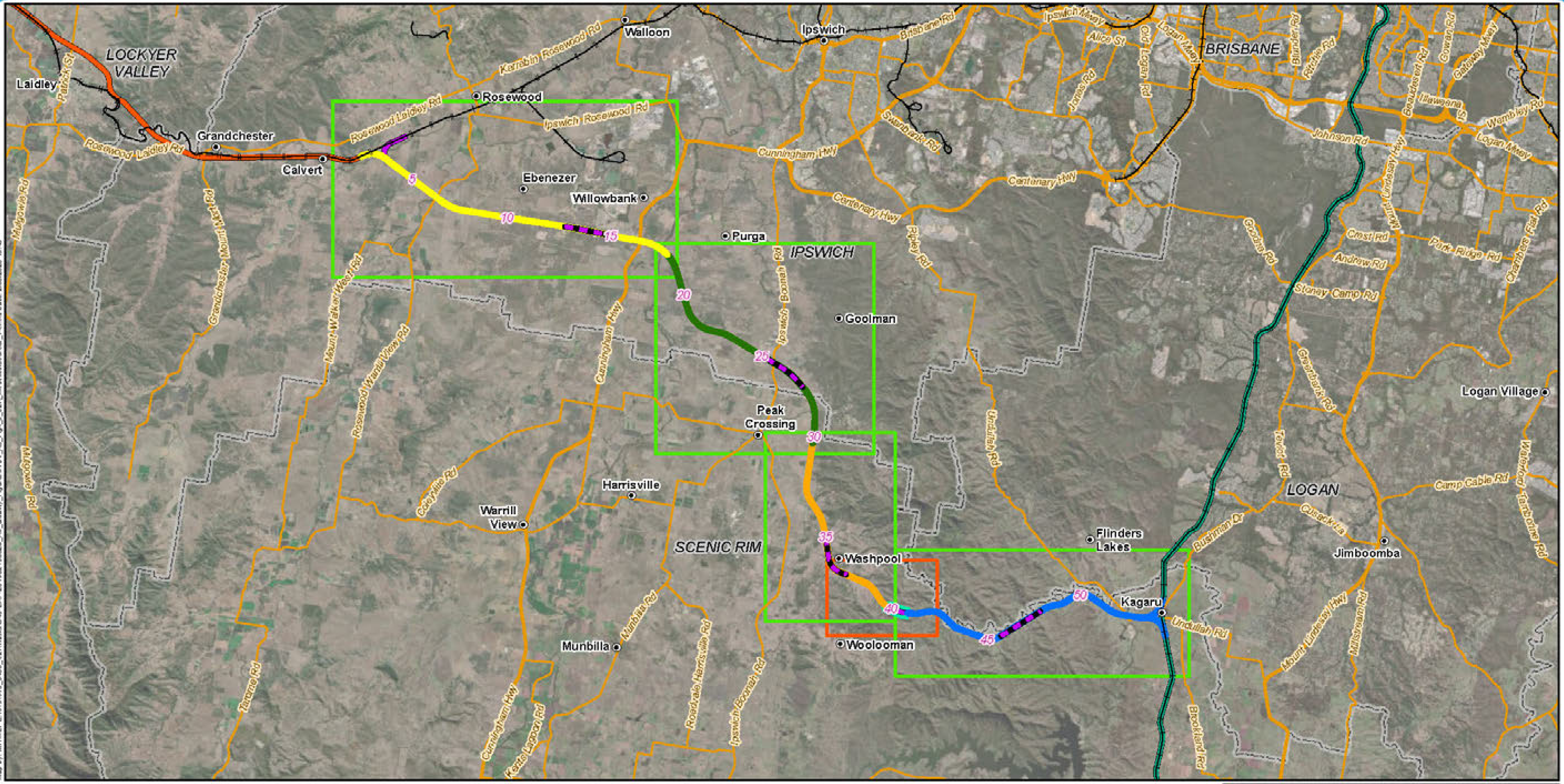
Parameter	Input
Reference grid coordinate (centre)	472,800m E, 6,926,000m S
Cell face heights in vertical grid	0, 20, 40, 80, 160, 320, 640, 1,200, 2,000, 3,000 and 4,000 m
Simulation length	1 January – 31 December 2013
Surface meteorological stations	CALMET Obs Mode: Run using surface observation data and pseudo upper air stations. ▪ Amberley AMO (BoM) ▪ Beaudesert (BoM) ▪ Mutdapilly (DES) ▪ North Maclean (DES)
Upper air meteorological stations	TAPM data derived Upper Air Stations: ▪ UA1 ▪ UA2 ▪ UA3
Terrain data	Shuttle Radar Topography Mission Version 3.0 Global meshed with Project design DEM (1 arc second)
Land use data	ABARES (2016)
TERRAD (Terrain radius of influence)	8.0 km
R1 (Distance from an observational station at which the observation and first guess field are equally weighted) – Surface	3.0 km
RMAX1 (Radius of influence of meteorological stations: Surface)	4.0 km
R2 (Distance from an observational station at which the observation and first guess field are equally weighted) - Upper air	3.0 km
RMAX2 (Radius of influence of meteorological stations: Upper)	4.0 km
IEXTRP (Vertical extrapolation of surface wind observation)	-4 (extrapolate using similarity theory, exclude upper air observations from layer 1)
BIAS (Relative weight of extrapolated observations versus upper air soundings in the computation of the initial guess field)	-1.0, -1.0, -1.0, -0.9, -0.9, -0.5, 0.0, 0.5, 1.0, 1.0
CALPUFF (v7.2.1)	
Computational grid	Model domain split into 4 sections along alignment: Grid 1 (47,132 to 145,182) Grid 2 (116, 87 to 181, 161) Grid 3 (151, 50 to 198,117) Grid 4 (172, 43 to 260,82)
Number of sensitive receptors	548
Dispersion option	Dispersion coefficient. use turbulence computed from micrometeorology
Dispersion modelling period	1 January 2013 – 31 December 2013
GRAMM (v17.1)	
Meteorology	
Meteorology station	CALMET Output at Western Portal Location
Period of meteorology	1 January – 31 December 2013
Meteorology parameters	Wind speed (m/s), wind direction, stability class
Number of wind speed classes	8
Wind speed classes (m/s)	0-0.5, 0.5-1.0, 1.0-2.0, 2.0-3.0, 3.0-4.0, 4.0-6.0, 6-9.0, >9.0

Parameter	Input
Number of wind speed sectors	36
Sector size (degrees)	10
Anemometer height above ground (m)	10
Number of classified wind conditions	842
Meteorological grids and general GRAMM input	
GRAMM domain in UTM	460,200 m (W); 500,200 m (E); 6,935,400 m (N); 6,905,200 m (S)
Horizontal grid resolution	200 m
Vertical thickness of the first layer	10 m
Number of vertical layers	15
Vertical stretching factor	1.40
Relative top level height	3874 m
Maximum time step	10 s
Modelling time	3600 s
Relaxation velocity	0.20
Relaxation scalars	0.20
GRAL (v18.1)	
General	
GRAL domain in UTM	477,375 m (W); 480,000 m (E); 6,920,475 m (N); 6,917,775 m (S)
Dispersion time	3,600 s
Number of particles per second	300
Surface roughness	Variable
Latitude	-27
Buildings	None
Concentration grid	
Vertical thickness of concentration layers	1 m
Horizontal grid resolution	5 m
Number of horizontal slices	1
Height above ground level	2 m
Internal flow field grid	
Horizontal grid resolution	5 m
Vertical thickness of first layer	2 m
Vertical stretching factor	1.01
Number of cells in z-direction	40

4.4.2.10 Modelling domains

Due to the size of the air quality study area several modelling domains were utilised as part of the assessment. Figure 4.3 presents the meteorological domains for CALMET and GRAMM, as well as the four CALPUFF domains and the two GRAL domains.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Crossing loops
- Tunnel
- Local Government Areas
- C2K Rail CALPUFF 1
- C2K Rail CALPUFF 2
- C2K Rail CALPUFF 3
- C2K Rail CALPUFF 4
- CALPUFF Domain
- GRAL Domain

A3 scale: 1:200,000

0 1.5 3 4.5 6 7.5km

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Integrating Community, Environment and Engineering

Issue date: 25/02/2020 Version: 4
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 4.3: Modelled sources

4.4.3 Source parameters

The following sections present the source parameters in CALPUFF and GRAL utilised for dispersion modelling of emissions for the Project.

4.4.3.1 CALPUFF

Table 4.17 presents the CALPUFF source parameters utilised in the dispersion modelling of the Project. The locations of the modelled sources are shown in Figure 4.3. Utilising guidance from US EPA (1992), the rail emission sources for diesel emissions and fugitive coal dust were modelled as line sources approximated by separated volumes sources, utilising guidance from US EPA (1992). Using this method it is possible to emulate the effects of initial dispersion due to plume downwash caused by the locomotive engines (CARB 2004).

The idling point sources represent Express Freight trains that consist of three stationary NR Class locomotives. The locomotive exit temperatures were sourced from locomotive emissions testing for the NSW EPA completed by (ABMARC 2016). Other cited emission parameters for idling locomotives were sourced from CARB (2004) for a similar locomotive of similar type and size.

Table 4.17 also presents the initial horizontal and vertical spreads used in the modelling of train travel, and the release height of the plume. The spreads and release height have been calculated using Lakes Environmental guidance (Lakes Environmental 2017) on the calculation of dispersion from haul roads, which is based on the US EPA Haul Road Workgroup Report (US EPA 2012). The dispersion of emissions from haul roads is very similar to dispersion from rail lines and is considered the most appropriate guidance. Initial vertical spread (sigma Z) is calculated by dividing the top of plume height (m) by 2.15. Top of plume height is equal to the vehicle (train) height (3.9 m) multiplied by 1.7 (6.63 m), with release height equal to the top of plume height divided by 2 (3.3 m). Initial horizontal spread (sigma Y) (18.6 m) is calculated by dividing the distance between the centre points of the segmented volume sources by 2.15. Plume width (not shown in Table 4.17) is calculated as the vehicle (train) width (3 m) plus 6 m to account for the mixing zone of a single line track.

The location of modelled sources are shown in Figure 4.3.

Table 4.17 CALPUFF source parameters

Source	Source type	Location (GDA 96, zone 56 m)	Release height above ground level (m)	Parameters
H2C (grid 1)	Segmented line-volume source (1.0 km, 29 sources)	454,367; 6,939,942 to 453,382; 6,939,802	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
C2K-1 (grid 1)	Segmented line-volume source (15.7 km, 394 sources)	454,370; 6,939,942 to 468,925; 6,935,276	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
C2K-2 (grid 2)	Segmented line-volume source (12.4 km, 311 sources)	468,925; 6,935,276 to 475,863; 6,926,290	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
C2K-3 (grid 3)	Segmented line-volume source (9.5 km, 239 sources)	475,863; 6,926,290 to 479,436; 6,918,493	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
C2K-4 (grid 4)	Segmented line-volume source (13.7 km, 345 sources)	480,398; 6,918,193 to 491,312; 6,918,002	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
K2AR spur	Segmented line-volume source (1.5 km, 39 sources)	491,312; 6,918,002 to 492,516; 6,918,776	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)

Source	Source type	Location (GDA 96, zone 56 m)	Release height above ground level (m)	Parameters
K2B spur	Segmented line-volume source (1.3 km, 33 sources)	491,555; 6,917,991 to 492,582; 6,917,402	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
Interstate Line	Segmented line-volume source (2.8 km, 72 sources)	492,481; 6,918,663 to 492,876; 6,915,923	3.3	18.6 m (initial horizontal spread) 3.1 m (initial vertical spread)
Crossing Loop 1 (grid 1)	Point source (6 sources)	464,181; 6,936,588 464,205; 6,936,584 464,228; 6,936,580 466,122; 6,936,216 466,099; 6,936,220 466,076, 6,936,225	4.3 (0.1 m above locomotive engine)	134 °C (exit temperature) 0.6 m (stack diameter) 2.4 m/s (exit velocity)
Crossing Loop 2 (grid 2)	Point source (6 sources)	473,762; 6,930,269 473,782; 6,930,257 473,802; 6,930,245 475,332; 6,929,032 475,318; 6,929,050 475,302; 6,929,068	4.3 (0.1 m above locomotive engine)	134 °C (exit temperature) 0.6 m (stack diameter) 2.4 m/s (exit velocity)
Crossing Loop 3 (grid 3)	Point source (6 sources)	476,502; 6,921,691 476,506; 6,921,669 476,509; 6,921,645 477,348; 6,920,063 477,326; 6,920,072 477,304; 6,920,081	4.3 (0.1 m above locomotive engine)	134 °C (exit temperature) 0.6 m (stack diameter) 2.4 m/s (exit velocity)
Crossing Loop 4 (grid 4)	Point source (6 sources)	484,932; 6,917,160 484,953; 6,917,173 484,972; 6,917,185 486,625; 6,918,215 486,606; 6,918,203 486,586; 6,918,191	4.3 (0.1 m above locomotive engine)	134 °C (exit temperature) 0.6 m (stack diameter) 2.4 m/s (exit velocity)

4.4.3.2 GRAL

Table 4.17 presents the GRAL source parameters utilised in the dispersion modelling of the Project. The location of the GRAL model domain is shown in Figure 4.3. Exit velocities are based upon a composite average travel speeds for stopping trains through the Teviot Range Tunnel.

In absence of ventilation temperature information, the temperature differential has been assumed to be 0 kelvin, which effectively assumes the plume will be at ambient temperature. This is a conservative assumption as it will model the plume as non-buoyant, resulting in decreased dispersion from the portal.

Table 4.18 GRAL source parameters

Source	Source type	Location (GDA 96, zone 56 m)	Release height above ground level (m)	Parameters
Western Tunnel Portal	Portal	479,441; 6,918,501	0.0	0 K (temperature differential) 8.7 m/s (exit velocity) 100 m^2 (cross sectional area)
Eastern Tunnel Portal	Portal	480,398; 6,918,185	0.0	0 K (temperature differential) 15.1 (exit velocity) 100 m^2 (cross sectional area)

4.4.3.3 Terrain and land use data

The underlying terrain and dominant land use are important functions of plume transport modelling. Gridded terrain elevations for the modelling domain were derived from the Shuttle Radar Topography Mission (SRTM) one arc-second or around 30 m resolution data. To reflect the final terrain formations post construction, this data was supplemented with detailed 1 metre data that indicate bulk earthworks along the proposed alignment and Teviot Range Tunnel portals.

Land use within the air quality study area primarily consists of rural and agricultural areas, which are interspersed with rangeland and forest land. Land use data within the air quality study area were derived from the QLD Land Use Mapping Program (QLUMP) utilising the Australian Land Use and Management Classification (ABARES 2016). The data are representative of the actual area associated with the Project, are recent and of a very fine resolution to increase the accuracy of the modelling. The land use data used in this application are different to the default land use data used in TAPM and for most CALMET model applications outside of the United States, which are the USGS one kilometre land use data. Until recently, the USGS one kilometre global land use data set was the most readily available data set for air quality applications. Limitations of this data set; however, include its age (more than 20 years old), coarse resolution (between 900 m and 1.2 km), and the fact that it is categorised according to the North American land use category system, which does not correspond to all relevant Australian land use types.

As stated above, plume transport is an important function of the underlying dominant land use. The inclusion of the Australian land use data set is; therefore, an important relevant addition to this modelling application as the data are recent, relevant and of a fine resolution.

4.4.4 Limitations

The atmosphere is a complex, physical system, and the movement of air in a given location is dependent on a number of different variables, including temperature, topography and land use, as well as larger-scale synoptic processes. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations. The model equations necessarily involve some level of simplification of these very complex processes based on our understanding of the processes involved and their interactions, available input data, and processing time and data storage limitations.

These simplifications come at the expense of accuracy, which particularly affects model predictions during certain meteorological conditions and source emission types. For example, the prediction of pollutant dispersion under low wind speed conditions (typically defined as those wind speeds less than 1 m/s) or for low-level, non-buoyant sources, is problematic for most dispersion models. To accommodate these known deficiencies, the model outputs tend to provide conservative estimates of pollutant concentrations at particular locations.

While the models contain a large number of variables that can be modified to increase the accuracy of the predictions under any given circumstances, the constraints of model use in a commercial setting, as well as the lack of data against which to compare the results in most instances, typically precludes extensive testing of the impacts of modification of these variables. With this in mind, model developers typically specify a range of default values for model variables that are applicable under most modelling circumstances. These default values are recommended for use unless there is sufficient evidence to support their modification.

As a result, the results of dispersion modelling provide an indication of the likely level of pollutants within the modelling domain. While the models, when used appropriately and with high quality input data, can provide very good indications of the scale of pollutant concentrations and the likely locations of the maximum concentrations occurring, their outputs should not be considered to be representative of exact pollutant concentrations at any given location or point in time. As stated above, however, the model predictions are typically conservative, and tend to over predict maximum pollutant concentrations at receiver locations.

This assessment was undertaken with the data available at the time of the assessment. Should changes to the Project be made, further assessment may be required to determine if the findings of this assessment are still applicable.

4.5 Tank water quality

4.5.1 Potential impacts

In rural and remote Australia where reticulated water supply is not always available, the use of domestic rainwater tanks is common practice. Rainfall is collected from roof run-off, and where installed is most commonly used as the primary source of household drinking water (enHealth 2010). Rainwater stored in tanks has the potential to be contaminated by chemical, physical and microbial sources, and become a hazard to human health. Industrial and traffic emissions have the potential to be a source of chemical contamination through their atmospheric deposition onto rooves where water is collected (Gunawardena 2012).

The potential for the operation of the Project to impact tank water quality collected via roof catchment was investigated. For the purpose of the assessment, the following assumptions were made:

- “First flush” systems were not installed on water tanks at any receptor location
- The average roof area was 200 m^2.

4.5.2 Fugitive coal dust deposition

Fugitive coal dust emissions from rail transport along the proposed alignment have potential to be deposited on surfaces that lead to rainwater tanks. Coal may contain many trace elements, some of which include the following – sulphur, chlorine, arsenic, boron, cadmium, lead, mercury, molybdenum, selenium, chromium, copper, fluorine, nickel, vanadium, and zinc. Several of these compounds can have toxic and chronic health effects, which is dependent on exposure length, concentration, and path of ingestion. A leaching test study completed by (Lucas 2009) showed through experimentation that even though these compounds exist within coal and coal dust, they have a low leachability potential into receiving water, and measured concentrations were well below the 2004 Australian Drinking Water Guidelines. Therefore it is expected that coal dust will not pose significant health impacts from exposure to toxic trace elements and its health impacts will be primarily related to exposure to particulate in the form of PM_{10} and $PM_{2.5}$.

4.5.3 Assessing impacts to water tank quality

Using the emissions inventory developed for assessment of impacts to air quality, dust deposition modelling was also completed using CALPUFF to determine the impact of diesel and fugitive coal dust emissions on tank water quality. As per the assessment of impacts to air quality and as required by the ToR, dust deposition was predicted for all receptors within the air quality study area. The methodology for predicting the potential impact to water tank quality is summarised as follows:

- Annual average dust deposition rates were predicted for every receptor in the air quality study area for peak and typical train operations. Every receptor was assumed to have a water tank.
- It was assumed that all deposited dust at each receptor was collected by a 10,000 litre (L) rainwater tank, which was 10 per cent full resulting in a receiving water volume of 1,000 L. This conservative assumption allows for periods where there may be prolonged periods of drought and short rainfall events that wash deposited pollutants into rainwater tanks.
- Based on the predicted annual average dust deposition rate, the concentration of particulates and other pollutant species with water quality guideline concentrations was determined by speciating the deposited dust using diesel locomotive emission factors (refer Table 4.7 in Section 4.4.1.1) and fugitive coal emission factors (refer Section 4.4.1.2).

The outcome of this method was pollutant concentrations in tank water which could be compared against the Australian Drinking Water Guidelines (NHMRC, NRMMC 2018).

Detailed dispersion modelling is not typically undertaken for construction activity and has not been undertaken for the construction phase assessment for the Project. Construction dust has therefore not been considered for the assessment of tank water quality.

Similarly, fugitive emissions from fuel storage tanks required for the construction phase have not been considered for the assessment of tank water quality. Fugitive emissions from fuel storage tanks will be gaseous and will not be a significant issue with respect to deposition and tank water quality.

4.5.4 Drinking water quality goals

The Australian Drinking Water Guidelines (NHMRC, NRMMC 2018) present guideline values on allowable contaminants within drinking water, such as from rainwater tanks. Table 4.19 presents the drinking water criteria for the pollutants of interest which have been used in the assessment.

Table 4.19 Drinking water quality guidelines

Pollutant	Guideline value (mg/L)	Environmental value	Source
Arsenic	0.01	Health	(NHMRC, NRMMC 2018)
Cadmium	0.002	Health	
Lead	0.01	Health	
Nickel	0.02	Health	
Chromium as Cr(IV)	0.05	Health	

4.6 Cumulative impact assessment

As part of the EIS process for the Project and as typically required for air quality impact assessments, a CIA is required. Air quality impact assessments are inherently cumulative assessments as they are required to consider background air quality when assessing against air quality goals.

In addition to consideration of background air quality (refer Section 5.2) this assessment has also considered cumulative impacts to sensitive receptors in the operational phase of the Project by assessing emissions from the adjoining Inland Rail projects (H2C and K2ARB) as discussed in Section 4.4. The results of the operational phase assessment are discussed in Section 7.

Existing emission sources in the air quality study area are discussed in Section 5.2.8. No existing emission sources require inclusion in the assessment of the operational phase of the Project. An existing quarry (Boral Purga Quarry) is considered in the assessment of the construction phase of the Project.

In addition to the assessment of the H2C and K2ARB projects and the Boral Purga Quarry, a qualitative CIA has been undertaken via review of other 'State significant' or 'strategic' projects. A summary of the assessable projects impact to air quality is provided in Section 8.

4.7 Decommissioning phase

Given the uncertainty associated with timeframe for decommissioning, this phase has not been considered in this air quality impact assessment.

5 Existing environment

The existing environmental values of the air environment that may be affected by the Project are described in a manner discussed in Section 3.2 whereby existing ambient pollutant concentrations are compared to the nominated air quality goals. Aspects of the ambient environment relevant to this assessment of the existing environmental values of the air environment include:

- Existing air quality due to regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed
- Meteorological conditions and climate
- Terrain and land use.

In addition to discussion of existing air quality and meteorological conditions, this section also introduces and presents the locations of sensitive receptors near the Project which have been used in establishing the environmental values of the air environment considered in the assessment.

5.1 Climate and meteorology

BoM operates a network of weather monitoring stations around Australia that have long-term climatic data available for analysis. A number of the air quality stations operated in SEQ by DES also record meteorological data. As the alignment spans a relatively significant distance laterally, local meteorological conditions may differ across this distance, especially at areas further inland and/or away from notable terrain features. Five stations (three BoM-operated and two DES operated) have been selected to provide a greater regional coverage of climatic conditions.

The Mutdapilly DES station and Amberley AMO BoM station are located on the western side of the alignment. While the North Maclean DES station and the Beaudesert BoM stations (Beaudesert Drumley Street and Beaudesert Cryna) are located to the east as shown in Figure 5.1. Details of the stations selected are provided in Table 5.1.

In addition to the measured meteorological data from the BoM and DES stations, output data from CALMET (refer Appendix A) has also been analysed and presented in this section to describe atmospheric stability and mixing height.

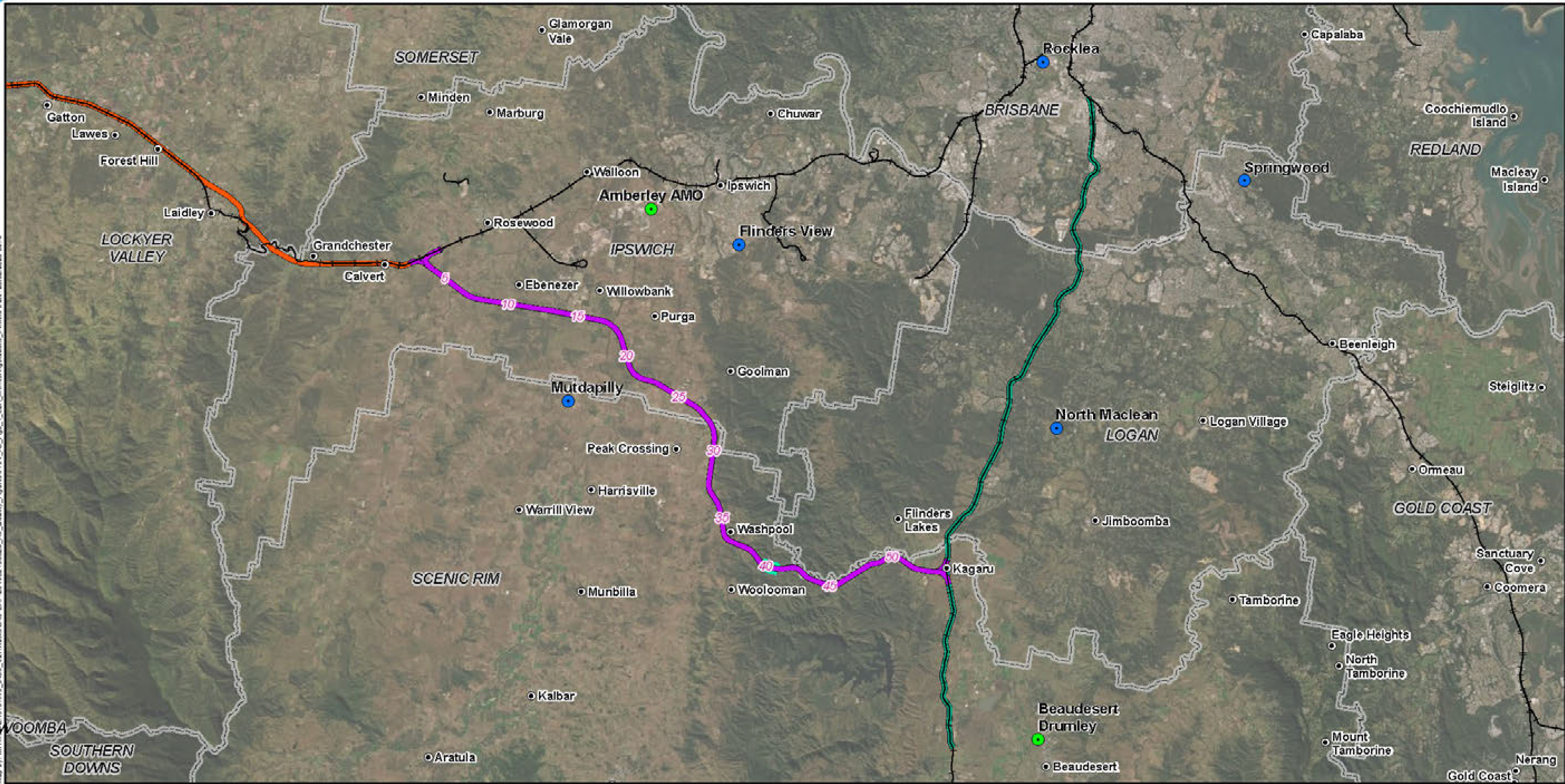
Table 5.1 Location of meteorological monitoring stations

Operator	Name	Coordinates	Distance from Project (closest point, km)	Direction from Project	Period operational	Elevation (m)
BoM	Amberley AMO	-27.6297, 152.7111	8.5	N – NE	1941 - Present	24
BoM	Beaudesert Drumley Street	-27.9707; 152.9898	12.8	SE	2007 - Present	48
BoM	Beaudesert Cryna[a]	-28.0206; 153.0131	12.8	SE	1887 - 2014	106
DES	Mutdapilly	-27.7530, 152.6510	5.0	S – W	1995 - Present	-
DES	North Maclean	-27.7708, 153.0301	14.4	E	1994 - Present	-

Table note:

a The BoM Beaudesert Cryna station is only used to present wind roses. The BoM Beaudesert Drumley Street station has more recent meteorological data but does not have wind roses available.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- BOM stations
- DES stations
- Chainage (km)
- Localities
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Existing rail
- Tunnel
- Local Government Areas

A3 scale: 1:300,000

0 2 4 6 8 10km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 25/02/2020 Version: 4
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.1:
Locations of meteorological and air quality monitoring stations

5.1.1 Temperature

Mean minimum and maximum temperatures have been collected from the two currently active BoM stations, and are displayed in Table 5.2. Temperatures recorded at the two stations are very similar: the annual mean minimum temperature is higher by 0.1°C in Amberley, and the annual mean maximum is 26.8°C at both locations. Temperature data is unavailable from the Mutdapilly station, and at North Maclean only average temperature (based on hourly values) is available. Average monthly temperature at North Maclean is consistent with a sub-tropical climate, with warm summers and cooler winters (refer Table 5.3).

In winter (June, July and August), mean minimum temperatures are slightly lower at Amberley (7.1°C, 5.4°C and 6.2°C respectively) than in Beaudesert (7.7°C, 6.1°C and 6.6°C). Mean maximum temperatures for winter are slighter higher in Beaudesert (22.0°C) than in Amberley (21.9°C).

In summer (December, January and February) mean minimum temperatures are higher in Amberley (18.4°C, 19.6°C and 19.5°C) than in Beaudesert (18.1°C, 19.2°C and 19.0°C). The mean maximum for summer is only slighter higher in Amberley (30.8°C) than in Beaudesert (30.7°C).

Overall, temperatures across the air quality study area are consistent with a warm sub-tropical climate. Temperature maximums and minimums are very similar at the two locations.

Table 5.2 Mean minimum (blue) and maximum (red) monthly temperatures for Amberley AMO and Beaudesert Bureau of Meteorology monitoring stations

Station	Mean, minimum and maximum temperature (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Amberley AMO[a]	19.6	19.5	17.8	14.0	10.0	7.1	5.4	6.2	9.5	13.3	16.3	18.4	13.1
	31.2	30.4	29.4	27.2	24.1	21.6	21.3	22.8	25.6	27.8	29.6	30.8	26.8
Beaudesert Drumley Street[b]	19.2	19.0	17.8	14.0	9.4	7.7	6.1	6.6	9.9	12.8	16.3	18.1	13.0
	31.3	30.6	29.1	26.8	24.2	21.5	21.5	23.1	26.1	28.1	29.7	30.3	26.8

Table notes:

a Mean maximum and minimum temperature values have been calculated based on 77 years of data (1941 to 2018)
b Mean maximum and minimum temperature values have been calculated based on 12 years of data (2007 to 2018)

Table 5.3 Mean monthly temperatures for North Maclean Department of Environment and Science monitoring station

Station	Average temperature (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
North Maclean[a]	24.7	24.3	23.3	20.1	17.0	14.9	13.7	14.7	17.6	20.2	22.4	23.8	19.7

Table notes:

a Average temperature values have been calculated using hourly temperature data available for download from QLD Government (2012 to 2017)

5.1.2 Rainfall

Mean monthly rainfall values for the Amberley AMO and Beaudesert Drumley Street BoM stations and the North Maclean DES station are presented in Table 5.4. A distinct wet (summer) and dry (winter) season is experienced by the region annually.

Of the three stations, Beaudesert Drumley Street receives the highest amount of rainfall annually (926.5 mm), followed closely by Amberley AMO (864.0 mm) and then North Maclean (604.5 mm).

In Amberley and Beaudesert over 40 per cent of average annual rainfall occurs during the three months of summer. Summer is also the distinct wet season for North Maclean, with a third of the average annual rainfall occurring. The months of winter are the driest at all stations: rainfall over winter accounts for approximately 13 per cent of annual average rainfall in Amberley (113.4 mm), 12 per cent in Beaudesert (107.2 mm), and 11 per cent in North Maclean (67.1 mm). It should be noted that the monthly mean rainfall values from the North Maclean station may not be as robust at the other stations due to the smaller dataset.

Table 5.4 Mean monthly and annual rainfall for selected monitoring stations

Station	Mean rainfall (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Amberley AMO[a]	116.9	121.2	85.5	54.5	52.8	46.9	37.6	28.9	33.6	73.3	81.5	119.4	864.0
Beaudesert Drumley[b]	152.4	121.4	121.4	46.8	54.6	51.3	24.4	31.5	33.1	69.1	91.2	121.1	926.5
North Maclean[c]	86.9	59.6	138.0	30.6	43.0	43.0	7.1	17.0	13.7	29.0	82.0	54.5	604.5

Table notes:

a Mean rainfall values have been calculated based on 73 years of data (1941 – 2010)

b Mean rainfall values have been calculated based on 12 years of data (2007 – 2018)

c Mean rainfall values have been calculated based on 5 years of data (2013 – 2017)

5.1.3 Wind speed and direction

Long-term annual wind roses for morning and afternoon conditions at the Amberley AMO BoM station were available for review. Annual wind roses were not available for the BoM Beaudesert Drumley Street Station. However, the BoM Beaudesert Cryna station, although no longer operational, does have a long-term annual wind rose for morning conditions. The 9.00 am and 3.00 pm annual wind roses for Amberley AMO are displayed with the 9.00 am annual wind rose for the Beaudesert Cryna station in Figure 5.2.

Morning winds at the Amberley AMO location are variable in direction and of low to moderate strength when not calm. Calm conditions represent 31 per cent of 9.00 am wind observations. At 9.00 am the most frequent wind direction is south and north west (both approximately 15 per cent of observations). Winds at 3.00 pm in Amberley are predominately from the east and north-east, and are considerably stronger. Calm conditions account for only 9 per cent of afternoon wind observations.

Morning wind conditions at the Beaudesert Cryna station location differ greatly to those recorded at Amberley. Winds are most frequently from the south west followed by south, and generally of low speed. Although 23 per cent of observations are classified as calm, unlike at Amberley, strong gusts of wind (>= 40 km/h) are also recorded. It should be noted that the Beaudesert Cryna station elevation of 106 m is greater than the elevations of the Beaudesert Drumley Street and Amberley AMO stations.

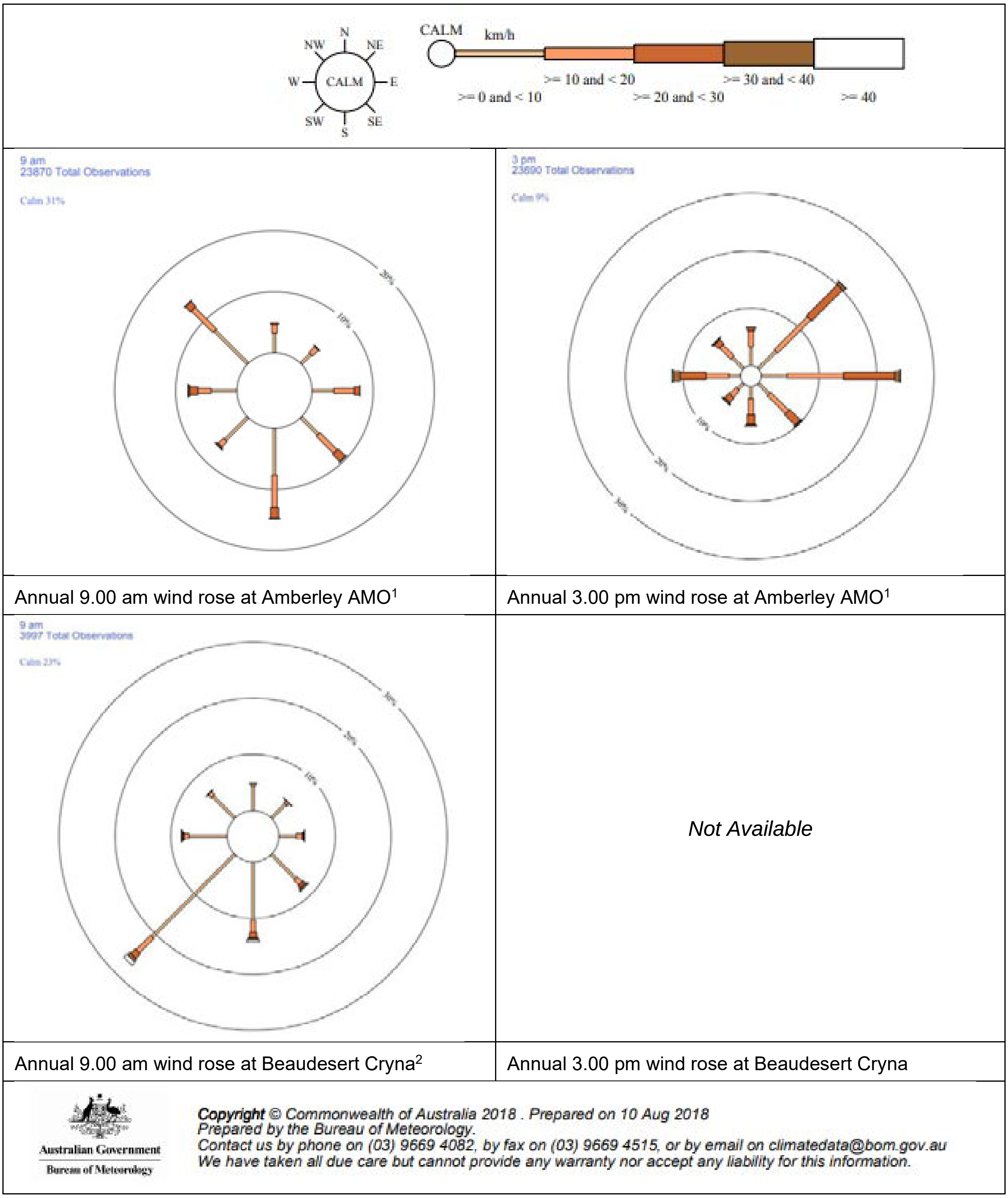


Figure 5.2 **Wind roses for Bureau of Meteorology monitoring stations Amberley AMO and Beaudesert Cryna**

Figure notes:

1 Annual wind rose of wind direction versus wind speed based on observations from 15 June 1952 to 10 August 2018.

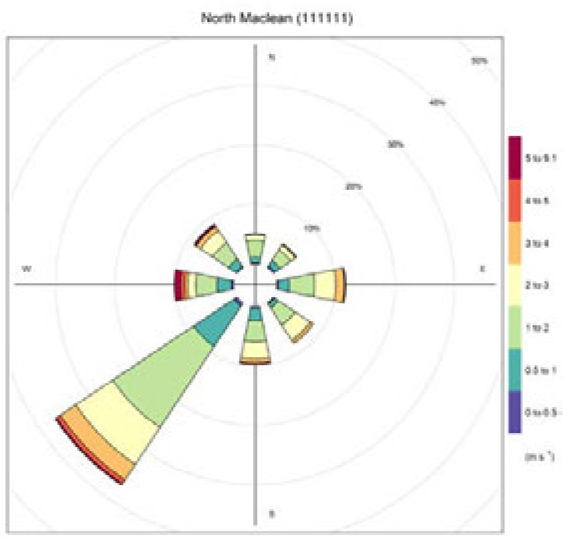
2 Annual wind rose of wind direction versus wind speed based on observations from 23 October 1967 to 13 December 1979.

For Mutdapilly and North Maclean, annual wind conditions for morning (9.00 am) and afternoon (3.00 pm) are presented in Figure 5.3. Wind speed is measured in meters per second (m/s), as opposed to kilometres per hour (km/hr) for the BoM stations.

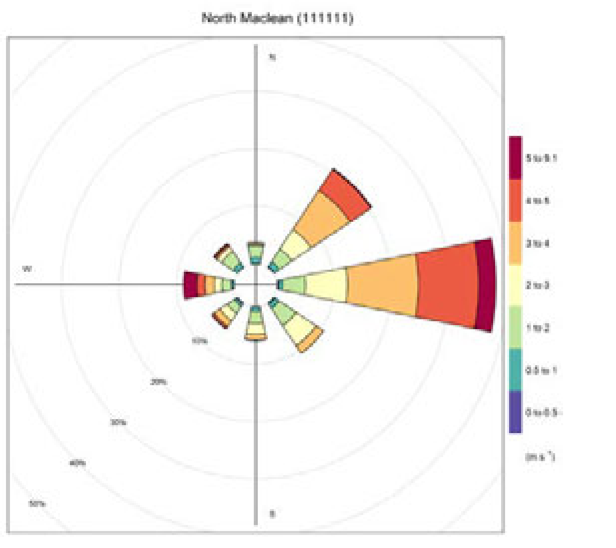
Morning winds at North Maclean are most frequently from the south west direction (>30 per cent) and of low strength. At 3.00 pm wind is mostly from the east followed by north east, and of greater strength than the morning (mostly above 3 m/s). At the Mutdapilly station location, morning wind is variable in direction and strength. Winds from the south east are most common with moderate to strong speeds. North westerly winds are also common in the morning (approximately 20 per cent of observations) but are generally weaker. In the afternoon, stronger winds are more prevalent and are from the north east and easterly directions.

Comparison of the annual wind conditions at the four station locations reveals some geographic trends. Morning conditions at the stations east of the alignment (North Maclean and Beaudesert Cryna) are very similar in both direction and speed. Similarities are also noted when comparing morning wind conditions at the two stations west of the alignment (Mutdapilly and Amberley AMO). Almost 20 per cent of winds at both stations are from the north west. However, wind direction at the Amberley AMO station is more variable than Mutdapilly, where south easterly winds are most common. In the afternoon, strong winds from the north east (most frequent at Mutdapilly) and east (most frequent direction at Amberley) prevail at both stations.

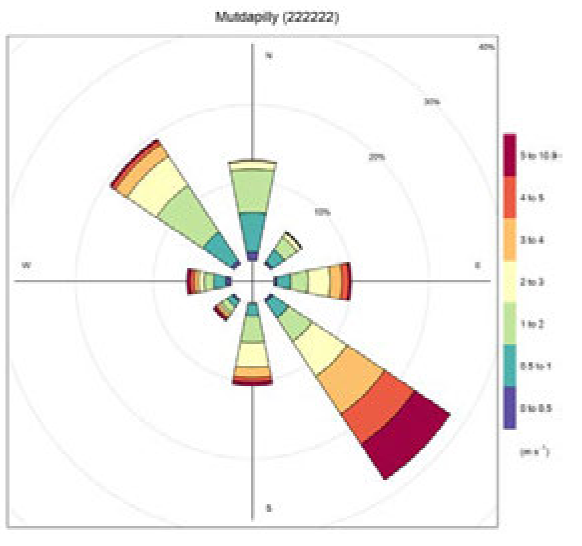
Overall, analysis of the annual wind roses for the four stations indicates that wind speed and direction is influenced on the local scale by terrain and land use. Terrain and land use are discussed further in Section 5.3. Synoptic scale winds modified by occasional afternoon sea breezes, and valley drainage flows originating from the nearby mountain ranges at night, affect wind speed and direction at the large scale.



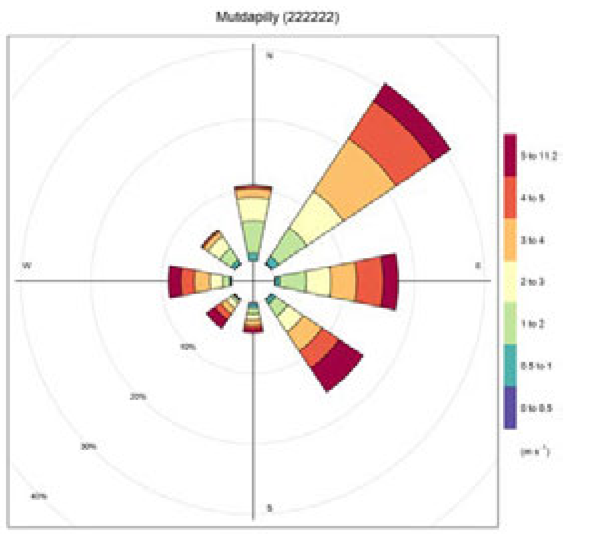
Annual 9.00 am wind rose at North Maclean



Annual 3.00 pm wind rose at North Maclean



Annual 9.00 am wind rose at Mutdapilly



Annual 3.00 pm wind rose at Mutdapilly

Figure 5.3 Wind roses for Department of Environment and Science monitoring stations North Maclean and Mutdapilly

5.1.4 Atmospheric stability

Stability is a measure of the convective properties of a parcel of air. Stable conditions occur when convective processes are low, while unstable conditions are associated with stronger convective processes, which are associated with potentially rapid changes in temperature. Stable atmospheres occur when a parcel of air is cooler than the surrounding environment, so the parcel of air (and any pollution within it) sinks. Conversely, unstable atmospheres occur when a parcel of air is warmer than the surrounding environment, making the parcel of air buoyant and, subsequently, leading to the parcel of air rising.

Stability is commonly explained using Pasquill-Gifford A – F stability class designations Classes A, B and C represent unstable conditions, with class A representing very unstable conditions and C representing slightly unstable conditions. Class D stability corresponds to neutral conditions, which are typical during overcast days and nights. Classes E and F correspond to slightly stable and stable conditions respectively, which occur at night.

Stability class data extracted from the CALMET files for locations representing the Mutdapilly DES station, Beaudesert Drumley Street BoM station and the Teviot Range Tunnel western portal locations are presented in Figure 5.4 to Figure 5.6. As expected, Figure 5.4 to Figure 5.6 indicate stable conditions during the night hours and neutral and unstable conditions during the day.

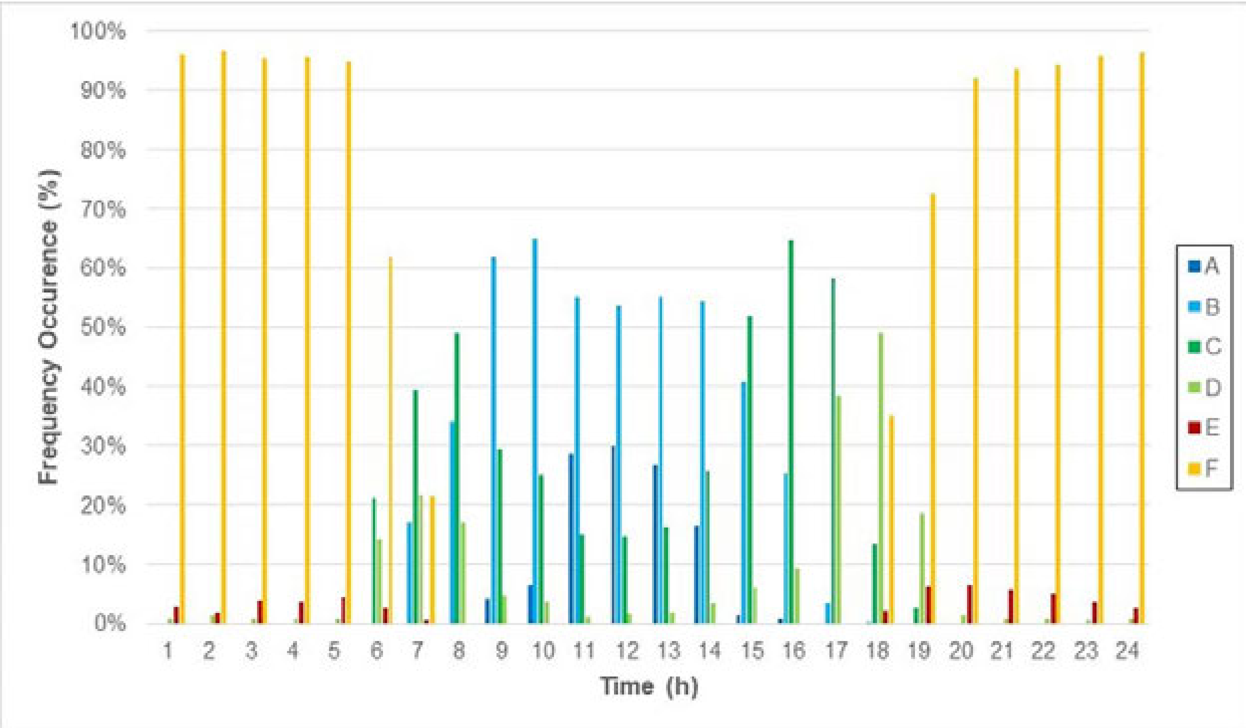


Figure 5.4 **Hourly stability class frequency for Mutdapilly Department of Environment and Science station (CALMET generated)**

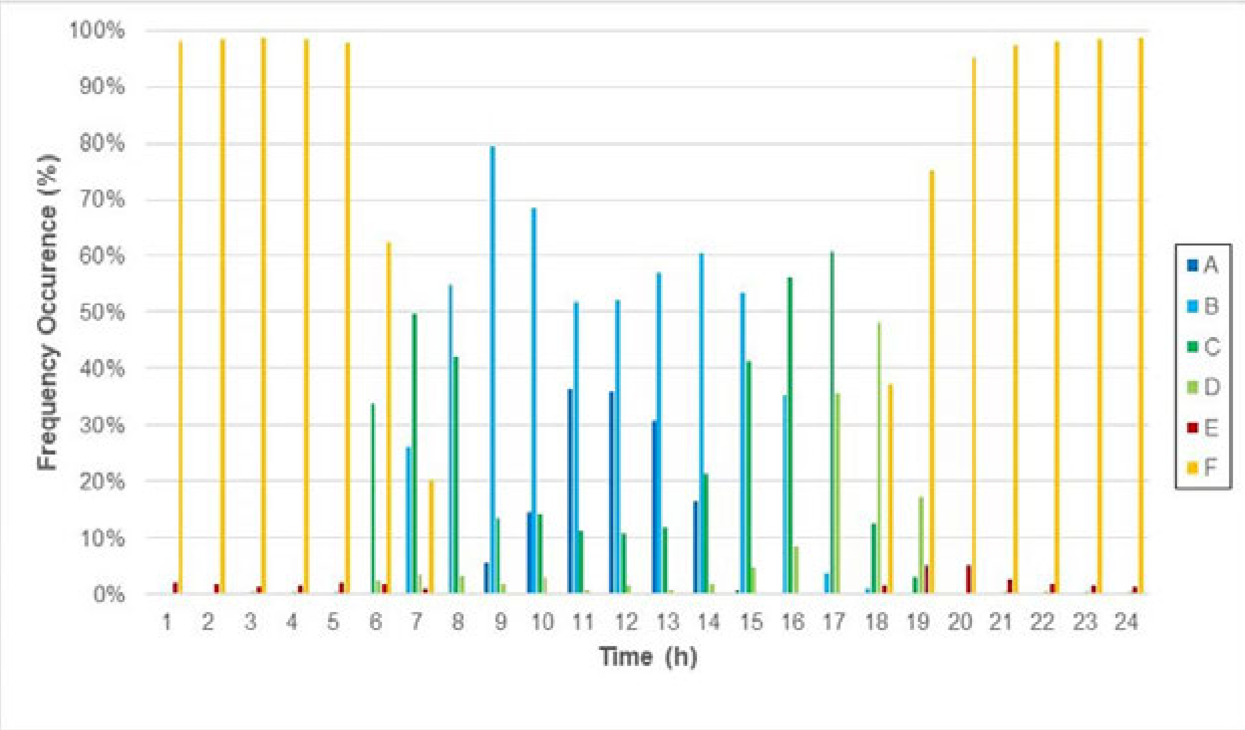


Figure 5.5 Hourly stability class frequency for Beaudesert Drumley Street Bureau of Meteorology station (CALMET generated)

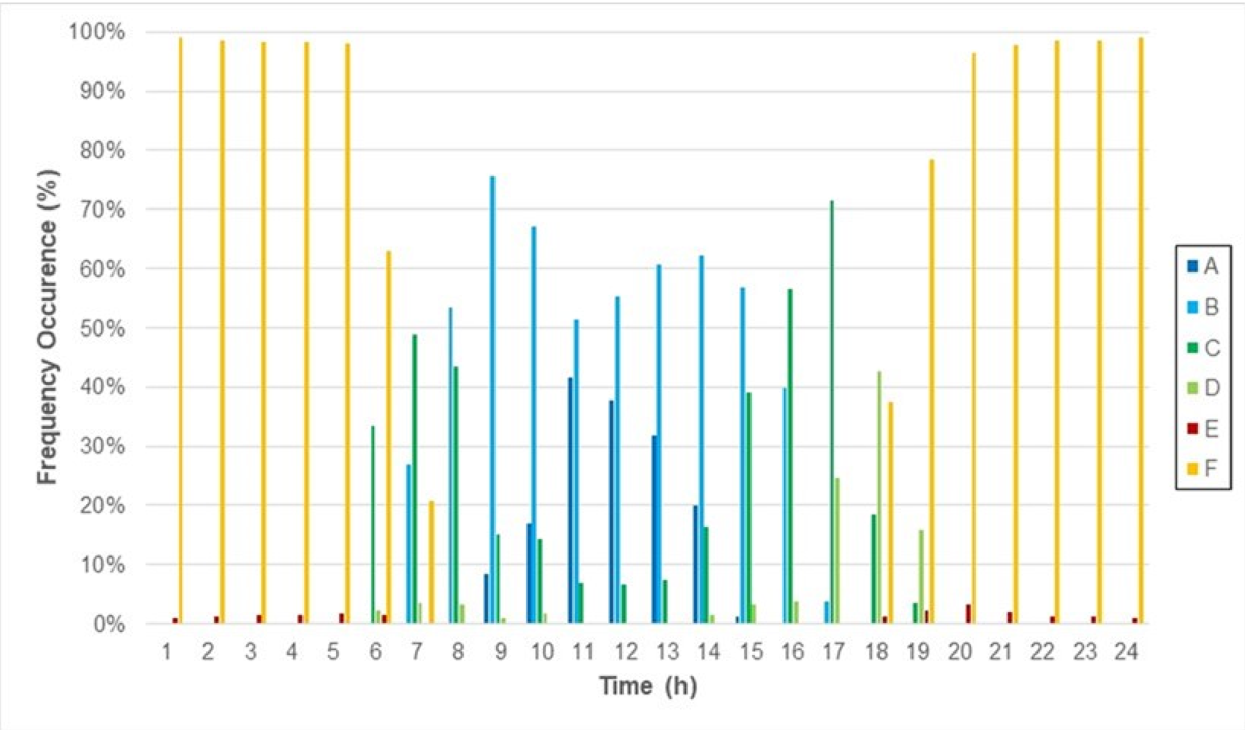


Figure 5.6 Hourly stability class frequency for Teviot Range Tunnel western portal (CALMET generated)

5.1.5 Mixing height

Mixing height is estimated within CALMET for stable and convective conditions (respectively), with a minimum mixing height of 50 m. Figure 5.7 to Figure 5.9 present mixing height statistics by hour of day across the meteorological dataset (2013) as generated by CALMET at the Mutdapilly DES station, Beaudesert Drumley Street BoM station and the Teviot Range Tunnel western portal locations. These results are consistent with general atmospheric processes that show increased vertical mixing with the progression of the day, as well as lower mixing heights during night time. In addition, peak mixing heights are consistent with typical ranges.

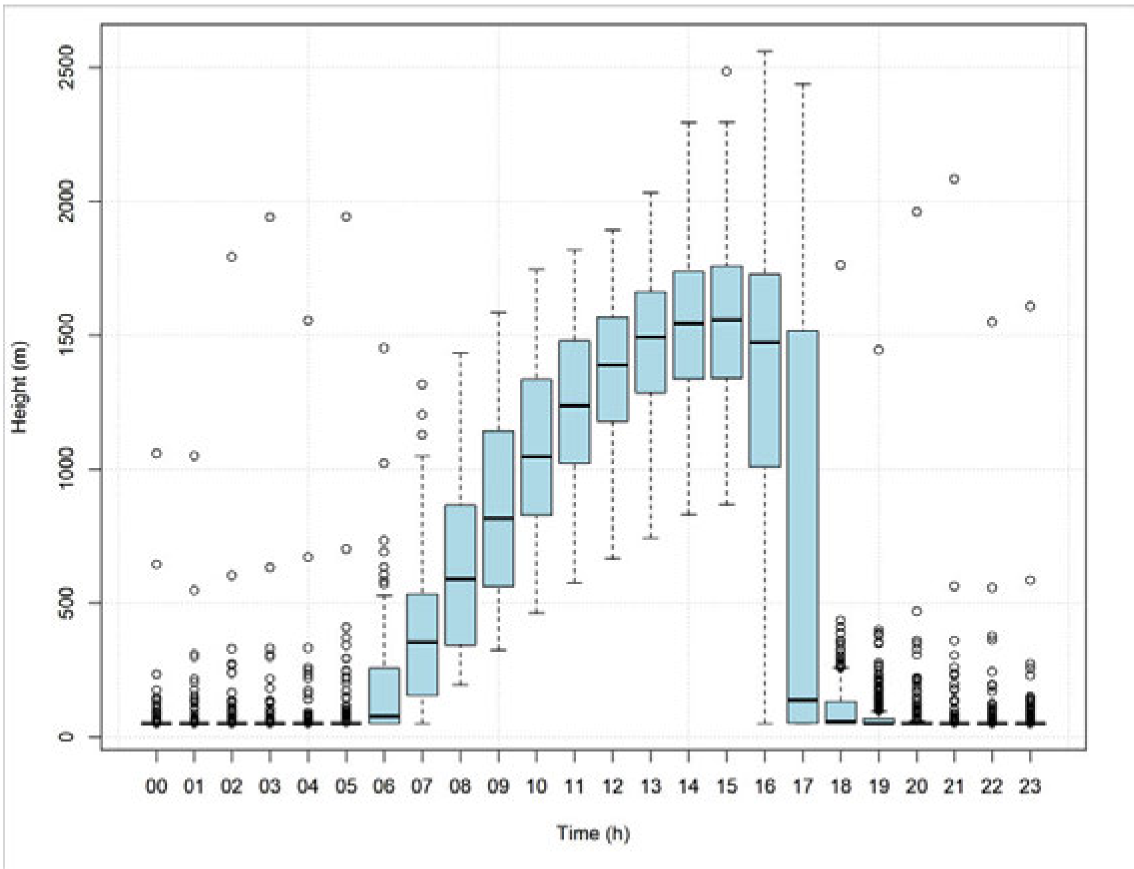


Figure 5.7 **Mixing height statistics by hour of day for Mutdapilly Department of Environment and Science station (CALMET generated)**

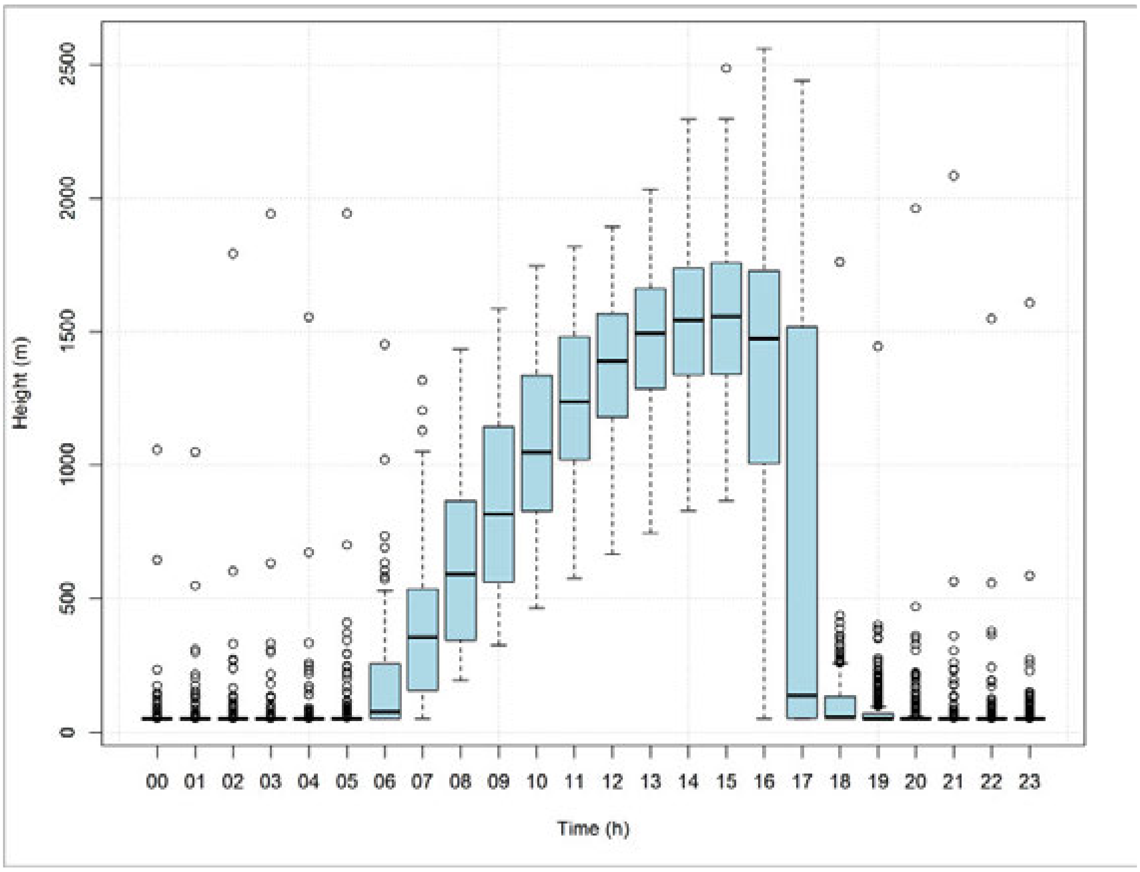


Figure 5.8 **Mixing height statistics by hour of day for Beaudesert Drumley Street Bureau of Meteorology station (CALMET generated)**

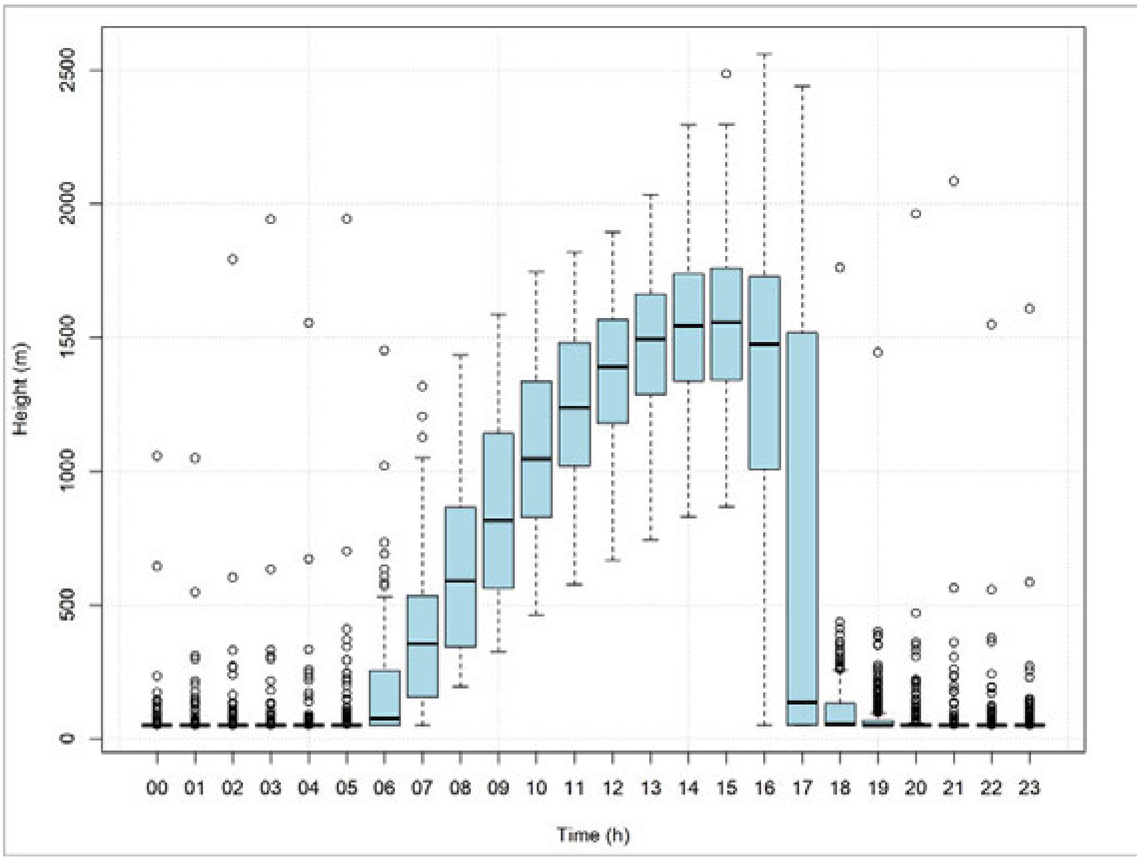


Figure 5.9 **Mixing height statistics by hour of day for Teviot Range Tunnel western portal (CALMET generated)**

5.2 Background air quality

In order to characterise the existing air quality values in the air quality study area, a review of available air quality monitoring data was conducted using publicly available data from DES (DES 2019a) and dust deposition monitoring data from monitoring undertaken for the Inland Rail Project in 2016.

DES has an ambient monitoring network across QLD that monitors for controlled pollutants in areas with large population bases or heavy industry adjacent to residential areas. There are no DES monitoring stations in the air quality study area. However, due to the length of the Project five DES monitoring stations are located in the surrounding regional area. These stations are Flinders View, Mutdapilly, North Maclean, Rocklea and Springwood; all of which are situated to the east of Toowoomba. Due to their location, monitoring data from these five stations can be reliably extrapolated for the assessment of background air quality for the air quality study area. The locations of the DES monitoring stations are shown in Figure 5.1.

Preference was given to the stations closest to the alignment and in a similar environment; however, not all pollutants species of interest are measured at each monitoring station. The Rocklea and Springwood stations are located a significant distance (35 km) from the proposed alignment, but have been considered as they are both neighbourhood type monitoring stations and provide an indication of the potential background air quality in the air quality study area. The Springwood monitoring station is also the only monitoring station which monitors VOCs, and therefore it has been considered to provide background concentrations for VOC species.

Monitoring data from DES stations from 2010 to 2017 has been reviewed, as this is the most recent available monitoring data. Monitoring data for 2018 was not available at the time the assessment was undertaken. The details of the DES stations considered in the assessment, including the pollutants monitored are presented in Table 5.5. The dust deposition monitoring data used in the assessment is presented in Section 5.2.3.

Table 5.5 Department of Environment and Science monitoring stations

Station name	Location	Location relative to alignment	Pollutants monitored
Flinders View	27.6528° S, 152.7741° E	10 km NW, in a residential area near a major roadway	NO_x, O_3, SO_2, PM_{10}
Mutdapilly	27.7528° S, 152.6509° E	5 km, between Calvert and Kagaru	NO_x, O_3
North Maclean	27.7708° S, 153.0030° E	15 km NE of Kagaru	NO_x, O_3
Rocklea	27.5358° S, 152.9934° E	35 km NE of Kagaru, in a light industrial and residential area	NO_x, O_3, PM_{10}, $PM_{2.5}$ and visibility-reducing particles.
Springwood	27.6125° S, 153.1356° E	35 km ENE of Kagaru, in the grounds of a high school	NO_x, O_3, SO_2, PM_{10}, $PM_{2.5}$ and VOCs (organic pollutants)

Table 5.5 shows that the pollutant species of interest which are monitored at the DES monitoring stations include NO_x, PM_{10}, $PM_{2.5}$ and VOCs. Monitoring of metals (e.g. arsenic, cadmium, etc) is not undertaken at any of the identified DES stations, but is undertaken at stations located in Townsville (Townsville Coast Guard) and Mt Isa (The Gap). However, the monitoring stations are located at in these areas due to the presence of heavy industrial activities which emit metals. Therefore these monitoring stations are not considered representative of background air quality and the monitoring data from these stations has not been considered in the assessment.

VOC monitoring at Springwood is undertaken specifically for benzene, toluene, xylene and formaldehyde. Monitoring of PAHs, 1,3-butadiene, dioxins and furans is not undertaken at Springwood or at any other DES monitoring stations in QLD, and therefore no background air quality data is available for these species.

The Project is not expected to emit significant quantities of metals, PAHs, 1,3-butadiene, dioxins and furans and the risk of exceeding the air quality goals for these species is considered to be low. Therefore monitoring of these pollutants has not been undertaken.

An air quality monitoring program was undertaken for the Inland Rail Program, with an air quality monitoring station (Inland Rail AQMS) installed at the InterLinkSQ site at Leeson Road, Gowrie. The station is located immediately adjacent to the northern end of the NSW Border to Gowrie (B2G) phase of the Inland Rail Program. The DES air quality monitoring stations described in Table 5.5 are located closer to the Project than the Inland Rail AQMS and therefore monitoring data from the Inland Rail AQMS has not been considered in the assessment.

5.2.1 Data analysis and availability

The DES datasets from additional monitoring locations reviewed below were sourced as validated datasets; however, the data do contain gaps that are either missing monitoring data or subsequently invalidated by DES. Data is considered to be representative of actual pollutant concentrations in the air at the time of monitoring. The datasets consist of hourly averages that have been summarised and analysed for the required averaging periods. Where there was less than 75 per cent available valid data for an averaging period, then that averaging period was not calculated. Annual averages were considered valid when at least three of the year's quarterly periods had a data availability threshold of at least 75 per cent, as per guidance from NEPM technical paper Data Collection and Handling (2001).

5.2.2 Particulate matter

Particulate matter is measured at three of the identified stations: Flinders View (PM_{10} only), Rocklea and Springwood (both PM_{10} and $PM_{2.5}$). As shown in Figure 5.1, the Flinders View station is located approximately 10 km to the north east of the alignment, and the Rocklea and Springwood stations are located approximately 35 km from the alignment in the same direction.

5.2.2.1 PM10

Available PM_{10} concentration data from Flinders View, Rocklea and Springwood from 2010 to 2017 has been analysed. Daily and annual average PM_{10} concentrations are presented in Table 5.6 and Table 5.7 in addition to the relevant air quality goals.

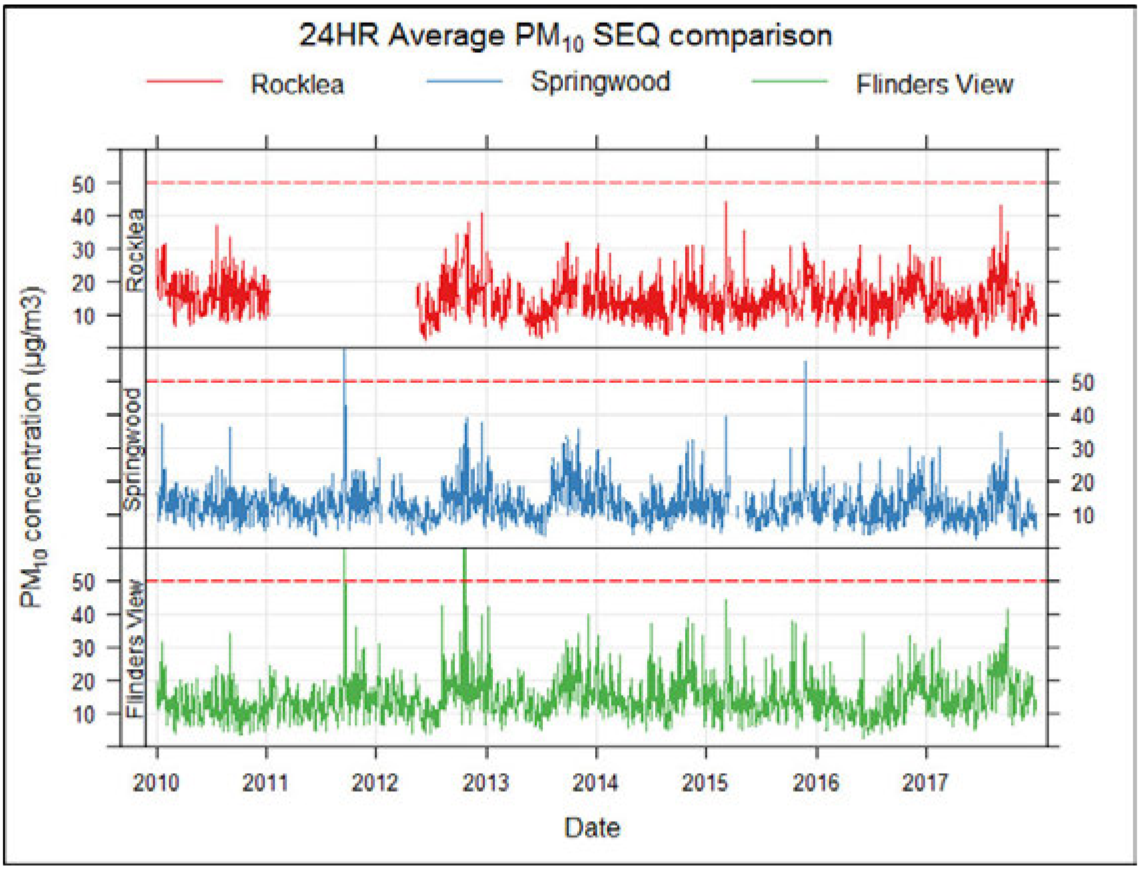


Figure 5.10 24 hour PM_{10} averages at Rocklea, Springwood, and Flinders View Department of Environment and Science monitoring stations

Table 5.6 24 hour PM_{10} concentrations (µg/m^3) for Rocklea, Springwood and Flinders View

Monitoring station	2010	2011	2012	2013	2014	2015	2016	2017
Maximum 24 hour average concentration								
Rocklea	36.8	20.4	41.0	32.2	31.6	<u>44.0</u>	31.2	43.2
Springwood	37.1	**<u>61.2</u>**	39.2	35.4	32.7	**56.1**	30.6	34.4
Flinders View	33.9	**67.0**	**<u>73.8</u>**	42.2	38.8	44.5	34.0	41.2
Number of exceedances								
Rocklea	0	0	0	0	0	0	0	0
Springwood	0	2	0	0	0	1	0	0
Flinders View	0	2	2	0	0	0	0	0
Highest concentration below criterion								
Rocklea	36.8	20.4	41.0	32.2	31.6	<u>44.0</u>	31.2	43.2
Springwood	37.1	<u>39.8</u>	39.2	35.4	32.7	39.6	30.6	34.4
Flinders View	33.9	35.8	<u>42.7</u>	42.2	38.8	44.5	34.0	41.2
70th Percentile 24 hour average concentration								
Rocklea	<u>18.8</u>	17.4	17.9	16.5	15.6	16.8	17.2	16.5
Springwood	14.5	14.6	14.7	<u>16.0</u>	13.9	14.3	14.3	13.5
Flinders View	13.9	15.6	16.7	17.2	17.8	16.0	15.4	<u>18.7</u>
EPP (Air) Criterion	**50**							

Table note:
Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

From review of the analysed data, several exceedances of the PM_{10} daily criterion (50 µg/m^3) were observed for the Springwood and Flinders View monitoring stations. These exceedances were recorded in 2011, 2012, and 2015, with the highest recorded concentrations at Springwood 73.8 µg/m^3 (2012) and 61.2 µg/m^3 (2011) for Flinders View. According to Department of Science, Information Technology and Innovation (2012, 2013), all exceedances in 2011 and 2012 at SEQ monitoring sites were the result of bushfire smoke. The exceedance recorded at the Springwood monitoring station in 2015 was cited to be resultant from localised sources and unlikely to be from industry or motor vehicle emissions (DSITI 2016). The highest recorded concentration at the Rocklea monitoring station occurred in 2015, with a maximum 24 hour concentration of 44.0 µg/m^3 (6 March 2015). As a peak concentration can be observed on this date for the Springwood and Flinders View stations, it is likely that this high concentration was resultant of a regional source such as a bushfire or regional dust event.

Table 5.7 Annual PM_{10} averages (µg/m^3) for Rocklea, Springwood and Flinders View

Monitoring station	2010	2011	2012	2013	2014	2015	2016	2017
Rocklea	16.7	-	15.1	14.2	14.0	14.9	15.1	14.3
Springwood	12.9	13.3	13.2	14.2	13.1	12.5	12.4	11.7
Flinders View	12.2	14.1	15.0	15.0	15.9	14.6	13.1	16.2
NEPM Criterion	**25**							

Table note:

Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

Analysis of the annual PM_{10} concentrations showed no exceedance of NEPM annual criterion. Rocklea annual averages ranged from 14.0 µg/m^3 (2014) to 16.7 µg/m^3 (2010). Concentrations from the Springwood station were consistently equal to or lower than those recorded at Rocklea, ranging from 11.7 µg/m^3 (2017) to 14.2 µg/m^3 (2013). Comparatively, Flinders View show greater variability than the other two stations with annual averages at this location ranging from 12.2 µg/m^3 to 15.9 µg/m^3.

Based upon the closer proximity of the Flinders View monitoring station to the Project in comparison to the Rocklea and Springwood monitoring stations, it is likely more representative of the PM_{10} concentrations expected within the Project location.

5.2.2.2 PM2.5

The past six years of available $PM_{2.5}$ concentration data has been reviewed from the Rocklea and Springwood stations for 24 hour averages. To provide regional context, additional data from the following monitoring stations further from the Project have been included in the analysis of annual concentrations:

- Wynnum North, Wynnum West, Lytton, and Cannon Hill (industry operated)
- Woolloongabba, South Brisbane, Rocklea, and Springwood (DES operated).

Daily averages for these stations are presented in Table 5.8 and compared with the relevant air quality goals. Daily PM_{10} concentrations for Springwood and Rocklea are also presented in Table 5.11.

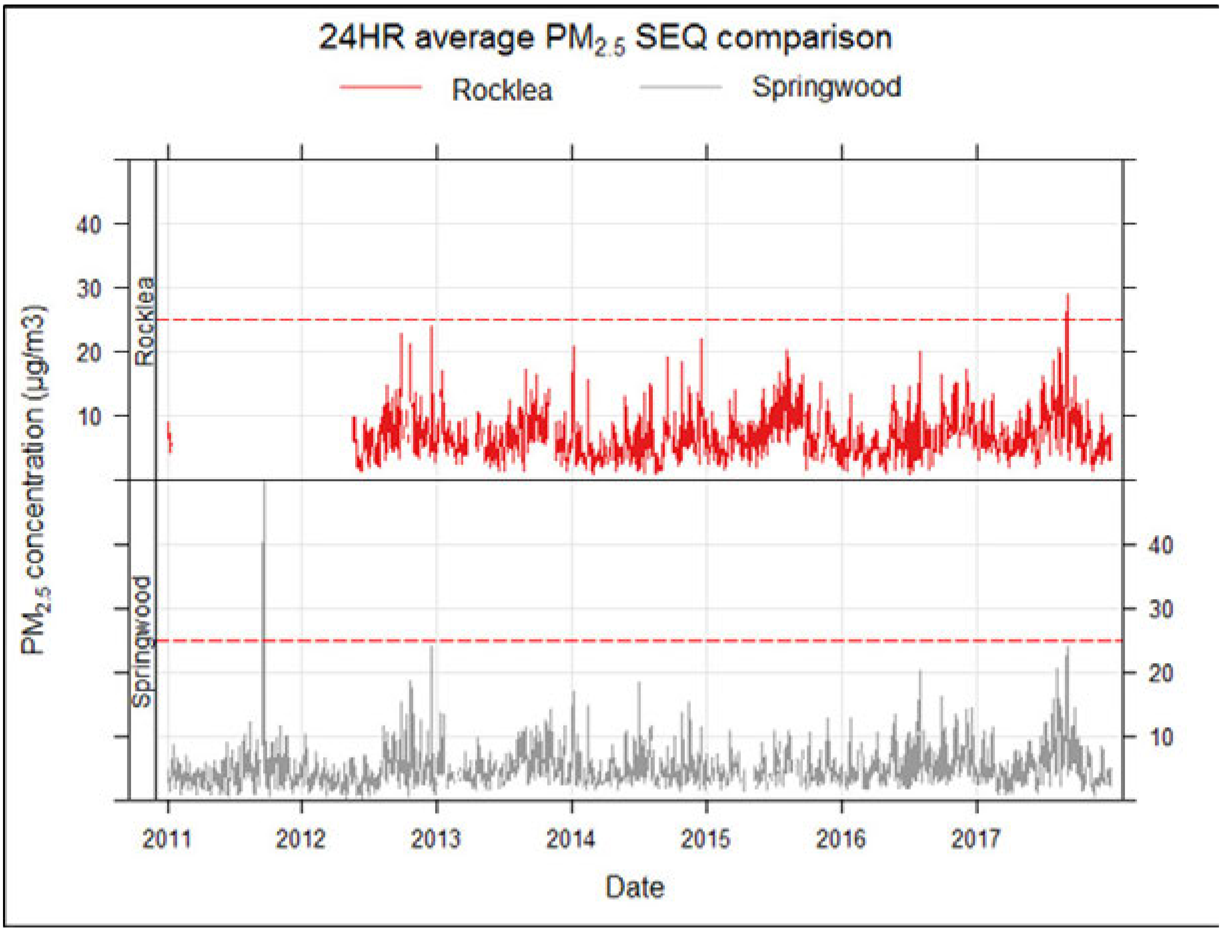


Figure 5.11 **24 hour $PM_{2.5}$ averages at Rocklea and Springwood monitoring stations**

Table 5.8 **24 hour $PM_{2.5}$ concentrations (µg/m^3) for Rocklea and Springwood**

Monitoring station	2011	2012	2013	2014	2015	2016	2017
Maximum 24 hour average concentration							
Rocklea	8.8	23.7	17.2	21.9	20.3	19.9	**28.9**
Springwood	**51.2**	23.7	14.2	18.4	12.6	20.1	23.9
Number of exceedances							
Rocklea	0	0	0	0	0	0	1
Springwood	3	0	0	0	0	0	0
Highest concentration below criterion							
Rocklea	8.8	23.7	17.2	21.9	20.3	19.9	23.3
Springwood	16.4	23.7	14.2	18.4	12.6	20.1	23.9
70th Percentile 24 hour average concentration							
Rocklea	-	8.1	7.6	6.6	8.8	7.8	8.3
Springwood	4.8	5.1	6.0	5.5	5.1	6.4	6.1
EPP (Air) Criterion	**25**						

Table notes:

Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

The EPP (Air) 24 hour average $PM_{2.5}$ criterion of 25 µg/m3 was exceeded once at Rocklea in 2017 and three times at Springwood in 2011. According to the QLD air monitoring reports from 2011 and 2017 (DSITI 2012, DES 2018), all $PM_{2.5}$ exceedances recorded at Rocklea and Springwood were due to bushfire smoke.

For the measurement of fine particulate matter, especially $PM_{2.5}$, it is important to understand the measurement methodology utilised. At all of the monitoring stations considered, $PM_{2.5}$ is measured utilising dichotomous tapered element oscillation microbalance (TEOM) following Australian Standard methodologies. In SEQ select monitoring stations utilise filter dynamics measurement systems (FDMS), which are an additional attachment to the TEOM measurement instruments. A FDMS system compensates for the loss of semi-volatile components from the collected particulate matter. This is especially important in the quantification of fine particulate matter, as semi-volatile components can make up a considerable proportion of measured particulate matter. Accordingly, monitoring by TEOM methods utilising a FDMS will likely result in higher measured $PM_{2.5}$ concentrations, presuming there is a significant semi-volatiles component. A significant semi-volatiles component would be expected in urban areas where emissions from industry and motor vehicles are present. Conversely, a TEOM $PM_{2.5}$ particulate monitoring instrument without an installed FDMS may underestimate concentrations, should a significant semi-volatile component be present. Therefore, it is an important consideration when interpreting $PM_{2.5}$ monitoring data to understand the monitoring methodology.

Table 5.9 presents the SEQ monitoring stations and whether FDMS instrumentation is used. Also, the monitoring station type is presented, as classified by the Ambient Air Quality NEPM.

Table 5.9 Monitoring stations types in SEQ and installed $PM_{2.5}$ TEOM with FDMS

Site	Station type	2011	2012	2013	2014	2015	2016	2017
		FDMS Installed on $PM_{2.5}$ TEOM						
Rocklea	GRUB[a]	-	-	Yes	Yes	Yes	Yes	Yes
Springwood	PMS[b] – Population Average	No	No	No	No	No	Yes[c]	Yes
Wynnum North	Industry operated	No	No	No	No	No	No	No
Wynnum West	Industry operated	-	-	-	No	No	No	No
Cannon Hill	Industry operated	-	-	-	Yes	Yes	Yes	Yes
Lytton	Industry operated	-	-	-	No	No	No	No
South Brisbane	Peak (roadside)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Woolloongabba	Peak (roadside)	Yes	Yes	Yes	Yes	-	-	Yes

Table notes:

a GRUB – Generally representative upper bound

b PMS – Performance monitoring station: nominated location to measure achievement against the goal of AAQ NEPM.

c FDMS installed on $PM_{2.5}$ TEOM at Springwood monitoring station on 25 February 2016.

The Wynnum North, Wynnum West, and Lytton monitoring stations are operated by Caltex Refineries (QLD) Ltd in order to assess the impacts of the Caltex Refinery emissions on nearby residential areas. The Cannon Hill monitoring station is situated next to the metropolitan rail line used to transport coal to the Port of Brisbane. The station measures particulate levels to assess the progress of ongoing measures to investigate coal dust emissions from rail wagons.

Average annual $PM_{2.5}$ concentrations for the period of 2011 to 2017 are presented in Table 5.10.

Table 5.10 Annual $PM_{2.5}$ averages (µg/m³) for monitoring stations in SEQ

$PM_{2.5}$ annual average (µg/m³)	2011	2012	2013	2014	2015	2016	2017
Rocklea	-	-	6.6	5.8	<u>7.3</u>	6.5	<u>7.3</u>
Springwood	4.4	4.4	5.2	4.9	4.5	<u>5.7</u>	5.4
Wynnum North	<u>5.0</u>	4.4	4.8	4.7	3.9	4.4	4.1
Wynnum West	-	-	-	<u>4.2</u>	3.4	3.9	3.9
Cannon Hill	-	-	-	5.0	4.3	4.9	<u>5.2</u>
Lytton	-	-	-	**<u>9.1</u>**	6.9	7.7	6.0
South Brisbane	7.0	6.8	7.8	7.0	7.4	**<u>8.3</u>**	7.7

$PM_{2.5}$ annual average (µg/m^3)	2011	2012	2013	2014	2015	2016	2017
Woolloongabba	**8.7**	7.8	8.0	7.4	-	-	-
EPP (Air) Criterion	**8**						

Table note:

Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

No exceedances were measured for the Rocklea and Springwood monitoring stations for the period of 2011 to 2017. At the Rocklea monitoring location, annual average $PM_{2.5}$ ranges from 5.8 µg/m^3 (2014) to 7.3 µg/m^3 (2015 and 2017), although full datasets prior to 2013 were not available. The Rocklea station is located in a residential area in the centre of a field and floodplain with light industrial emissions sources nearby. Annual average $PM_{2.5}$ concentrations at Springwood are lower in comparison, ranging from 4.4 µg/m^3 (2011 and 2012) to 5.7 µg/m^3 (2016). For Springwood, the years 2016 and 2017 represent the highest measurement concentrations. This is likely a result of the installation of FDMS on the $PM_{2.5}$ TEOM in early 2016 enabling a more robust representation of the actual $PM_{2.5}$ concentrations. The Springwood monitoring station has no major emissions sources nearby and is classified as a 'performance monitoring station' as per the Ambient Air Quality NEPM, which is to be located in area that will provide a representative measure of the air quality likely to be experienced by the general population in a region or sub-region.

The Lytton monitoring site recorded the single highest annual $PM_{2.5}$ concentration at 9.1 µg/m^3 (2014), exceeding the annual EPP (Air) $PM_{2.5}$ criterion of 8 µg/m^3. This concentration is considered likely to be a measurement of emissions from the nearby Lytton Refinery. The South Brisbane and Woolloongabba monitoring sites represent the highest average measured concentrations, ranging from 7.0 µg/m^3 (2011 and 2014) to 8.7 µg/m^3 (2011). These elevated concentrations are expected due to the monitoring locations close proximity to high traffic areas. The Wynnum North and Wynnum West sites show no exceedances of the $PM_{2.5}$ criterion, with concentrations ranging from 3.4 µg/m^3 (2015) to 5.0 µg/m^3 (2011). The Wynnum monitoring sites are located within residential areas with no major emissions sources nearby, which is a probable cause for the lowest measured concentrations of all the SEQ stations. Also, these monitoring stations do not have FDMS installed on the $PM_{2.5}$ TEOM instruments, which is likely an attributing factor to the measured low $PM_{2.5}$ concentrations.

From the $PM_{2.5}$ monitoring locations analysed few represent a good choice that would be representative of Project location due to significant industrial and traffic sources near the monitoring locations. The Wynnum North and Wynnum West locations could possibly provide accurate estimates for $PM_{2.5}$ concentrations in the region due to the absence of local emission sources nearby. However, as the TEOM instrumentation used do not have FDMS, measured concentrations have potential to be underestimates; and as such, they are considered not suitable sources of background data. All other air quality monitoring stations, with the exception of Springwood, are situated in close proximity of local emission sources that positively bias the measured $PM_{2.5}$ concentrations. Therefore, due to the lack of localised emissions and the use suitable monitoring equipment, data from the 2016 and 2017 periods of Springwood represent the best estimates of background $PM_{2.5}$ for SEQ and the Project.

5.2.2.3 Total suspended particulates

There are no measured values that were sampled using compliant methodologies for TSP in the DES data. Consequently, TSP was estimated from the measured annual PM_{10} using a ratio of 2.5, which is based on a PM_{10}:TSP ratio of 0.4 as reported by the Australian Coal Association Research Program (ACARP, 1999). This ratio is commonly applied for air quality assessments in QLD. This is considered a conservative estimate and is likely an over estimation of the actual TSP present. However, this is a common ratio for dust and is considered appropriate in the absence of recently monitored data. Table 5.11 presents the derived annual average TSP concentrations for the Rocklea, Springwood, and Flinders View stations.

Table 5.11 Calculated annual TSP averages (µg/m³) for Rocklea, Springwood and Flinders View

Monitoring station	2010	2011	2012	2013	2014	2015	2016	2017
Rocklea	41.8	-	37.8	35.5	35.0	37.3	37.8	35.8
Springwood	32.3	33.3	33.0	35.5	32.8	31.3	31.0	29.3
Flinders View	30.5	35.3	37.5	37.5	39.8	36.5	32.8	40.5
EPP (Air) Criterion	**90**							

Table notes:
Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

5.2.3 Deposited dust

A short, three-month deposited dust monitoring program was conducted for the Inland Rail Project in 2016, as part of the Yelarbon to Gowrie (Y2G) Preliminary Environmental Assessment (PEA) Report (AECOM 2017). The monitoring was conducted at four sites in accordance with AS/NZS 3580.10.1:2003. The locations of each site and dust deposition rates (reported as total insoluble solids) are presented in Figure 5.1 and Table 5.12. The highest measured rate of 50 mg/m²/day (measured at Site 3 during May/June 2016) has been adopted as the background concentration for the air quality impact assessment.

Table 5.12 Deposited dust concentrations measured for the Project

Site	Location (UTM, zone 56)	Dust deposition Rate (mg/m²/day)		
Monitoring period		**3/05/2016 - 2/06/2016**	**2/06/2016 - 30/06/2016**	**30/06/2016 - 28/07/2016**
Site 2 (Brookstead)	347243 m E, 6928614 m S	27	36	29
Site 3 (Pampas)	343377 m E, 6924651 m S	50	36	25
Site 4 (Mt Tyson)	358930 m E, 6949387 m S	20	25	18
Site 5 (Aubigny)	369867 m E, 6956982 m S	40	36	18

5.2.4 Nitrogen dioxide

The Mutdapilly, Flinders View, and North Maclean monitoring stations measure NO_2 and are all located within 15 km of the Project alignment. The Mutdapilly monitoring site is located the closest at 5 km from the proposed alignment and is close to the centre of the air quality study area. As this site has no local emissions sources, it provides an ideal source of background data for NO_2.

Maximum 1 hour and annual average NO_2 concentrations for Mutdapilly, North Maclean, and Flinders View from the period of 2010 to 2017 are presented in Table 5.13 and Table 5.14.

Table 5.13 1 hour NO_2 maximum concentrations (µg/m³) for Mutdapilly, North Maclean, and Flinders View

Monitoring station	2010	2011	2012	2013	2014	2015	2016	2017
Maximum 1 hour concentration (µg/m³)								
Mutdapilly	69.8	55.4	51.3	57.5	59.6	53.4	69.8	69.8
North Maclean	51.3	47.2	39.0	39.0	51.3	45.2	57.5	53.4
Flinders View	80.1	82.1	80.1	86.3	102.7	84.2	94.5	90.4
EPP (Air) Criterion	**246**							

Table note:
Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

Table 5.14 Annual NO_2 average concentrations (µg/m^3) for Mutdapilly, North Maclean, and Flinders View

Monitoring station	2010	2011	2012	2013	2014	2015	2016	2017
Annual average concentration (µg/m^3)								
Mutdapilly	6.5	8.3	7.2	7.7	6.9	6.5	7.6	7.6
North Maclean	6.1	5.4	5.3	5.8	6.5	6.6	7.0	6.8
Flinders View	16.4	16.3	13.9	14.4	16.4	13.0	16.3	14.1
EPP (Air) Criterion	**62**							

Table note:

Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

5.2.5 Volatile organic compounds

Of all the monitoring stations considered for the assessment, toluene, xylenes, and benzene are only recorded at Springwood. The Springwood station is located 35 km east north east of the alignment in a built up residential area close to a major traffic corridor. Background concentrations based on Springwood data have been calculated and adopted. However, due to the differing nature of the station's location (in contrast to the study area) and concentrations should be considered conservative. Table 5.15, Table 5.16 and Table 5.17 present the measured concentrations for toluene, xylenes, and benzene at the Springwood station for the period of 2010 to 2017.

Table 5.15 1 hour toluene concentrations (µg/m^3) for Springwood

Pollutant	201	2011	2012	2013	2014	2015	2016	2017
Maximum 1 hour concentration								
Toluene	71.5	207	182	299	535	497	164	678
70th Percentile 1 hour average concentration								
Toluene	6.6	7.8	16.4	19.3	20.1	21.8	23.0	8.6
EPP (Air) Criterion	**1,100**[a.]							

Table notes:

a 30 minute average as per the EPP (Air)

b Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

Table 5.16 24 hour toluene and xylenes concentrations (µg/m^3) for Springwood

Pollutant	2010	2011	2012	2013	2014	2015	2016	2017
Maximum 24 hour concentration								
Toluene	15.6	18.4	37.3	37.3	88.6	52.9	46.6	107
Xylenes	25.3	31.1	30.3	18.2	19.1	18.9	28.5	43.8
70th Percentile 24 hour average concentration								
Toluene	6.6	7.6	15.6	18.9	19.0	19.4	21.7	8.9
Xylenes	13.3	19.5	15.5	13.3	12.6	15.4	16.2	31.5
EPP (Air) Criterion	**4,100** – Toluene **1,200** – Xylenes							

Table notes:

Highest monitored concentrations for the year are underlined, with exceedances of assessment criterion presented in bold.

Table 5.17 Annual benzene average concentrations (µg/m³) for Springwood

Pollutant	2010	2011	2012	2013	2014	2015	2016	2017
Benzene	2.5	3.9	3.1	2.5	2.4	3.0	3.3	5.2[a]
Toluene	5.9	6.9	14.0	16.2	17.5	18.5	17.8	8.1
Xylenes	11.9	18.3	14.6	12.0	11.4	14.2	15.8	26.0
EPP (Air) Criterion	**5.4** – Benzene **410** – Toluene **950** – Xylenes							

Table notes:

Highest monitored concentrations for the year are underlined.

a. The background concentration for the Springwood monitoring station for 2017 had been reported by DES as 5.5 µg/m³. FFJV were advised by DES on 17/01/2020 that as part of the review of the 2018 Springwood hourly dataset, DES identified that an incorrect offset had been applied to part of the 2017 Springwood benzene dataset. The corrected 2017 Springwood dataset results in an annual average of 5.2 µg/m³.

No exceedances of the annual benzene EPP (Air) criterion were recorded, with measured concentrations ranging from 2.4 ug/m³ (2014) to 5.2 µg/m³ (2017).

5.2.6 Adopted background air quality

Table 5.18 summarises the existing environment background concentrations adopted for the air quality assessment. In accordance with the BCC AQPSP (2014) the 70th percentile concentration was selected as the adopted background concentration for assessment of the 24-hour average goals for PM_{10}, $PM_{2.5}$, toluene and xylene, and the 1-hour goal for toluene.

Table 5.18 Summary of adopted existing pollutant concentrations compared to adopted air quality goals

Pollutant	Averaging time and statistic	Adopted air quality goal (µg/m³)	Adopted background concentration (µg/m³)	Monitoring location
Deposited dust	30 days, maximum	120 mg/m²/day	50 mg/m²/day	4 locations along the alignment (Y2G PEA)
Nitrogen dioxide (NO_2)	1 hour, maximum	246	57.5	Mutdapilly
	Annual average	62	7.8	
TSP	Annual average	90	40.5[a.]	Flinders View
PM_{10}	24 hours, 70th percentile	50	18.7	
	Annual average	25	16.2	
$PM_{2.5}$	24 hours, 70th percentile	25	6.4	Springwood
	Annual average	8	5.7	
Benzene	Annual average	5.4	5.2 [b]	
Toluene	1 hour, 70th percentile	1,100	23.0	
	24 hours, 70th percentile	4,100	21.7	
	Annual average	400	18.5	
Xylenes	24 hours, 70th percentile	1,200	31.5	
	Annual average	950	26.0	

Table note:

a Calculated from PM_{10} concentrations measured at Flinders View using a ratio of 2.5 which is based on a PM_{10}:TSP ratio of 0.4 as reported by the Australian Coal Association Research Program (ACARP, 1999).

b. The background concentration for the Springwood monitoring station for 2017 had been previously reported by DES as 5.5 µg/m³. FFJV were advised by DES on 17/01/2020 that as part of the review of the 2018 Springwood hourly dataset, DES identified that an incorrect offset had been applied to part of the 2017 Springwood benzene dataset. The corrected 2017 Springwood dataset results in an annual average of 5.2 µg/m³.

5.2.7 Assimilative capacity of the receiving environment

The assimilative capacity of the receiving air environment can be quantified through the difference between these adopted background concentrations and the air goals defined in Table 3.1. For most pollutants and averaging times, the background concentrations represent less than half of the criteria, indicating a moderate assimilative capacity of the receiving environment. Pollutants that show lower levels of assimilative capacity include the following:

- PM_{10} 16.2 µg/m^3 annual average, representing 65 per cent of the 25 µg/m^3 criterion
- $PM_{2.5}$ 5.7 µg/m^3 annual average, representing 71 per cent of the 8 µg/m^3 annual criterion
- Benzene 5.2 µg/m^3 annual average, representing 96.3 per cent of the 5.4 µg/m^3 annual criterion.

5.2.8 Consideration of climate change influence on background air quality

Changing climatic conditions due to climate change also has the ability to influence ambient air quality via increased frequency of atypical events such as bushfires and dust storms. However, it is considered difficult to confidently predict the influence of climate change on the duration, frequency and magnitude of extreme air quality events. It is also highlighted that in comparative terms, emissions from the operation of the Project could be considered insignificant in comparison to major regional air quality events such as bushfires and dust storms. Due to the uncertainty which would be inherent in assessing the influence of changing climatic conditions due to climate change on the background air quality, climate change has not been considered beyond the bushfires and dust storms that are already present in the datasets used to establish the existing environment background concentrations adopted for the air quality assessment.

5.2.9 Existing emission sources

The NPI, regulated by the Australian Government is tracking pollution across Australia, and ensuring that the community has access to information about the emission and transfer of toxic substances which may affect them locally. All major polluters are required by the Australian Government to submit annual reports of their emissions to air. The NPI has emission estimates for 93 toxic substances and the source and location of these emissions. These substances have been identified as important due to their possible effect on human health and the environment. The data comes from facilities like mines, power stations and factories, as well as other sources. NPI data has a tendency to be a conservative over estimate of industry emissions for sites like quarries and mines due to the broad and generalised assumptions made during the emission estimations.

An NPI search conducted for the air quality study area shows two nearby facilities required to report emissions annually:

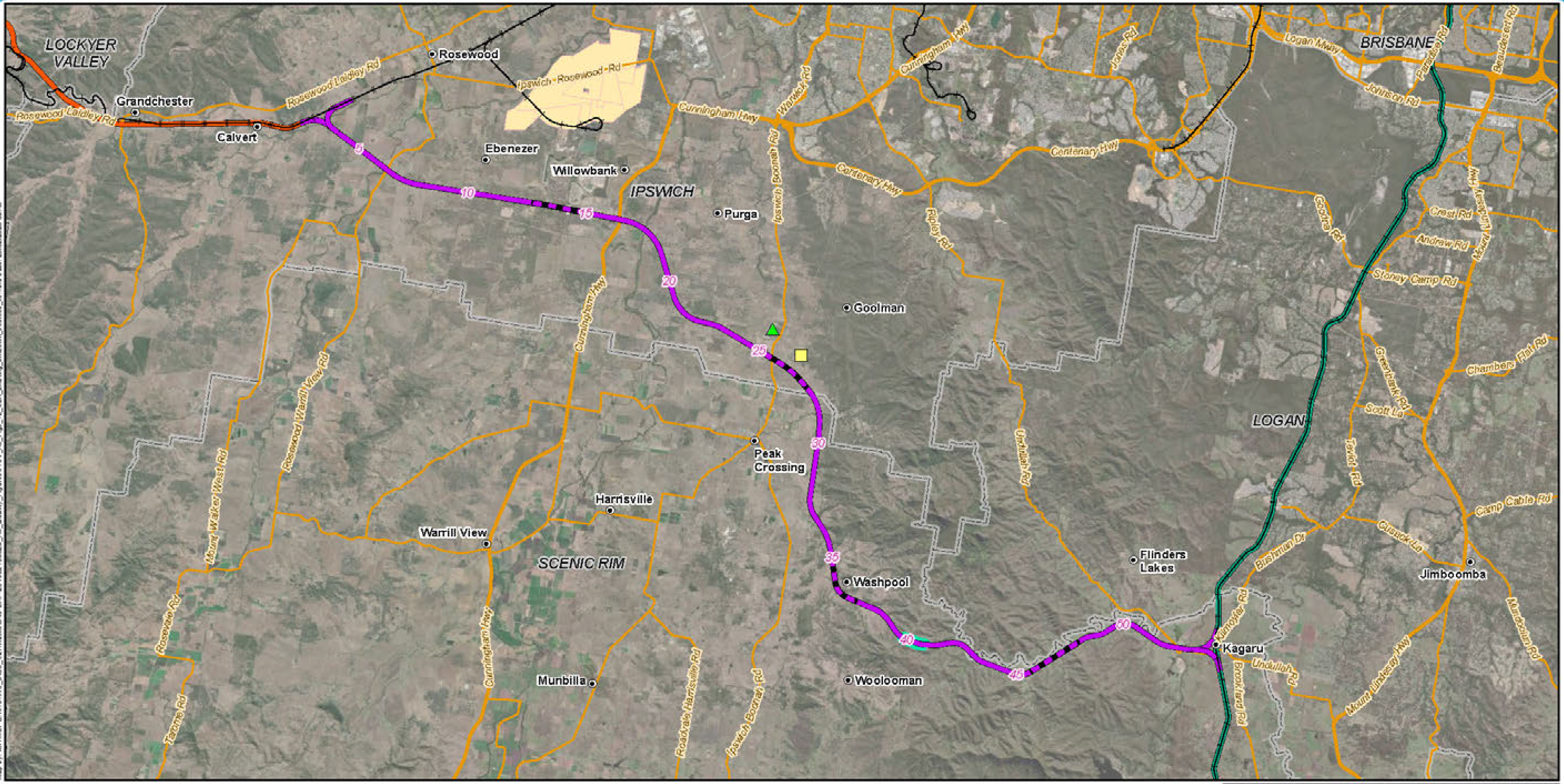
- Boral quarry located at Purga
- Bartter Enterprises poultry farms.

The locations of these nearby facilities are shown in Figure 5.12. A description of each existing emission source and its approximate distance from the Project alignment is presented in Table 5.19.

Table 5.19 NPI listed facilities in the air quality study area

Facility name	Industry	Coordinates	Distance from alignment (km)	Direction from alignment
Boral Purga Quarry	Gravel and sand quarrying	-27.751345, 152.748528	0.4	North
Bartter Enterprises Poultry Farms	Poultry farming	-27.745138, 152.733217	0.55	North

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Boral Quarry
- Poultry Farm
- 5 Chainage (km)
- Localities
- Crossing loops
- Existing rail
- Major roads
- Minor roads
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Tunnel
- Jeebropilly Mining Lease
- Local Government Areas

A3 scale: 1:175,000

0 1 2 3 4 5km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 25/02/2020 Version: 5
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.12: Existing emission sources

On 15 February 2017 Boral lodged a request to Ipswich City Council to alter the existing development approval (Approval Council Ref: 943/98) for the Purga Quarry. The request included a proposed amendment to the approved time period for the operation of the quarry, and proposed to extend extractive activities until 23 December 2023, and extend associated sales and rehabilitation works until 23 June 2025. The purpose of the request was to allow Boral sufficient time to extract and sell the remaining resource within the site. Following the submission from Boral, Ipswich City Council approved the minor alteration to the approval (Council Letter Ref: 945/2017/MA:NM) and approved the proposed end dates for extractive activities and sales and rehabilitation works.

Based on the approved operating period for the quarry, the quarry will be operational (extraction, sales and rehabilitation) during the construction phase of the Project, but will not be active during the operation phase of the Project, which is anticipated to begin in 2026.

Due to the location of the quarry, emissions from the quarry have been considered when assessing the impact of the construction phase of the Project. It is expected that due to emissions from the quarry, particulate concentrations at sensitive receptors near the quarry may be higher than the background particulate concentrations adopted for the assessment (refer Section 5.2.6) as measured by the DES monitoring stations. The influence of higher background concentrations for receptors near the quarry has been considered in the assessment of construction phase impacts for these receptors.

Emissions from the quarry during the operational phase of the Project have not been considered as the quarry will not be active in 2026 when the operation phase of the Project is anticipated to begin.

Significant emissions to air from the Bartter Enterprises poultry farms would be limited to odour only. Odour is not assessed cumulatively unless the emission source is the same type of industry, and therefore this existing source has not been considered specifically.

In addition to the NPI sources listed in Table 5.19, the Jeebropilly open-cut coal mine is located approximately 3.5 km to the north of the alignment (coordinates -27.665845, 152.658296). Emissions from the Jeebropilly open-cut coal mine were not considered specifically due to the mines location outside the air quality study area, and as it is anticipated that assumed background concentrations of particulate matter would adequately represent emissions from this source at sensitive receptors due to the separation distance to receptors. It is also noted that local reporting (Richter 2019) states that the Jeebropilly open-cut coal mine closed operations in December 2019.

In addition to the NPI sources listed in Table 5.19, other local emission sources will include ERAs and vehicle traffic. Sites with ERAs emit lower quantities of pollutants than these land uses that report to the NPI. As such, it is expected that emissions from ERAs and vehicle traffic will be adequately represented by the assumed background concentrations.

Based on review of the existing emission sources within and near the air quality study area, no existing emission sources are required to be modelled for the assessment of cumulative impacts.

5.3 Terrain and land use

Terrain features and land use can influence meteorological conditions on both a local and regional scale. The terrain along the proposed alignment running east to west begins at an elevation of 50 m at Kagaru and gradually increases as it crosses through the Teviot Range. Approximately 12 km west of Kagaru elevation increases to 220 m; at this point is where the proposed Teviot Range Tunnel will be constructed. After the tunnel, elevation slowly drops as the alignment moves north west from the Teviot Range. The alignment ends in the west at Calvert, an elevation of approximately 50 m, with the Little Liverpool Range to the immediate west.

The land uses in the air quality study area and surrounding area are predominately agricultural with some industry (i.e. Boral Quarry and Jeebropilly Coal Mine). Several small townships exist within 5 km of the alignment, these include Calvert, Rosewood, Willowbank, Peak Crossing, Mutdapilly, Washpool, and Kagaru.

The influence of terrain on wind flows and dispersion has been considered in the meteorological modelling undertaken for the assessment as discussed in Section 4.4.2. The effect of land use on surface roughness and dispersion has also been included in the meteorological model developed for the air quality study area. The height of the train emission source included in the model was based on the proposed design elevations for the alignment.

5.4 Sensitive receptors

Sensitive air quality receptors in the air quality study area were identified as per the DES guideline Application requirements for activities with impacts to air (DES 2019b). As per the DES guideline, a sensitive receptor can include the following:

- A dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises
- A motel, hotel or hostel
- A kindergarten, school, university or other educational institution
- A medical centre or hospital
- A protected area under the *Nature Conservation Act 1992* (Qld), the *Marine Parks Act 2004* (Qld) or a World Heritage Area
- A public park or garden
- A place used as a workplace including an office for business or commercial purposes.

The Project is located in a predominantly rural setting, a significant distance away from major population centres. There are no World Heritage Areas or areas protected under the *Nature Conservation Act 1992* (Qld) or the *Marine Parks Act 2004* (Qld) located within the air quality study area and there are no pollutant species considered in this assessment which require assessment of impacts to agricultural uses. The primary sensitive receptor types in the air quality study area are residential dwellings. As per the ToR, surfaces that lead to potable water tanks in the vicinity of the Project are also considered sensitive receptors and have been considered in the assessment.

Figure 5.13 shows the location of sensitive receptors considered during the air quality assessment. The sensitive receptors were identified via a desktop review and no field verification was undertaken. Only sensitive receptors within the air quality study area were considered for inclusion in dispersion modelling.

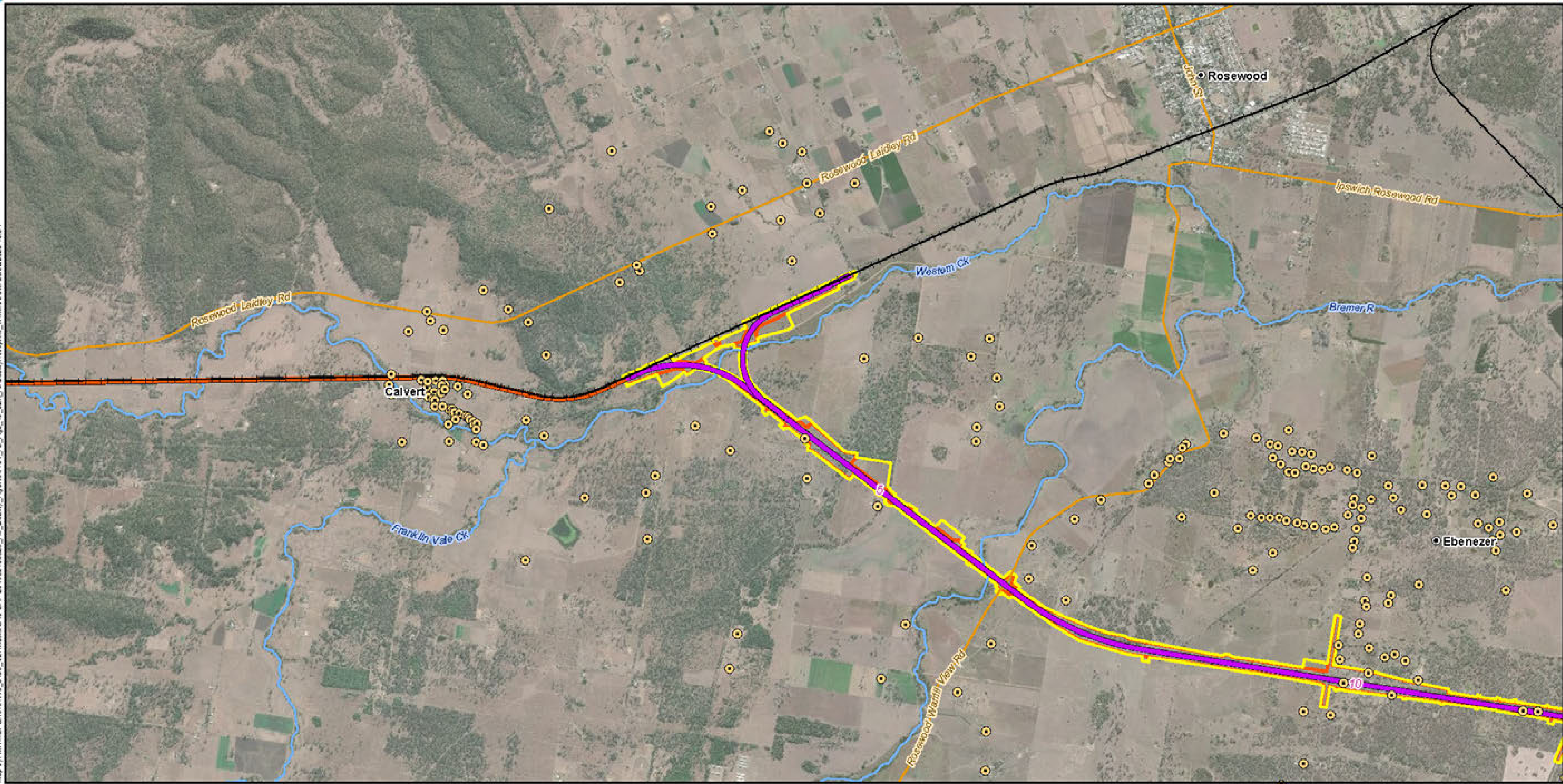
A goal provided in the ToR is for the Project to maintain the quality of water resources and ensure that these resources are not adversely impacted by the Project. To demonstrate this, surfaces that lead to potable water tanks in the vicinity of the Project have also been considered as sensitive receptors.

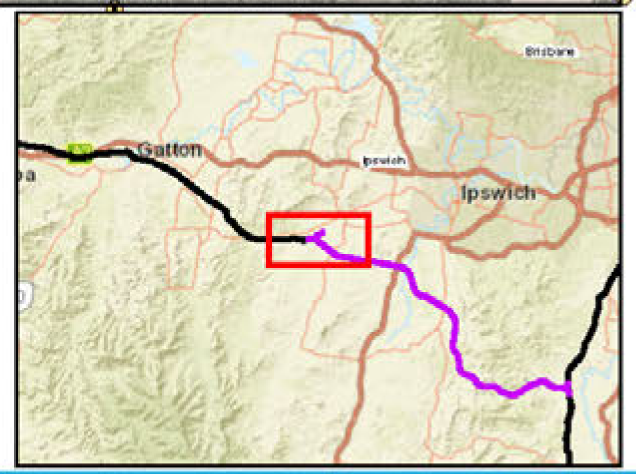
It should be noted that the number of sensitive receptors estimated in this report are based on a review of satellite imagery and may change as the Project progresses. Due to the large-scale nature of the Project, it has been assumed that receptors within the Project disturbance footprint will be acquired prior to construction works commencing. These receptors have not been considered in the assessment of construction impacts but have been considered in the operational assessment as they may be inhabited following the completion of construction.

The total number of sensitive receptors included in the air quality impact assessment may be inconsistent with other technical assessments due to variations in the definition of sensitive receptors (e.g. land use) and the separation distance (between emission sources and receptors) at which significant impacts could occur. Due to the large spatial extent required to model the Project and the significant computing resource required to run large scale models, the number of sensitive receptors included in the modelling of operational impacts was reduced to those located closest to the Project and which therefore have the highest potential to be impacted.

Discrete receptors points have been included for sensitive receptors and have been modelled at ground level (0 m above ground) as per the requirements of the DES guideline ‘Application requirements for activities with impacts to air’ (DES 2019b). In addition to the discrete receptors, grids of receptors have been included in the modelling (at a height of 0 m above ground) to facilitate the generation of concentration contours.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

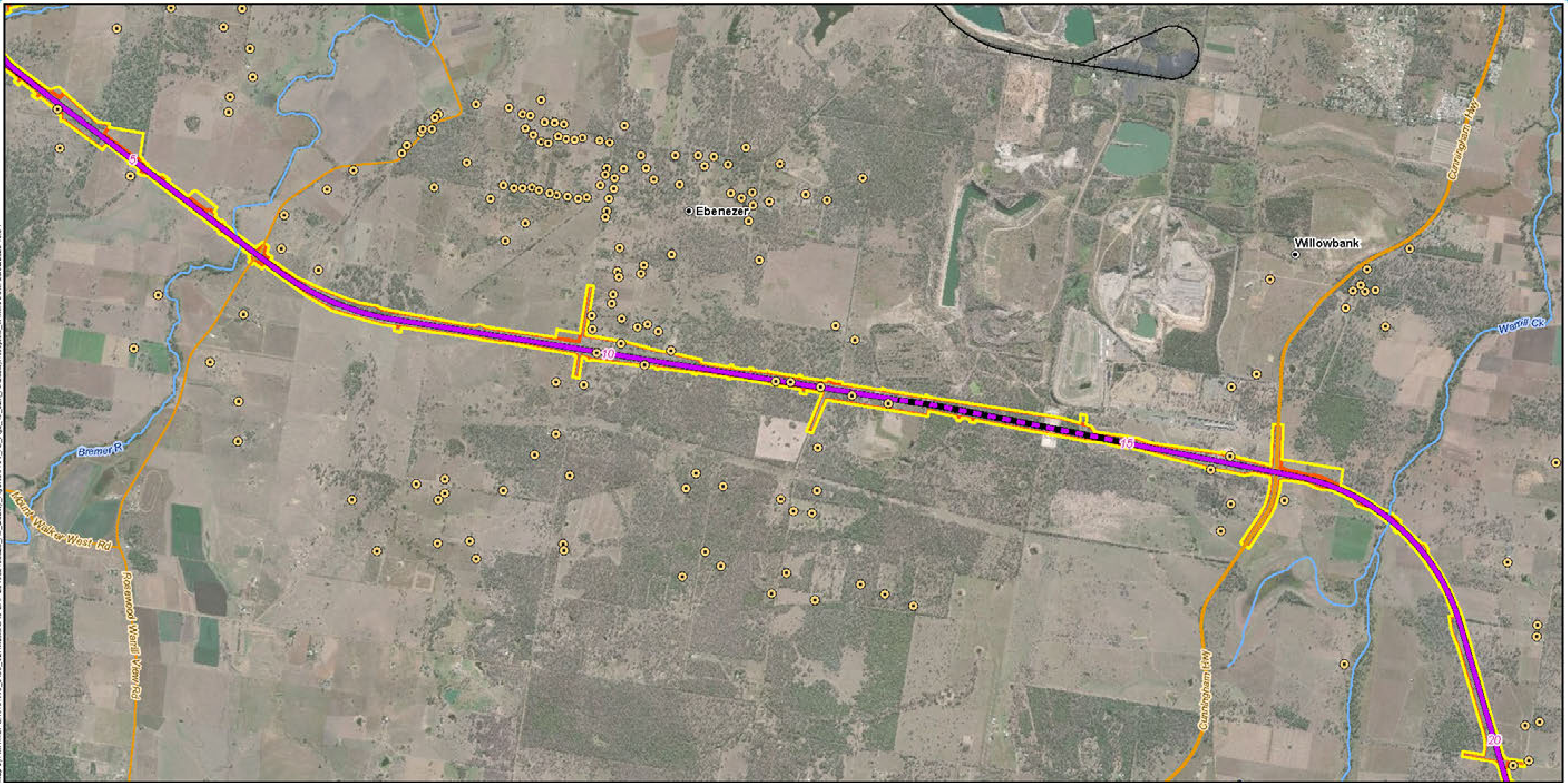
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13a:
Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

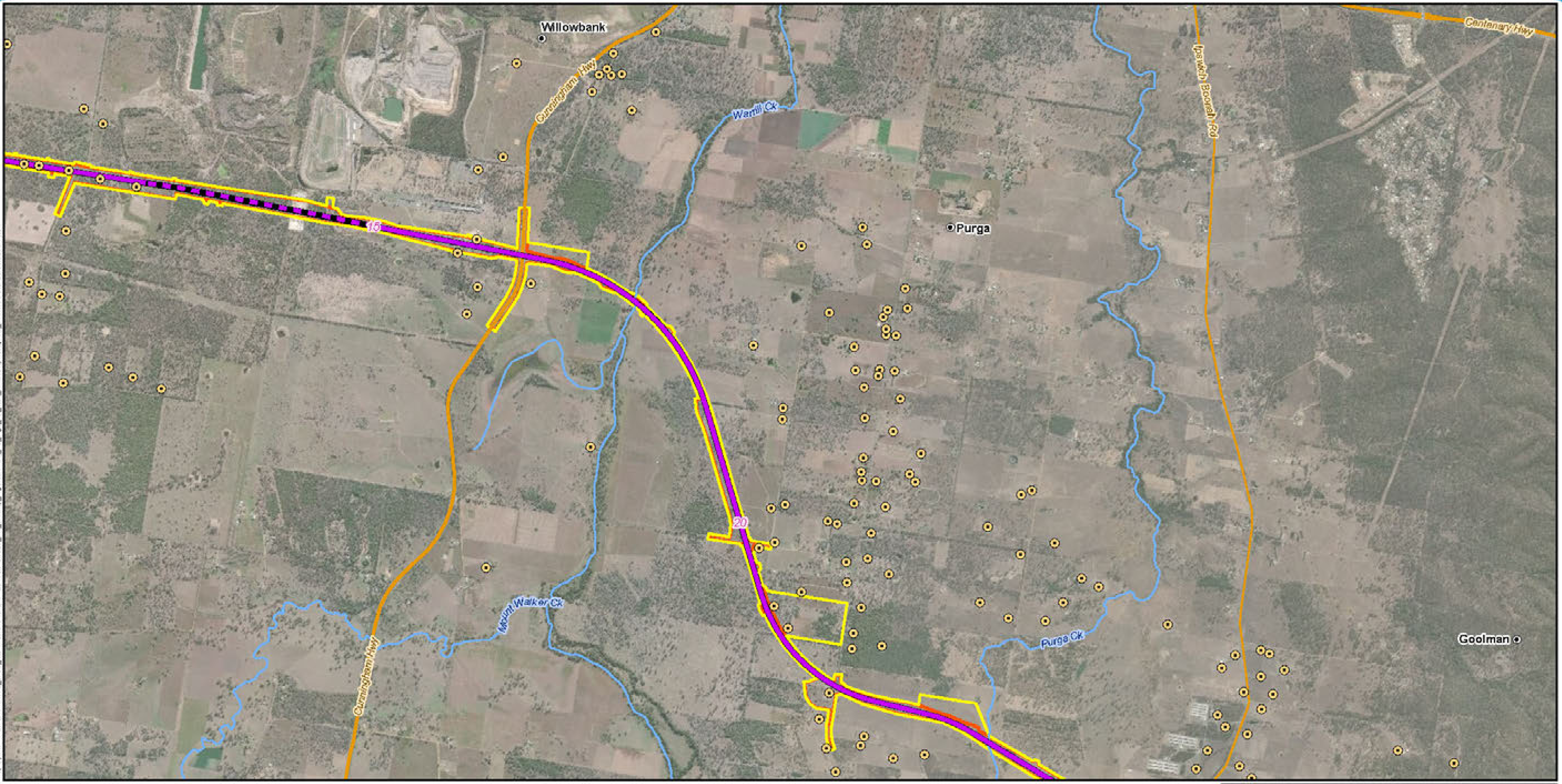
Future Freight
Integrating Community, Environment and Engineering

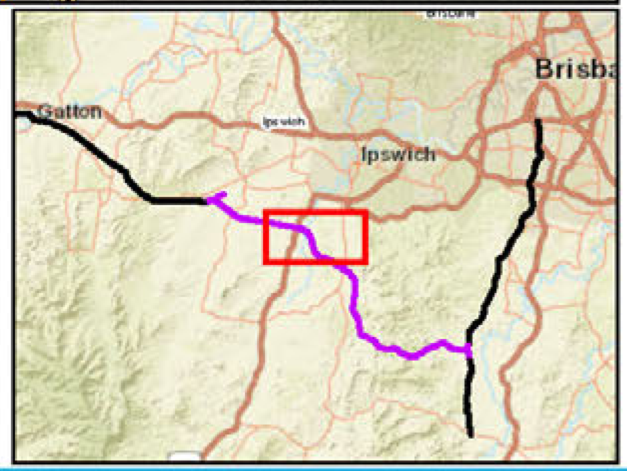
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13b: Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

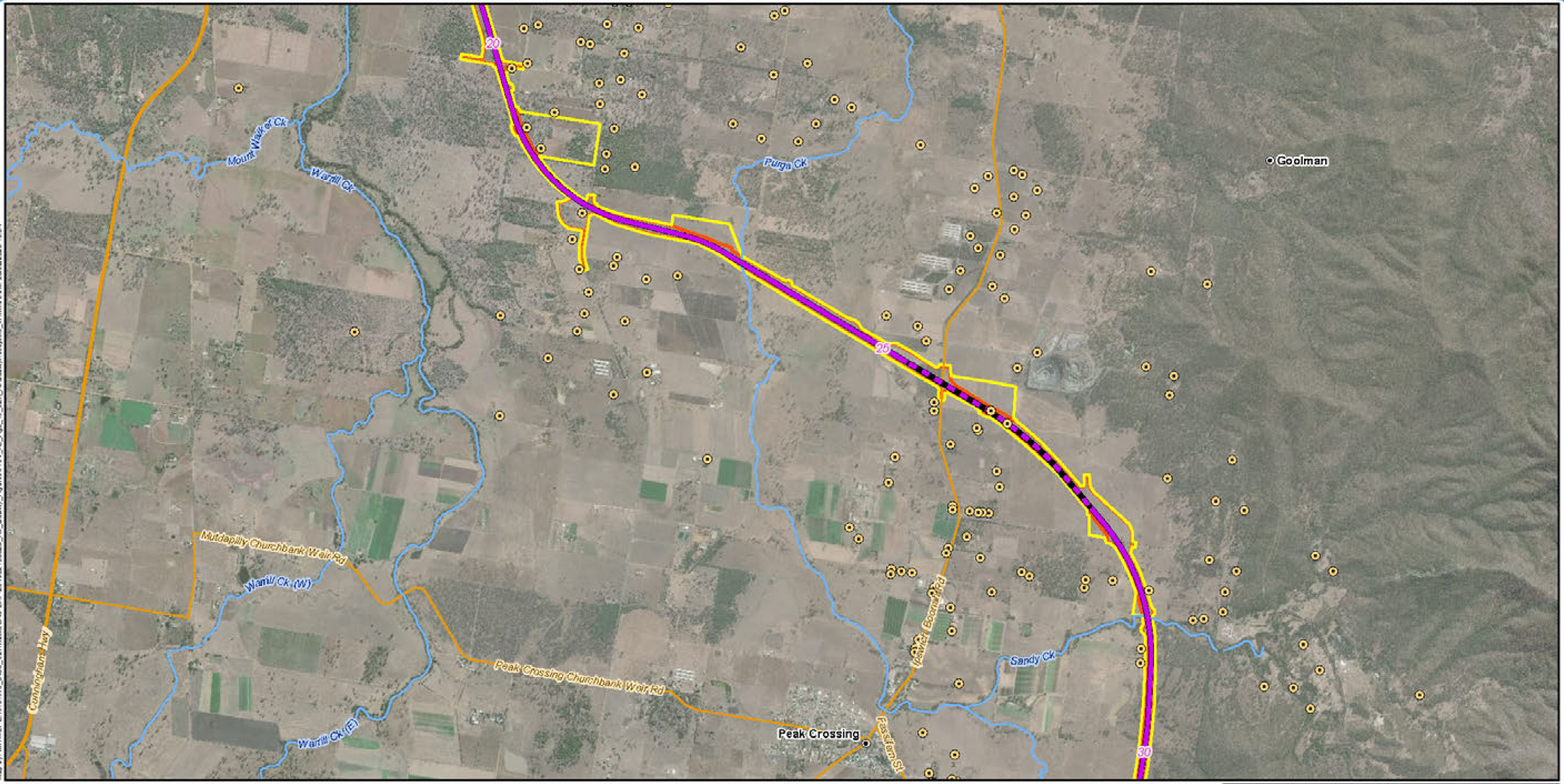
Future Freight
Integrating Community, Environment and Engineering

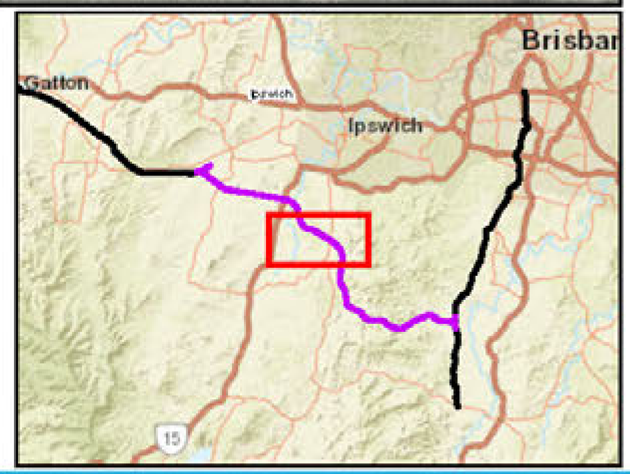
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13c:
Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

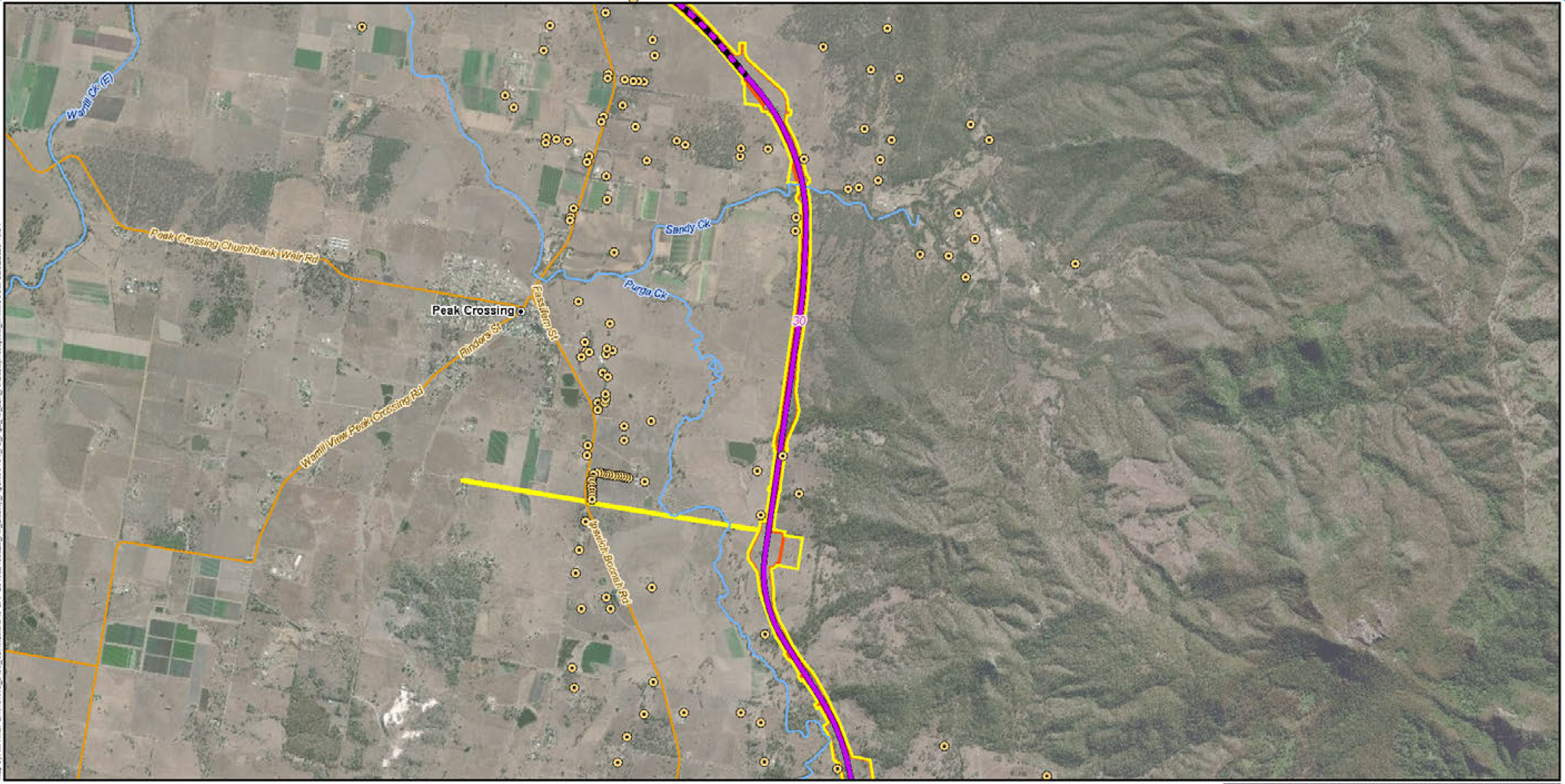
0 0.4 0.8 1.2 1.6 2km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13d:
Identified sensitive receptor locations



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

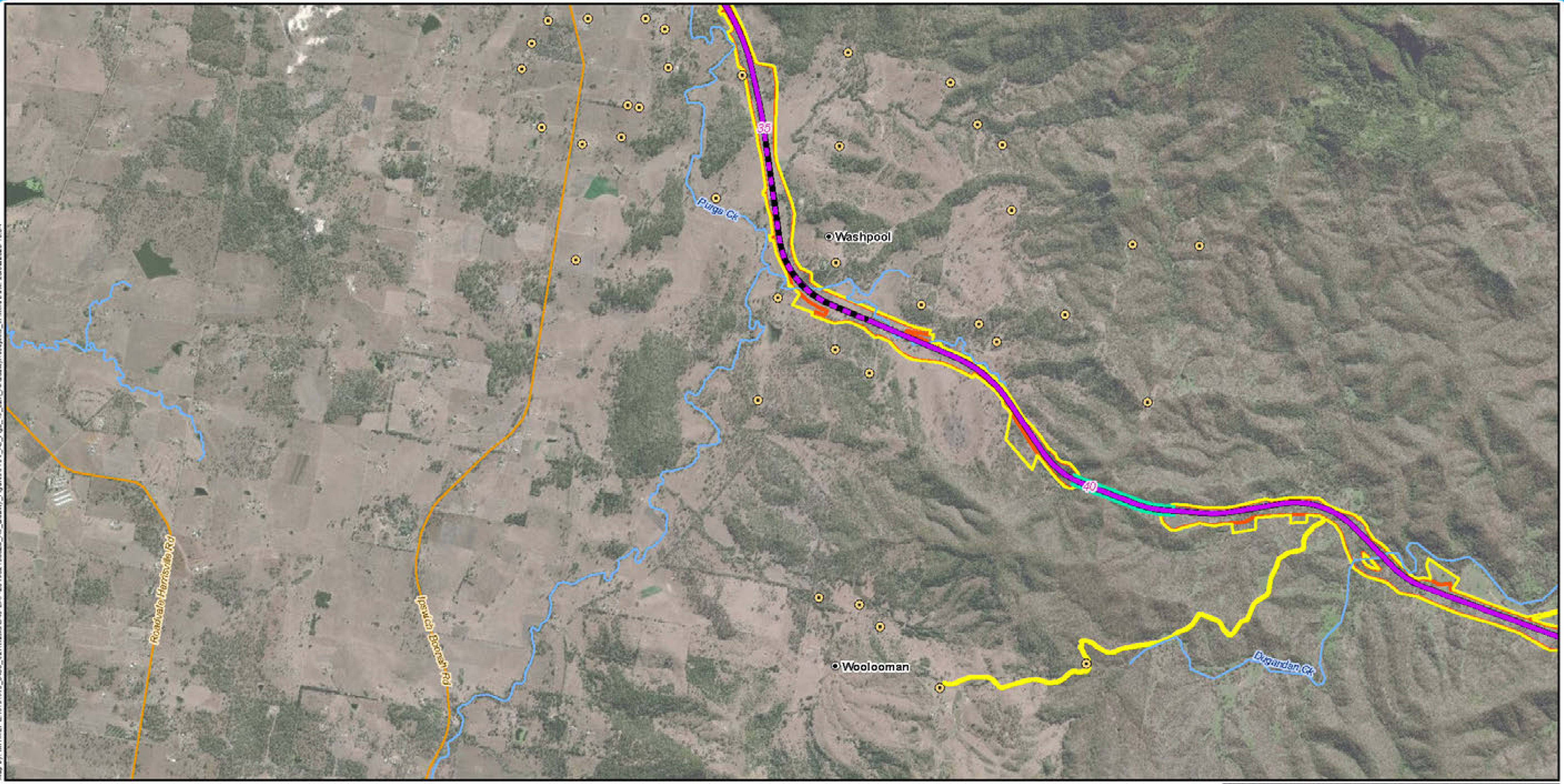
Future Freight
Integrating Community, Environment and Engineering

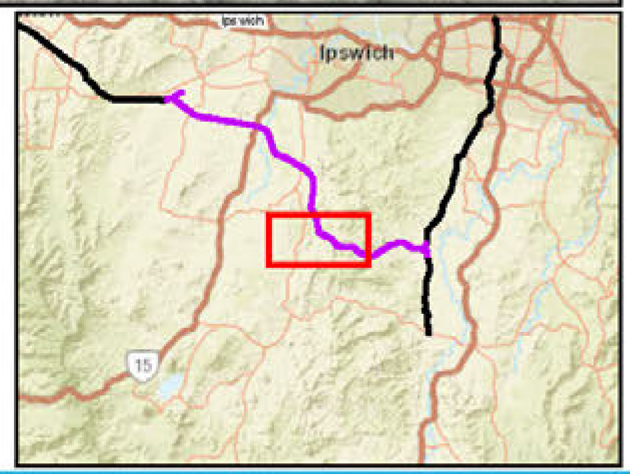
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13e: Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

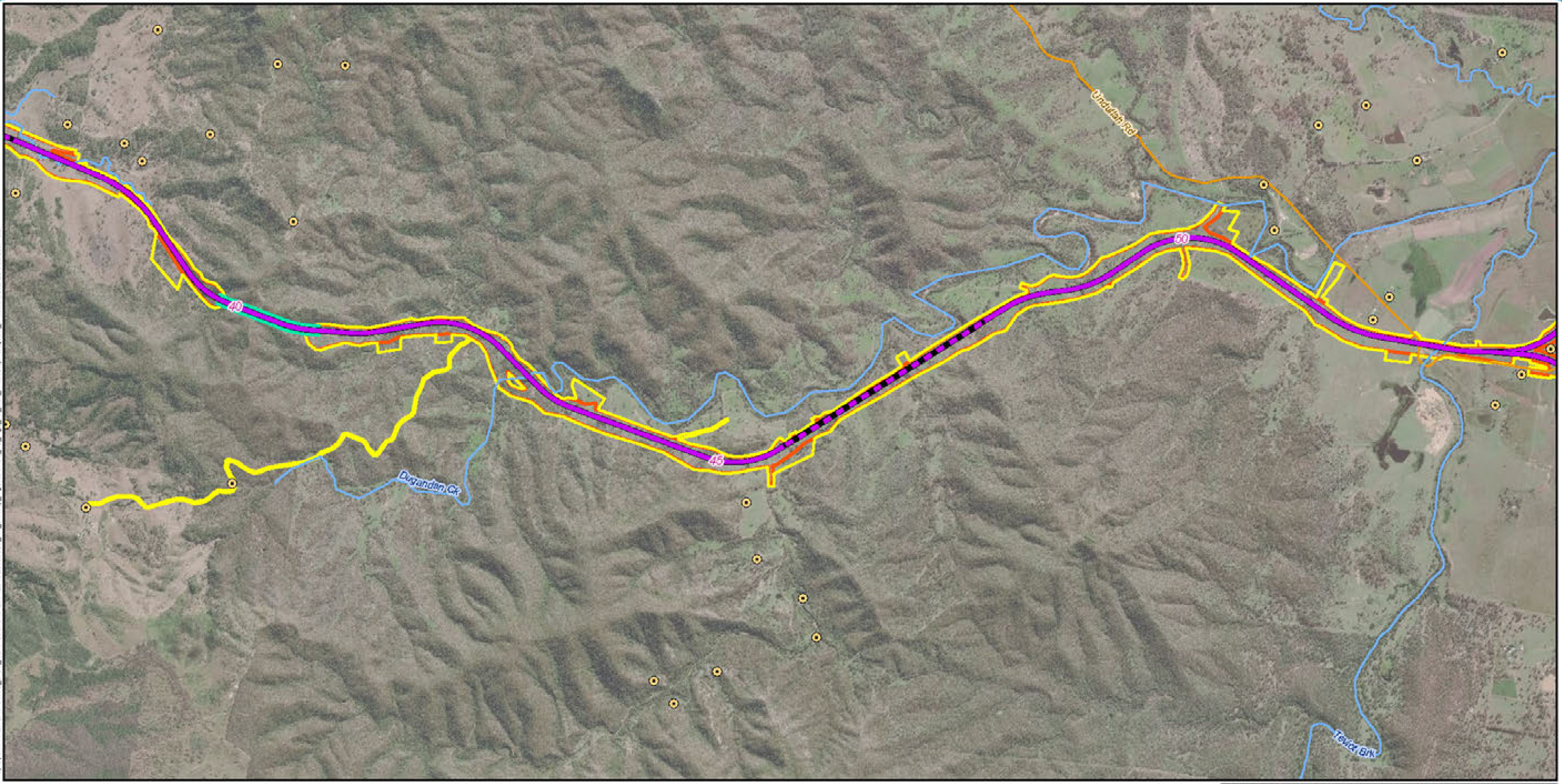
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13f:
Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

Note that due to topography constraints and the realignment of Wild Pig Creek Road and to minimise impacts on Dugandan Creek, there is a small area not within the disturbance footprint between Chainage 42 and 44.

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

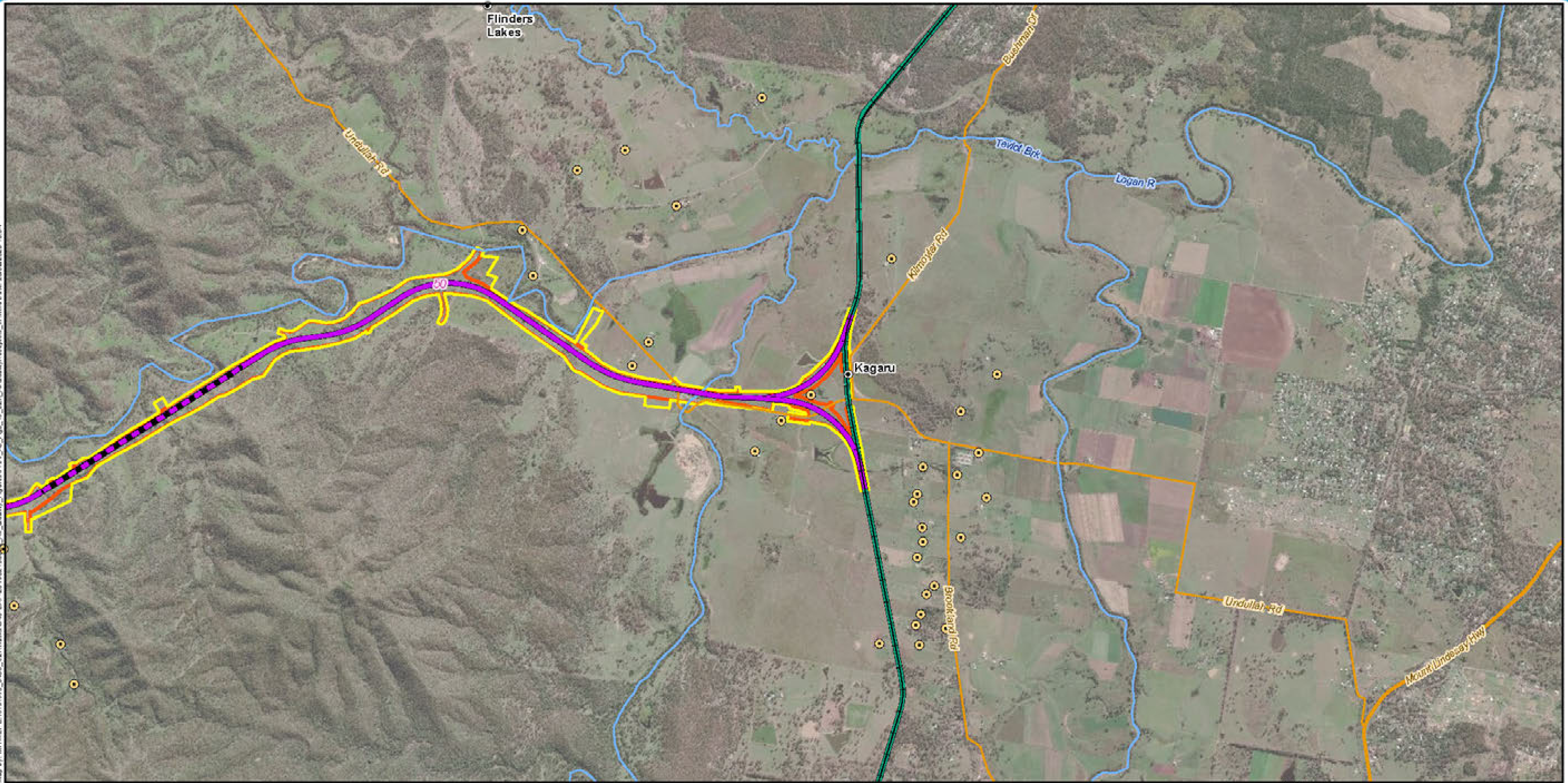
Future Freight
Integrating Community, Environment and Engineering

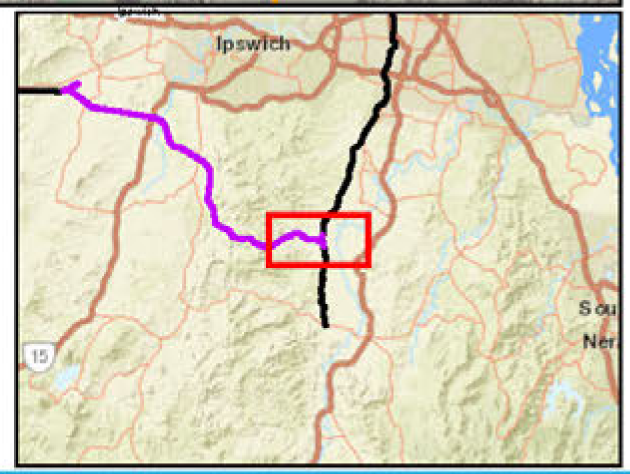
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 5.13g:
Identified sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- Tunnel
- EIS disturbance footprint
- Permanent disturbance footprint

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 5.13h:
Identified sensitive receptor locations

6 Construction air quality impact assessment

The following sections provide an assessment of air quality impacts during the construction of the Project.

The highest proportion of construction emissions results from mechanical activity, e.g. material movement or mobile equipment activity, which typically generate coarser particulate emissions (PM_{10} and TSP). Airborne PM_{10} and deposited dust (TSP) are the main pollutants of concern for construction activities and these pollutant species are the focus of the assessment for construction dust. Airborne PM_{10} has the potential to impact human health due to inhalation of particulate matter, whilst deposited dust has the potential to cause nuisance impacts but does not directly impact human health.

Particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) is typically emitted in minor quantities from mechanical sources, and is more predominant from combustion point sources (i.e. combustion engines). Point source emissions of combustion gases (e.g. oxides of nitrogen (NO_x) and carbon monoxide (CO)) and $PM_{2.5}$ from diesel construction vehicles and mobile plant will be significantly lower than particulate emissions from construction activities. Emissions of combustion gases and $PM_{2.5}$ are considered unlikely to result in exceedance of air quality goals or cause nuisance to sensitive receptors and therefore have not been assessed for the construction phase.

In addition to construction dust, odour and VOCs will be emitted as fugitive emissions from fuel tanks located at laydown areas. Impacts from fuel storage have been assessed in Section 6.2.

No other significant pollutant emissions (excluding dust, odour and VOCs) are anticipated from the construction phase of the Project.

6.1 Dust

The dust impact assessment was based on the methodology described in the UK IAQM document, Guidance on the assessment of dust from demolition and construction. The risk of dust deposition and human health impacts due to particulate matter (PM_{10}) on surrounding areas were determined based on the scale of activities and proximity to sensitive receptors. The IAQM method uses a four-step process to assess dust impacts:

- Step 1: Screening based on distance to nearest sensitive receptors
- Step 2: Assess risk of dust impacts from activities based on:
  - Scale and nature of the works, which determines the potential dust emission magnitude
  - Sensitivity of the area
- Step 3: Determine site-specific mitigation for dust-emitting activities
- Step 4: Reassess risk of dust impacts after mitigation has been considered.

Figure 6.1 presents the disturbance footprint for the Project, including the location of laydown areas and haul routes.

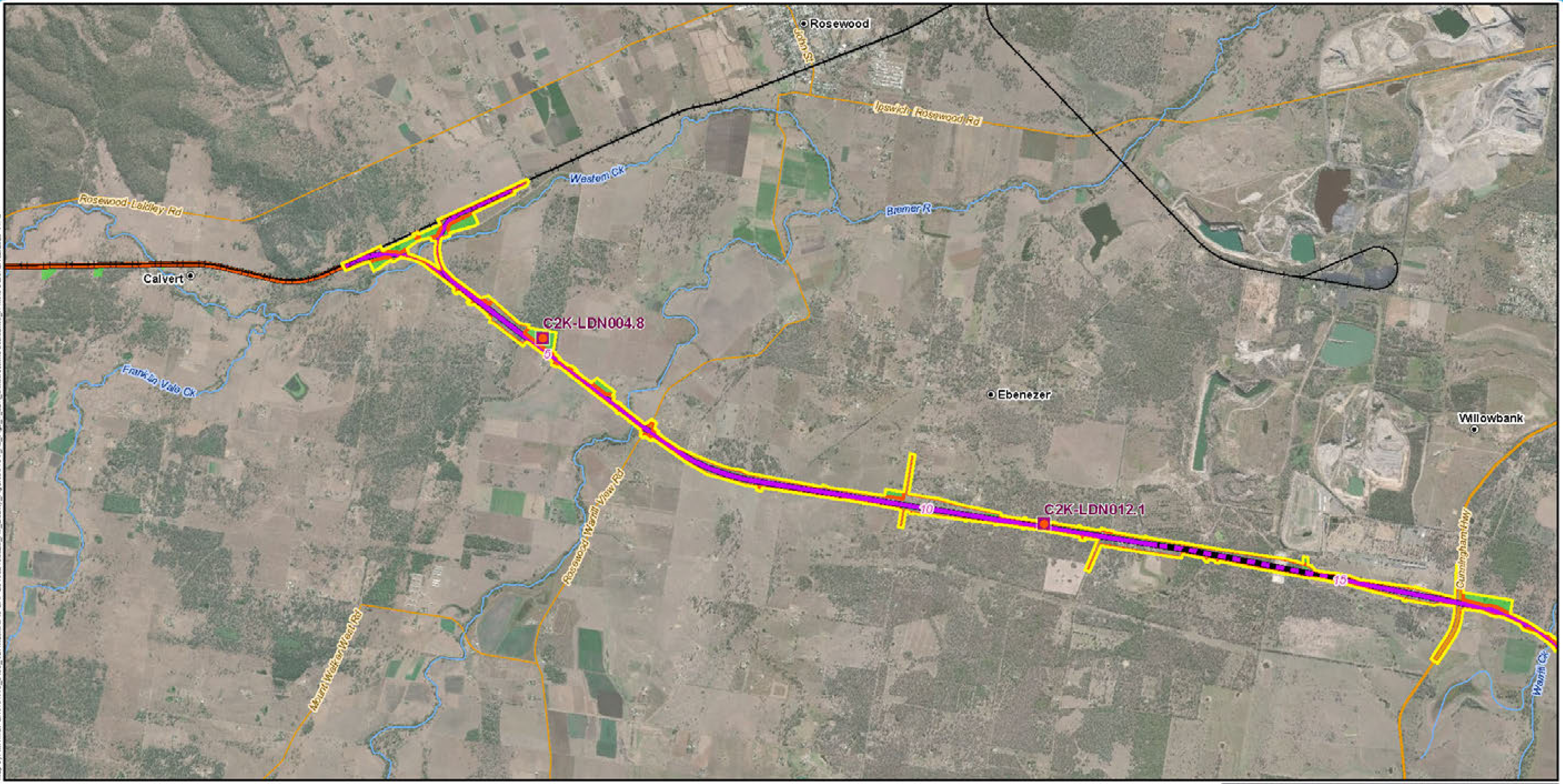
The IAQM assessment process is described in the following sections.

6.1.1 Step 1 – Screening assessment

The IAQM method recommends further assessment of dust impacts for construction activities where sensitive receptors are located closer than:

- 350 m from the boundary of the site
- 50 m from the route used by all construction vehicles on public roads more than 500 m from the site entrance.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Tank fuel storage
- Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

A3 scale: 1:50,000

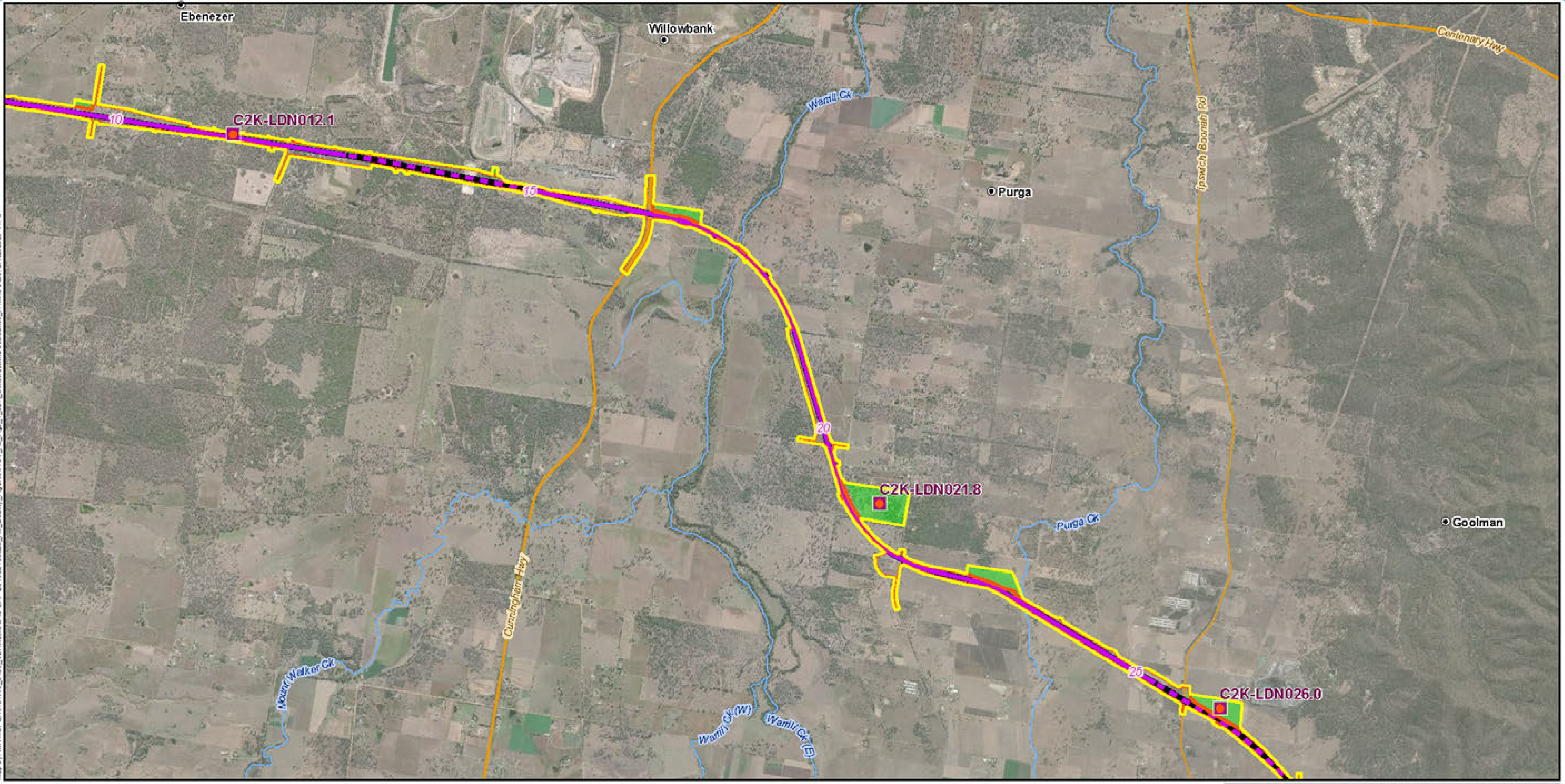
0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 6.1a:
Construction disturbance areas

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Tank fuel storage
- Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

A3 scale: 1:50,000

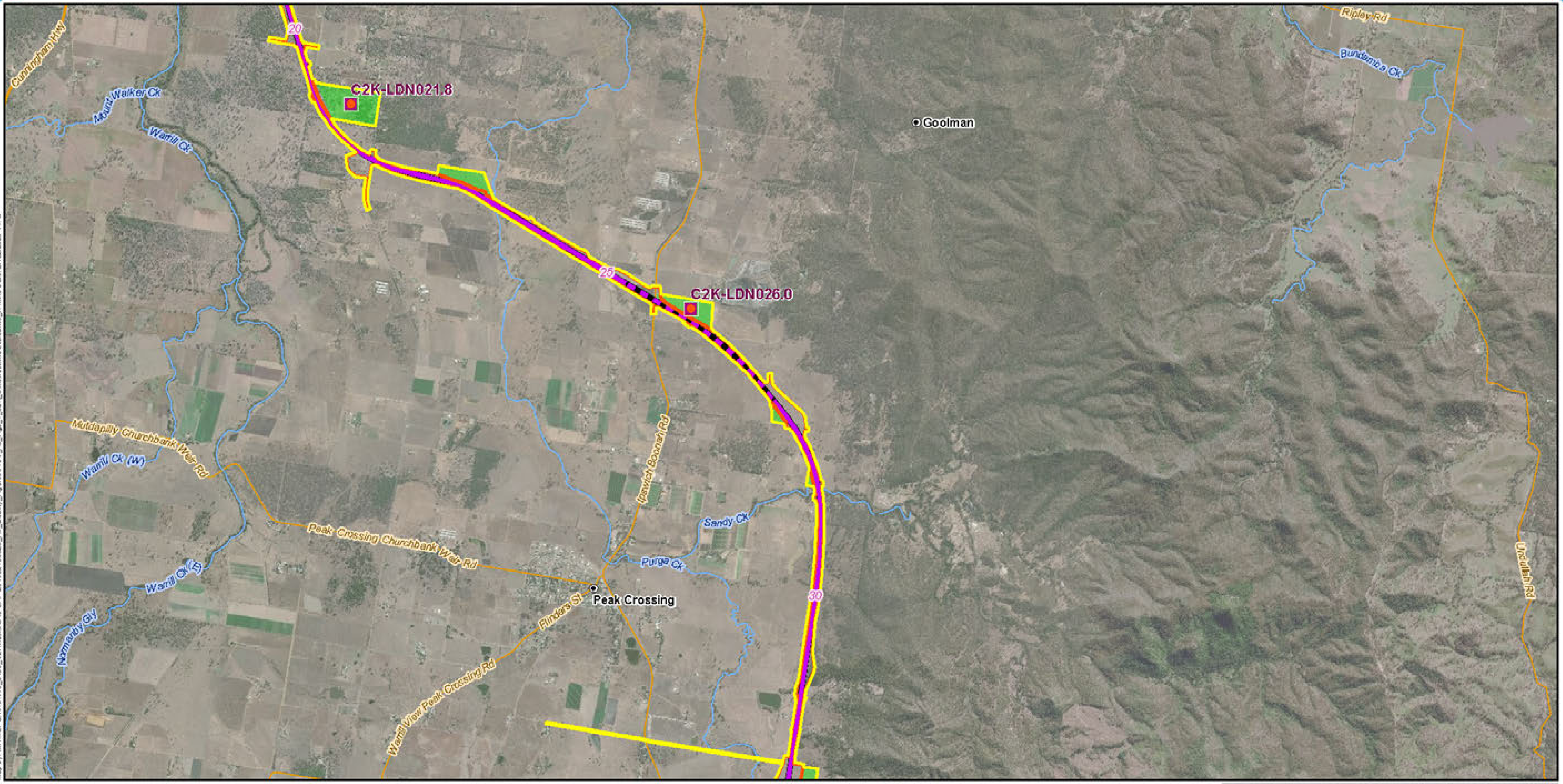
0 0.5 1 1.5 2 2.5 km

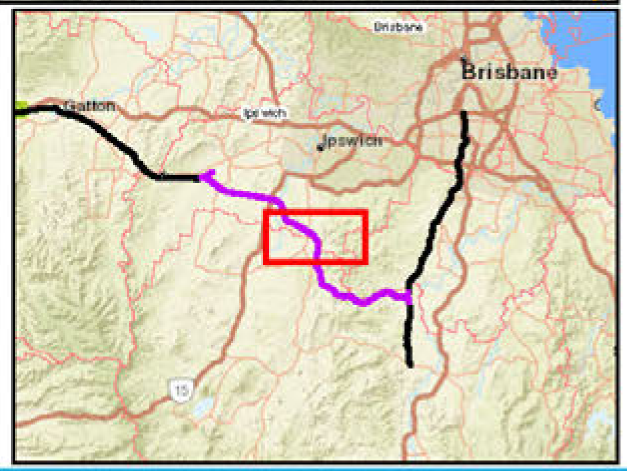
Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 6.1b:
Construction disturbance areas

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Tank fuel storage
- 5 Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

A3 scale: 1:50,000

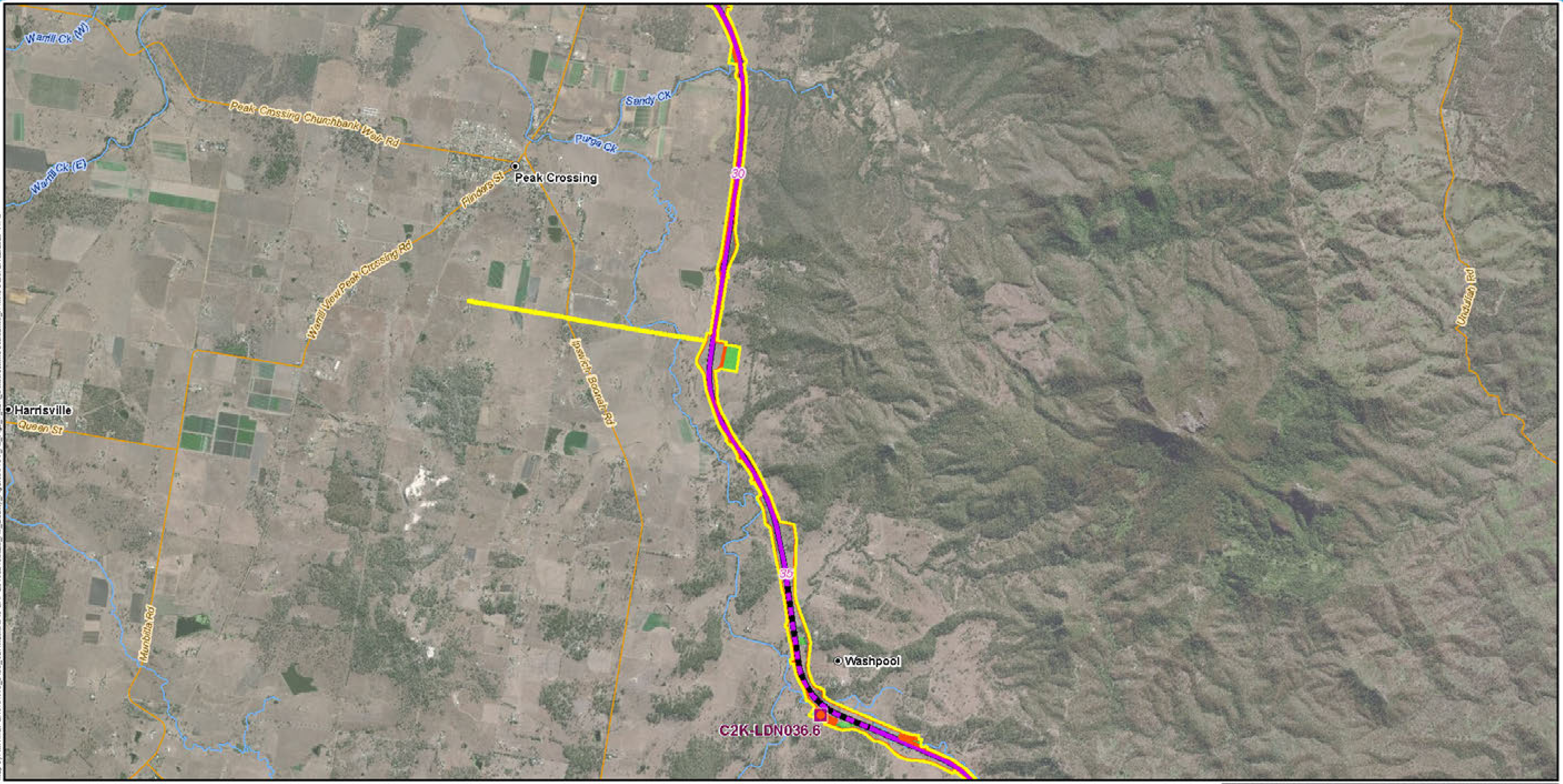
0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 6.1c:
Construction disturbance areas

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Tank fuel storage
- 5 Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

A3 scale: 1:50,000

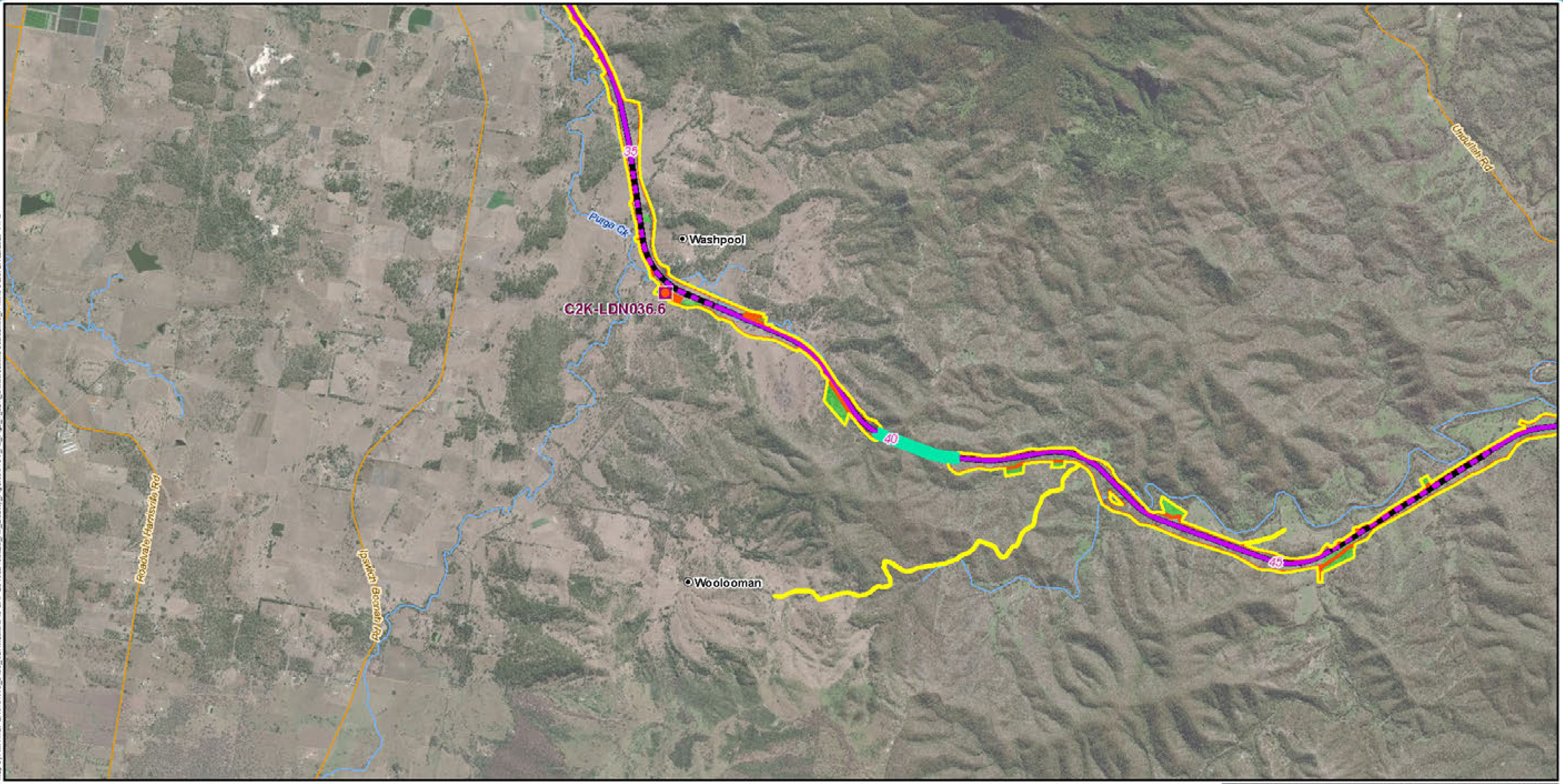
0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 6.1d:
Construction disturbance areas

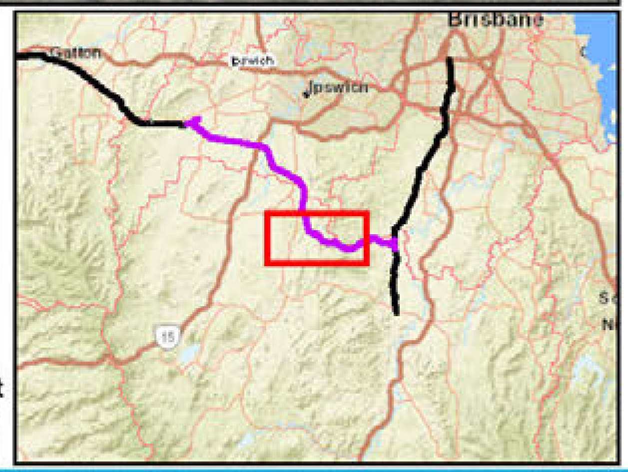
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Tank fuel storage
- 5 Chainage (km)
- Localities
- C2K project alignment
- Crossing loops
- Major roads
- Minor roads
- Tunnel
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

Note that due to topography constraints and the realignment of Wild Pig Creek Road and to minimise impacts on Dugandan Creek, there is a small area not within the disturbance footprint between Chainage 42 and 44.



A3 scale: 1:50,000

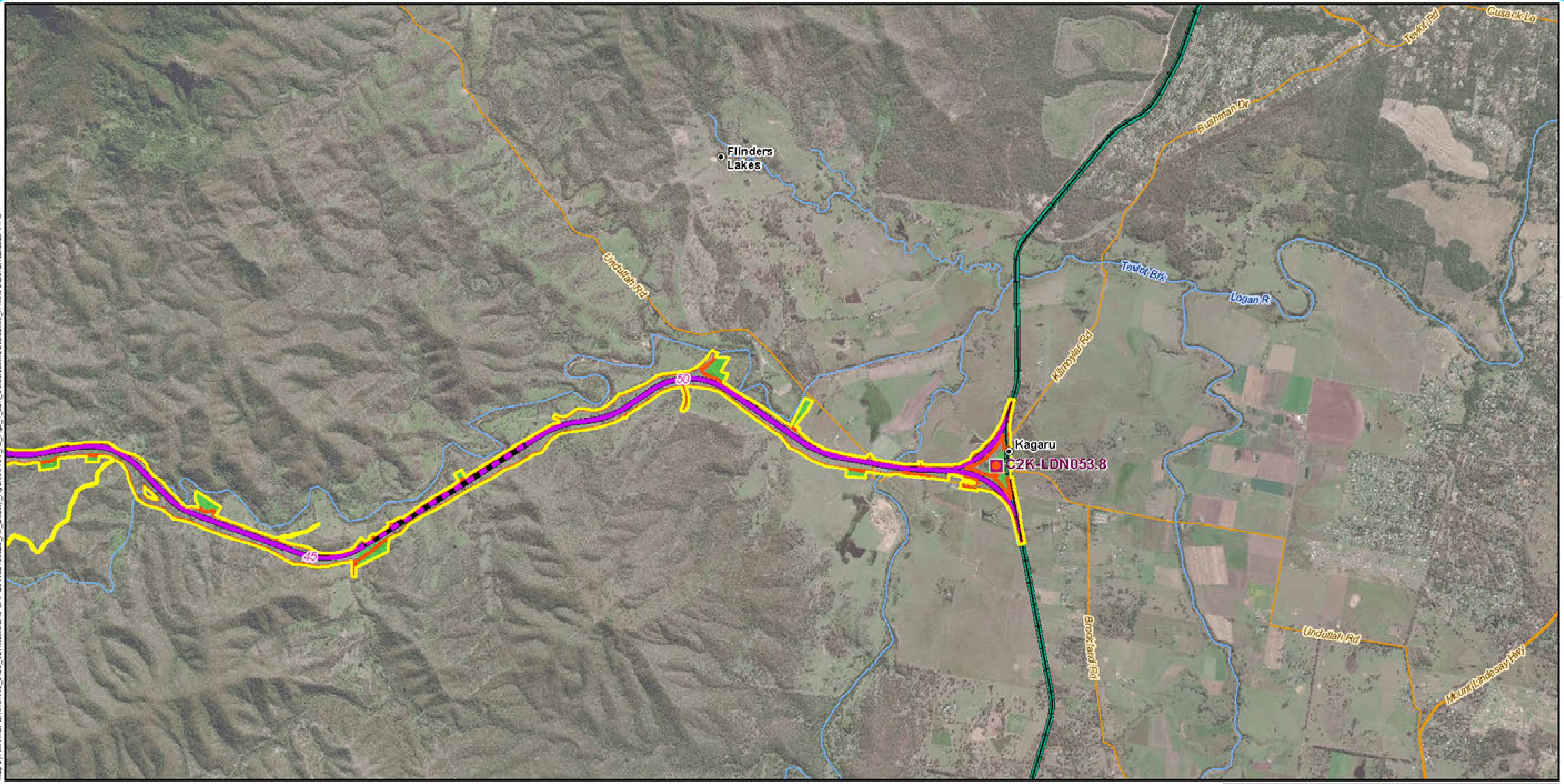
0 0.5 1 1.5 2 2.5km

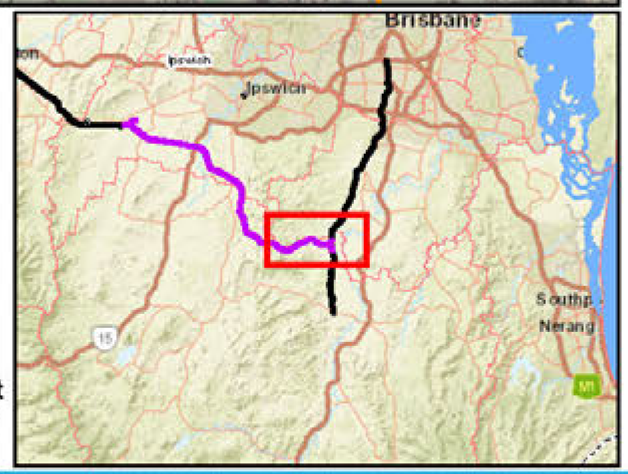
Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru
Figure 6.1e:
Construction disturbance areas

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Tank fuel storage
- Chainage (km)
- Localities
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Crossing loops
- Major roads
- Minor roads
- Watercourses
- EIS disturbance footprint
- Permanent disturbance footprint
- Proposed laydown areas

Note that due to topography constraints and the realignment of Wild Pig Creek Road and to minimise impacts on Dugandan Creek, there is a small area not within the disturbance footprint between Chainage 42 and 44.

A3 scale: 1:50,000

0 0.5 1 1.5 2 2.5km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 27/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 6.1f: Construction disturbance areas

The number of sensitive receptors considered within the air quality study area is 548. Their respective distances from the alignment are in Table 6.1.

Table 6.1 Summary of sensitive receptors

Distance from (m)	Number of receptors		
	Access tracks	Laydown areas	Construction corridor[a]
0	0	2	17
<20	1	2 (4)[b]	4 (21)[b]
21 to 50	3	3	12
51 to 100	2	7	10
101 to 350	11	37	67
>350	531	497	438
Total	**548**		

Table notes:

a Permanent and temporary disturbance areas

b It is assumed that the 19 receptors that fall within the disturbance footprint, including the 2 that fall within laydown areas, will be acquired at the time of construction and thus no longer be sensitive receptors.

It should be noted that the number of sensitive receptors estimated in this report are based on information provided to date, and may change as the Project progresses. Due to the large-scale nature of the Project, it has been assumed that receptors located within the disturbance footprint will be acquired prior to construction works commencing, and have therefore not been considered in the assessment of impacts for this phase of the Project.

6.1.2 Step 2 – Dust risk assessment

Step 2 in the IAQM is a risk assessment tool designed to appraise the potential for dust impacts due to unmitigated dust emissions from a construction project. The key components of the risk assessment are defining the dust emission magnitudes (Step 2A), the surrounding area sensitivity (Step 2B), and then combining these in a risk matrix (Step 2C) to determine an overall risk of dust impacts.

6.1.3 Step 2A – Dust emission magnitude

Dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general demolition methodology. The IAQM guidance provides examples to aid classification, as presented in the following excerpt from IAQM:

> *The dust emission magnitude is based on the scale of the anticipated works and should be classified as Small, Medium, or Large. The following are examples of how the potential dust emission magnitude for different activities can be defined. Note that, in each case, not all the criteria need to be met, and that other criteria may be used if justified in the assessment:*

Demolition: Any activity involved with the removal of an existing structure (or structures). This may also be referred to as de-construction, specifically when a building is to be removed a small part at a time.

Example definitions for demolition are:

- Large: Total building volume >50,000 m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities >20 m above ground level
- Medium: Total building volume 20,000 m^3 to 50,000 m^3, potentially dusty construction material, demolition activities 10 to 20 m above ground level
- Small: Total building volume <20,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber), demolition activities <10 m above ground, demolition during wetter months.

Earthworks: Earthworks will primarily involve excavating material, haulage, tipping and stockpiling. This may also involve levelling the site and landscaping.

Example definitions for earthworks are:

- Large: Total site area >10,000 m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8 m in height, total material moved >100,000 tonnes
- Medium: Total site area 2,500 m^2 to 10,000 m^2, moderately dusty soil type (e.g. silt), 5 to 10 heavy earth moving vehicles active at any one time, formation of bunds 4 m to 8 m in height, total material moved 20,000 tonnes to 100,000 tonnes
- Small: Total site area <2,000 m^2 – soil type with large grain size, e.g. sand, <5 heavy earth moving vehicles at one time, formation of bunds <4 m in height, total material moved <20,000 tonnes, earthworks during wetter months.

Construction: The key issues when determining the potential dust emission magnitude during the construction phase include the size of the building(s)/infrastructure, method of construction, construction materials, and duration of build.

Example definitions for construction are:

- Large: Total building volume >100,000 m^3, on site concrete batching, sandblasting
- Medium: Total building volume 25,000 m^3 to 100,000 m^3, potentially dusty construction material (e.g. concrete), on site concrete batching
- Small: Total building volume <25,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber).

Trackout: Factors which determine the dust emission magnitude are vehicle size, vehicle speed, vehicle numbers, geology and duration. As with all other potential sources, professional judgement must be applied when classifying trackout into one of the dust emission magnitude categories.

Example definitions for trackout are:

- Large: >50 truck (>3.5 t) outward movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road length 50 m to 100 m
- Medium: 10 to 50 truck (>3.5 t) outward movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50 m to 100 m
- Small: <10 truck (>3.5 t) outward movements in any one day, surface material with low potential for dust release, unpaved road length <50 m.

Potential dust emission magnitudes for the Project were estimated based on the IAQM examples listed above. Justification and the factors used in determining the magnitudes are presented in Table 6.2. Multiple work fronts will be active at any one time along the alignment.

Table 6.2 Construction activities and dust emission magnitude justification

Activity	Potential dust emission magnitude	Justification
Demolition	Small	▪ Existing buildings likely to be demolished, all assumed to be small homesteads ▪ Buildings assumed to be primarily of low dust potential material (wood/cladding). Materials to be confirmed prior to demolition ▪ Total building volume presently unknown although assumed to be <10,000 m^3 ▪ Possible demolition and realignment of existing roads – to be confirmed in detailed design phase of the Project.

Activity	Potential dust emission magnitude	Justification
Earthworks	Large	■ Multiple work fronts at any one time along the alignment ■ Vegetation clearing along the alignment for new access tracks and laydown areas will occur where necessary – no known quantities at this stage. Where practical, clearing and grubbing will be staged to limit the size of exposed areas. ■ Topsoil along entire alignment (53 km long) will be stripped (approximate depth of 0.3 m) and stockpiled. Wherever possible and appropriate material will be reused within the Project. ■ 18 laydown areas along the alignment, primarily to act as locations for excavation stockpiling. Stockpiles to be located as close as possible to the excavation source. ■ The total cut across the disturbance area, excluding the tunnel, has been estimated to be 5,768,166 m^3 ■ Approximately 4,255,382 m^3 of fill material will be needed for the construction of embankments in the disturbance area. The current construction methodology includes utilising the material from the cuts in the embankments works. ■ Of the 18 laydown areas, it is assumed six will act as Laydown Area Delivery Points (LADP). One will store <10,000 t of ballast and the other five will store <20,000 t of ballast each. Up to 110,000 t of ballast material movement in total. ■ Drilling and blasting may occur to create tunnel portals – to be confirmed during the detailed design phase of the Project ■ Utility relocations – more information to be provided in the detailed design phase ■ Earthworks material likely to be dusty especially during dry season. Soil types along the alignment are to be confirmed.
Construction	Large	■ Construction period of approximately four years, with multiple work fronts at any one time along the alignment ■ Installation of approximately 53 km of railway utilising steel rail, sleepers, ballast and concrete. Concrete and ballast present high dust risk ■ Construction of railway tunnel approximately 1,015 m long, including a tunnel control centre (single story to be located at western portal) and a substation building to provide and distribute power to tunnel systems (steel and concrete material). Further information regarding tunnel construction to be confirmed. ■ Construction of 27 new bridge structures – steel material low dust risk but concrete high dust risk ■ Temporary site offices and parking facilities likely to be constructed at each LADP ■ Onsite batching plant and ballast handling facility assumed to be located at LADP (ID C2K-LDN053.8) – high dust risk materials ■ Construction of six fuel storage facilities: two <40,000 L, and four <20,000 L ■ Laydown areas to also include temporary parking facilities for construction workers ■ Construction of temporary and permanent fencing – total lengths to be determined during detailed design phase.
Trackout	Large	■ Multiple work fronts at any one time along alignment ■ High amount of daily vehicle movements expected per work site (both light and heavy vehicles) ■ Movement of ballast from sources, and between LADPs and ballast handling facility via 18 t dump trucks ■ After construction, access tracks are expected to only be used for maintenance activities ■ Total length of unpaved road/access tracks unknown until design is finalised but will be >100 m due to the size of the Project.

6.1.4 Step 2B – Sensitivity of surrounding area

The IAQM methodology allows the sensitivity of an area to dust deposition and human health impacts due to PM_{10} to be classified as high, medium, or low. The classifications are determined according to matrix tables provided in the IAQM guidance document. Individual matrix tables for dust deposition and human health impacts are provided. Factors used in the matrix tables to determine the sensitivity of the surrounding area are described as follows:

- Receptor sensitivity (for individual receptors in the area):
  - *High sensitivity – locations where members of the public are likely to be exposed for eight hours or more in a day. For example private residences, hospitals, schools, or aged care homes.*
  - *Medium sensitivity – places of work where exposure is likely to be eight hours or more in a day*
  - *Low sensitivity – locations where exposure is transient – i.e. one or two hours maximum. For example parks, footpaths, shopping streets, playing fields.*
- Ambient annual mean PM_{10} concentrations (only applicable to the human health impact matrix)
- Number of receptors in the area
- Proximity of receptors to dust sources.

Table 6.3 details the IAQM guidance sensitivity levels from dust deposition effects on people and property. As detailed in Section 6.1.1 the total number of receptors identified in the land resources study area is 548. All 548 receptors are classified as high sensitivity as they are private places of residence. Of the 548 receptors, 159 are located within 350 m of a construction dust source; and 7 of the 159 receptors are located less than 20 m away. As such, the air quality study area sensitivity level to dust deposition effects is expected to be 'Medium'.

Table 6.3 IAQM surrounding area sensitivity to dust deposition impacts

Receptor sensitivity	Number of receptors	Distance from the source			
		<20	<50	<100	<350
High	>100	High	High	Medium	Low
	10-100	High	Medium	Low	Low
	1-10	Medium	Low	Low	Low
Medium	>1	Medium	Low	Low	Low
Low	>1	Low	Low	Low	Low

A modified version of the IAQM guidance for assessing the sensitivity of an area to human health impacts is shown in Table 6.4. For high and medium sensitivity receptors, the IAQM methods takes the existing background concentrations of PM_{10} (as an annual average) experienced in the area of interest (e.g. air quality study area). As the UK goals for PM_{10} differ from the ambient air quality goals adopted for use in this assessment (QLD air quality goals) the annual mean concentration categories used in the assessment (refer Table 6.4) have been modified from those presented in the IAQM method. This approach is consistent with the IAQM guidance, which notes that in using the tables to define the sensitivity of an area, professional judgement may be used to determine alternative sensitivity categories.

Table 6.4 IAQM guidance for categorising the sensitivity of an area to human health impacts

Receptor sensitivity	Annual mean PM_{10} concentration[a]	Number of receptors	Distance from the source (m)				
			<20	<50	<100	<250	<350
High	> 25 µg/m³	> 100	High	High	High	Medium	Low
		10 - 100	High	High	Medium	Low	Low
		1 - 10	High	Medium	Low	Low	Low
	21 – 25 µg/m³	> 100	High	High	Medium	Low	Low
		10 - 100	High	Medium	Low	Low	Low
		1 - 10	High	Medium	Low	Low	Low
	17 – 21 µg/m³	> 100	High	Medium	Low	Low	Low
		10 - 100	High	Medium	Low	Low	Low
		1 - 10	Medium	Low	Low	Low	Low
	< 17 µg/m³	> 100	Medium	Low	Low	Low	Low
		10 - 100	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
Medium	> 25 µg/m³	> 10	High	Medium	Low	Low	Low
		1 - 10	Medium	Low	Low	Low	Low
	21 – 25 µg/m³	> 10	Medium	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
	17 – 21 µg/m³	> 10	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
	< 17 µg/m³	> 10	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
Low	Any	>1	Low	Low	Low	Low	Low

Table notes:

a The annual mean PM_{10} concentration categories have been modified from the IAQM guidance to adjust for assessment of a site in QLD.

As detailed in Section 5.2.6, the adopted annual average PM_{10} background concentration (Flinders View monitoring station) is 16.2 µg/m³, which falls within the <17 µg/m³ category. As there are less than ten receptors within 20 m of a disturbance area (dust source), the sensitivity of the air quality study area to human health impacts is determined to be Low.

The Boral Purga quarry will be operational during the construction phase of the Project, and as a result, background concentrations of PM_{10} may be higher at receptors located near the quarry. The two nearest sensitive receptors to the quarry are located 70 m and 120 m from the quarry, with these receptors located in excess of 180 m from the boundary of the nearest disturbance area (laydown area LDN026.0). Due to the significant separation distance between the nearest Project disturbance area and sensitive receptors, the sensitivity for receptors in this area would still be classified as Low if elevated background PM_{10} concentrations were assumed.

Although receptors located near the quarry have a higher risk of significant impact due to the presence of the quarry, the sensitivity of the entire air quality study area to human health impacts is determined to be Low. Mitigation measures and considerations for receptors located near the quarry are included in Section 9.

6.1.5 Step 2C – Unmitigated risks of impacts

The dust emission magnitudes for each activity as determined in Step 2A were combined with the sensitivity of the area (in Table 6.3 and Table 6.4) to determine the risk of construction dust air quality impacts, with no mitigation applied. The risk of impacts for each activity is assessed according to the IAQM risk matrix for each construction activity which is presented in Table 6.5. The 'without mitigation' dust risk impacts for each activity are summarised in Table 6.6.

Table 6.5 IAQM risk matrix

Activity	Surrounding area sensitivity	Dust emission magnitude		
		Large	Medium	Small
Demolition	High	High risk	Medium risk	Medium risk
	Medium	High risk	Medium risk	Low risk
	Low	Medium risk	Low risk	Negligible
Earthworks	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Medium risk	Low risk
	Low	Low risk	Low risk	Negligible
Construction	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Medium risk	Low risk
	Low	Low risk	Low risk	Negligible
Trackout	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Low risk	Negligible
	Low	Low risk	Low risk	Negligible

Table 6.6 Without mitigation dust risk impacts for Project construction activities

Potential Impact	Risk			
	Demolition	Earthworks	Construction	Trackout
Scale of Activity (IAQM Table 4)	Small	Large	Large	Large
Dust Deposition	Low	Medium	Medium	Medium
Human Health	Negligible	Low	Low	Low

The result of the qualitative air quality risk assessment shows that the unmitigated air emissions from the construction of the Project poses a 'Low' risk of human health impacts but a 'Medium' risk of dust deposition.

6.1.6 Step 3 – Management strategies

The outcome of Step 2C is used to determine the level of management that is required to ensure that dust impacts on surrounding sensitive receptors are maintained at an acceptable level. A high or medium-level risk rating means that suitable management measures must be implemented during the Project.

A Construction Environment Management Plan (CEMP) will be developed to mitigate and manage potential impacts during the construction. The implementation of approved site-specific and in-principle management measures, as listed in Section 9, is expected to result in minimal risk of dust impacts on surrounding receptors.

6.1.7 Step 4 – Reassessment

The final step of the IAQM methodology is to determine whether there are significant residual impacts, post mitigation, arising from a proposed development. The guidance states:

> *For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be "not significant".*

The dust risk assessment in Table 6.6 shows that without mitigation there is an anticipated medium high risk of impact from dust deposition as a result of earthworks, construction and trackout. The risk to human health is anticipated to be low.

The construction dust sources associated with the Project are common emission sources. Industry standard best practice measures to reduce dust emissions exist for all the identified sources and it is expected that emissions can be well managed through diligent implementation of best practice controls. In addition to mitigation at the source, visual monitoring of dust generation (visible plumes) and deposition on horizontal sources is an effective way to monitor the effectiveness of mitigation measures to ensure impacts to sensitive receptors are minimised.

It is anticipated that with effective mitigation of construction dust sources the residual impact on both dust deposition and human health will not be significant. Further discussion of mitigation measures and an assessment of the residual significance of impact from construction with the implementation of the proposed mitigation measures is presented is provided in Section 9.

6.2 Tank fuel storage

Fuel storage is proposed to be undertaken at six locations (laydown areas) along the proposed alignment during the construction of the Project. Fuel storage has the potential to impact nearby sensitive receptors due to the emission of VOCs and odour. Table 6.7 presents the proposed construction areas that will include diesel fuel storage, the volumes proposed to be stored, and the distance from each area to the closest identified sensitive receptor.

Table 6.7 Fuel tank storage locations

Construction area ID	Chainage (km)	Location	Fuel storage proposed (L)	Distance from boundary of laydown area to closest sensitive receptor (m)
C2K-LDN004.8	4.8	Hayes Road	<20,000	175
C2K-LDN012.1	12.1	Paynes Road	<20,000	8
C2K-LDN021.8	21.8	Middle Road	<40,000	41
C2K-LDN026.0	26.0	Ipswich-Boonah Road	<20,000	25
C2K-LDN036.6	36.6	Washpool Rd	<20,000	159
C2K-LDN053.8	53.8	Undullah Road	<40,000	98

Table 6.7 shows that for the largest fuel storage tanks of 40,000 L, the distance to the closest receptor is 41 m, whilst for the for the smaller tanks of 20,000 L the distance to the closest receptor is 8 m.

Vic EPA (2013) provides guidance on separation distances for the storage of petroleum products (100 m for floating roof tanks, and 250 m for fixed roof tanks), but this guidance is for tanks exceeding 2,000 tonnes, which is far greater than the size of the tanks proposed for the Project.

The BCC Service Station Code provides performance outcomes and acceptable outcomes for service stations to ensure that service station developments are located at "sufficient distance from dwellings to maintain residential amenity in adjoining, adjacent or surrounding areas". Acceptable Outcome AO7.2 specifies acceptable separation distances based on annual fuel throughput. For service stations with an annual fuel throughput of less than 1.2 megalitres (ML) the acceptable separation distance is 10 m, whilst for service stations with annual fuel throughput of between 1.2 to 9 ML, the accepted distance is 50m. The service station code specifically excludes diesel from the definition of fuel, however, diesel is less volatile than petrol and other motor spirits and therefore the application of these buffers is considered conservative for diesel.

To exceed an annual throughput of 9 ML, the 20,000 L tanks would need to be refilled more than once per day (450 times per year), whilst the 40,000 L tanks would need to be refilled more than once every two days (225 times per year). It is considered improbable that this volume of diesel will be consumed, and it is expected that annual fuel throughput will be considerably less than 9 ML.

All construction areas with the exception of C2K-LDN012.1, C2K-LDN021.8, and C2K-LDN026.0 have separation distances from the nearest boundary to the closest receptor of greater than 50 m. However, the dimensions of C2K-LDN012.1 (1,400 m x 30 m), C2K-LDN021.8 (400 m x 550 m), and C2K-LDN026.0 (290 m x 680 m) will allow for the fuel tanks in these construction areas to be located at a position which is further than 50 m from the nearest receptor.

It is recommended that at minimum fuel tanks should be located at least 50 m from the nearest sensitive receptor, but separation distances should be maximised as far as practical within site restrictions. A minimum separation distance of 50 m and compliance with Australian Standard AS 1940:2017 The storage and handling of flammable and combustible liquids is expected to result in negligible impacts to sensitive receptors based on the recommendations of the BCC Service Station Code.

7 Operational air quality impact assessment

This section presents the results of the assessment impacts to air quality and tank water quality from the operational phase of the Project.

Air emissions from the commissioning phase of the Project are expected to be insignificant and are considered unlikely to generate nuisance or risk exceedance of the Projects air quality goals and therefore have not been assessed.

Given the uncertainty associated with timeframe for decommissioning, this phase has not been considered in this assessment.

7.1 Air quality

7.1.1 Modelled results

The results of the modelling of operational impacts are presented in this section. The results are itemised in the increments described below in Table 7.1.

Table 7.1 Modelling increment descriptions

Increments	Description
Project only contribution	Represents the predicted concentrations from modelled Project locomotive emissions
Background concentration	Adopted background concentrations as per Section 5.2.6
Total cumulative concentration	The cumulative concentration of the Project contribution and the adopted background concentration
With veneering	Contribution from trains with veneering (75 per cent reduction to emissions from coal wagons) (only applicable for TSP, PM_{10}, $PM_{2.5}$ and deposited dust)
Without veneering	Contribution from trains without veneering (no reduction to coal wagon emissions) (only applicable for TSP, PM_{10}, $PM_{2.5}$ and deposited dust)

The results of the dispersion modelling for the worst affected receptor are shown in Table 7.2 and Table 7.3 for the peak and typical train volume scenarios respectively. Table 7.2 and Table 7.3 also present the air quality goals for each pollutant of concern.

Table 7.2 and Table 7.3 show that compliance is predicted for all pollutant species for both the typical and peak traffic volume scenarios with the inclusion of veneering. Without veneering, the annual PM_{10} and $PM_{2.5}$ goals are predicted to be exceeded for both typical and peak train volumes. Consequently, it is expected that veneering will be required to ensure compliance with the adopted annual goals for PM_{10} and $PM_{2.5}$ based on the train volumes assessed.

The air quality goals adopted for the assessment are prescribed to protect the environmental values of health and wellbeing and protecting the aesthetic environment. Assessment of the Projects impact to these environmental values is discussed in the following sections.

Modelled results for PM_{10}, $PM_{2.5}$ and NO_2 for every receptor for the peak train volume scenario with the inclusion of veneering are presented in Appendix F. Appendix G provides additional detailed figures for the sensitive receptors included in the modelling.

Table 7.2 **Highest predicted ground level concentrations at worst affected sensitive receptor for peak operations**

Pollutant	Receptor	Average period	Highest predicted ground level pollutant concentration at identified sensitive receptor locations (µg/m^3)			Air quality goal (µg/m^3)	Environmental values protected
			Project only contribution (A)[a]	Background concentration (B)	Total cumulative concentration (Project + Background) (A + B)		
TSP	sr461	Annual average (with veneering)	10.1	40.5	50.6	90	Health and wellbeing
	sr461	Annual average (without veneering)	36.0		76.5		
PM_{10}	sr461	24 hour maximum (with veneering)	9.3	18.7	28.0	50	Health and wellbeing
	sr461	24 hour maximum (without veneering)	30.2		48.9		
	sr461	Annual average (with veneering)	5.7	16.2	21.9	25	Health and wellbeing
	sr461	Annual average (without veneering)	18.7		**34.9**		
$PM_{2.5}$	sr503	24 hour maximum (with veneering)	4.4	6.4	10.8	25	Health and wellbeing
	sr461	24 hour maximum (without veneering)	6.5		12.9		
	sr461	Annual average (with veneering)	2.0	5.7	7.7	8	Health and wellbeing
	sr461	Annual average (without veneering)	3.9		**9.6**		
Deposited dust	sr461	30 day (with veneering)	0.05	50	50.1	120 mg/m^2/day	Nuisance
	sr461	30 day (without veneering)	0.19	50	50.2		
NO_2	sr503	1 hour maximum	149.2	26.7	175.9	250	Health and wellbeing
	sr461	Annual average	16.59	7.8	24.4	62	Health and wellbeing
Arsenic and compounds	sr461	Annual average	3.74×10^{-4} ng/m^3	-[a.]	-[a.]	6 ng/m^3	Health and wellbeing

Pollutant	Receptor	Average period	Highest predicted ground level pollutant concentration at identified sensitive receptor locations (µg/m^3)			Air quality goal (µg/m^3)	Environmental values protected
			Project only contribution (A)[a]	Background concentration (B)	Total cumulative concentration (Project + Background) (A + B)		
Cadmium and compounds	sr461	Annual average	3.74×10^{-2} ng/m^3	-[a.]	-[a.]	5 ng/m^3	Health and wellbeing
Chromium III and compounds	sr461	1 hour maximum	8.64×10^{-4}	-[a.]	-[a.]	9	n/a
Chromium VI and compounds	sr461	1 hour maximum	8.64×10^{-4}	-[a.]	-[a.]	0.1	Screening health risk assessment
	sr461	Annual average	1.88×10^{-4}	-[a.]	-[a.]	0.01	Screening health risk assessment
Lead and compounds	sr461	Annual average	3.31×10^{-6}	-[a.]	-[a.]	0.5	Health and wellbeing
Nickel and compounds	sr461	Annual average	0.46 ng/m^3	-[a.]	-[a.]	22 ng/m^3	Health and wellbeing
Dioxins and furans	sr441	Annual average	6.53×10^{-11}	-[a.]	-[a.]	3×10^{-8}	Screening health risk assessment
Polycyclic aromatic hydrocarbon (as benzo[a]pyrene)	sr441	Annual average	0.021 ng/m^3	-[a.]	-[a.]	0.3 ng/m^3	Health and wellbeing
1,3-butadiene	sr441	Annual average	0.24	-[a.]	-[a.]	2.4	Health and wellbeing
Benzene	sr441	Annual average	0.0023	5.2	5.2	5.4	Health and wellbeing
Toluene	sr503	30 minute maximum	0.0082	23.0	23.0	1,100	Protecting aesthetic environment
	sr503	24 hour maximum	0.0016	21.7	21.7	4,100	Health and wellbeing
	sr441	Annual average	0.00033	18.5	18.5	400	Health and wellbeing
Xylenes	sr503	24 hour maximum	0.22	31.5	31.7	1100	Health and wellbeing
	sr441	Annual average	0.045	26.0	26.1	950	Health and wellbeing

Table notes:

a No background monitoring data available for modelled pollutant.

b 30 minute averages calculated from 1 hour modelling results as per (Turner 1970)

Predicted concentrations which exceed the air quality goal are shown in **bold**.

Table 7.3 Highest predicted ground level concentrations at worst affected sensitive receptor for typical operations

Pollutant	Receptor	Average period	Highest predicted ground level pollutant concentration at identified sensitive receptor locations (µg/m^3)			Air quality goal (µg/m^3)	Environmental aspect protected
			Project only contribution (A)	Background concentration (B)	Project only contribution + Background concentration (A + B)		
TSP	sr461	Annual average (with veneering)	7.9	40.5	48.4	90	Health and wellbeing
	sr461	Annual average (without veneering)	28.3		68.8		
PM_{10}	sr461	24 hour maximum (with veneering)	7.4	18.7	26.1	50	Health and wellbeing
	sr503	24 hour maximum (without veneering)	23.7		42.4		
	sr461	Annual average (with veneering)	4.5	16.2	20.7	25	Health and wellbeing
	sr461	Annual average (without veneering)	14.6		**30.8**		
$PM_{2.5}$	sr503	24 hour maximum (with veneering)	4.1	6.4	10.5	25	Health and wellbeing
	sr503	24 hour maximum (without veneering)	5.4		11.8		
	sr461	Annual average (with veneering)	1.5	5.7	7.2	8	Health and well eing
	sr461	Annual average (without veneering)	3.1		**8.8**		
Deposited dust	sr461	30 day (with veneering)	0.04	50	50.0	120 mg/m^2/day	Nuisance
	sr461	30 day (without veneering)	0.15	50	50.2		
NO_2	sr503	1 hour maximum	149.0	26.7	175.9	250	Health and wellbeing
	sr461	Annual average	16.6	7.8	24.4	62	Health and wellbeing
Arsenic and compounds	sr461	Annual average	2.94 x 10^{-4} ng/m^3	-[a.]	-[a.]	6 ng/m^3	Health and wellbeing
Cadmium and compounds	sr461	Annual average	2.94 x 10^{-2} ng/m^3	-[a.]	-[a.]	5 ng/m^3	Health and wellbeing
Chromium III and compounds	sr503	1 hour maximum	7.79 x 10^{-4}	-[a.]	-[a.]	9	n/a
Chromium VI and compounds	sr503	1 hour maximum	7.79 x 10^{-4}	-[a.]	-[a.]	0.1	Screening health risk assessment
	sr461	Annual average	1.47 x 10^{-4}	-[a.]	-[a.]	0.01	Screening health risk assessment

Pollutant	Receptor	Average period	Highest predicted ground level pollutant concentration at identified sensitive receptor locations (µg/m^3)			Air quality goal (µg/m^3)	Environmental aspect protected
			Project only contribution (A)	Background concentration (B)	Project only contribution + Background concentration (A + B)		
Lead and compounds	sr461	Annual average	2.59 x 10^{-6}	-[a.]	-[a.]	0.5	Health and wellbeing
Nickel and compounds	sr461	Annual average	0.36 ng/m^3	-[a.]	-[a.]	22 ng/m^3	Health and wellbeing
Dioxins and furans	sr461	Annual average	5.72 x 10^{-11}	-[a.]	-[a.]	3 x 10^{-8}	Screening health risk assessment
Polycyclic aromatic hydrocarbon (as benzo[a]pyrene)	sr461	Annual average	0.018 ng/m^3	-[a.]	-[a.]	0.3 ng/m^3	Health and wellbeing
1,3-butadiene	sr461	Annual average	0.21	-[a.]	-[a.]	2.4	Health and wellbeing
Benzene	sr461	Annual average	0.0020	5.2	5.2	5.4	Health and wellbeing
Toluene	sr503	30 minute maximum	0.0061	23.0	23.0	1,100	Protecting aesthetic environment
	sr503	24 hour maximum	0.0015	21.7	21.7	4,100	Health and wellbeing
	sr461	Annual average	0.00029	18.5	18.5	400	Health and wellbeing
Xylenes	sr503	24 hour maximum	0.21	31.5	31.7	1,100	Health and wellbeing
	sr461	Annual average	0.039	26.0	26.0	950	Health and wellbeing

Table notes:

a No background monitoring data available for modelled pollutant.

b 30 minute averages calculated from 1 hour modelling results as per (Turner 1970)

Predicted concentrations which exceed the air quality goal are shown in **bold**.

7.1.2 Impacts to human health

All of the pollutant species considered in detail for the assessment of operational impacts are set for the protection of human health with the exception of dust deposition and toluene (30 minute average). With the inclusion of veneering, the predicted cumulative concentrations for all pollutants assessed are below the adopted goals for both the peak and typical train volumes assessed.

The assessment has considered background air quality in the prediction of cumulative concentrations, and therefore the results of the assessment can be used to assess the impact on human health. As predicted cumulative concentrations are compliant with the adopted air quality goals, the operation of the Project is not expected to significantly impact the environmental aspect of health and wellbeing.

7.1.3 Impacts to amenity

The pollutant species which have air quality goals set for the protection of the aesthetic environment are toluene (30 minute average) and dust deposition. Table 7.2 and Table 7.3 show that the Project contribution to toluene (30 minute average) is 0.0082 ug/m^3 for the peak scenario and 0.0061 ug/m^3 for the typical scenario, which both represent less than 0.1 per cent of the 30 minute average goal of 1,100 ug/m^3.

The predicted maximum Project contribution to deposited dust for the peak scenario is 0.05 mg/m^2/day with veneering and 0.19 mg/m^2/day without veneering. For the typical scenario, the predicted Project contribution to deposited dust is 0.04 mg/m^2/day with veneering and 0.15 mg/m^2/day without veneering. Each of these predicted contributions represent less than 0.2 per cent of the adopted goal of 120 mg/m^2/day.

Based on the magnitude of the predicted Project contributions, and as the predicted cumulative concentrations are well below the air quality goals for toluene and deposited dust, the operation of the Project is not expected to significantly adversely impact the environmental values of aesthetic environment and the risk of amenity impacts as a result of the operation of the Project is considered to be low.

7.1.4 Impacts to the assimilative capacity of the air environment

The assessment has considered background air quality in the prediction of cumulative concentrations and deposition levels at sensitive receptors and has therefore considered the assimilative capacity of the air environment in determining compliance with the adopted air quality goals.

The remaining assimilative capacity of the receiving environment with the operation of the Project has been calculated for TSP, PM_{10}, $PM_{2.5}$ and NO_2, which are the pollutants emitted in the highest quantities by the operation of the Project. The remaining assimilative capacity for the peak and typical train volume scenarios have been calculated for the worst affected receptor with the results presented in Table 7.4 and Table 7.5. It is highlighted that this is a conservative assessment of the assimilative capacity of the receiving environment as predicted concentrations vary significantly at different receptors.

Table 7.4 and Table 7.5 show that the pollutant with the highest predicted change to the assimilative capacity of the air environment is NO_2, which is predicted to change by 60 per cent for 1 hour predictions and 27 per cent for annual average predictions at the worst affected receptor. However, it is noted that even at the worst affected receptor, the remaining assimilative capacity is 30 per cent for 1 hour concentrations, and 61 per cent for annual average concentrations.

For particulates, Table 7.4 and Table 7.5 show that with veneering included the maximum change to the assimilative capacity of the receiving environment for peak train volumes is 25 per cent for annual average $PM_{2.5}$, with a maximum change of 22 per cent calculated for annual average $PM_{2.5}$ for typical train volumes.

Table 7.4 **Remaining assimilative capacity for peak operation for worst affected receptor**

Pollutant	Averaging period	Project only contribution ($\mu g/m^3$)	Total cumulative concentration ($\mu g/m^3$)	Air quality goal ($\mu g/m^3$)	Remaining assimilative capacity at worst affected receptor (per cent)[a, b]	Change to assimilative capacity at worst affected receptor (per cent)
TSP	Annual average (with veneering)	10.1	50.6	90	44	11
	Annual average (without veneering)	36.0	76.5	90	15	40
PM_{10}	24 hour maximum (with veneering)	9.3	28	50	44	19
	24 hour maximum (without veneering)	30.2	48.9	50	2	60
	Annual average (with veneering)	5.7	21.9	25	12	23
	Annual average (without veneering)	18.7	34.9	25	-40	75
$PM_{2.5}$	24 hour maximum (with veneering)	4.4	10.8	25	57	18
	24 hour maximum (without veneering)	6.5	12.9	25	48	26
	Annual average (with veneering)	2.0	7.7	8	4	25
	Annual average (without veneering)	3.9	9.6	8	-20	49
NO_2	1 Hour	149.2	176	250	30	60
	Annual	16.6	24.4	62	61	27

Table notes:

a The remaining assimilative capacity of the receiving environment at the worst affected receptor considering contributions from the operation of the Project.
b Negative percentage values occur for pollutants where the goal is exceeded.

Table 7.5 Remaining assimilative capacity for typical operations for worst affected receptor

Pollutant	Averaging period	Project only contribution (µg/m³)	Total cumulative concentration (µg/m³)	Air quality goal (µg/m³)	Remaining assimilative capacity at worst affected receptor (per cent)[a, b]	Change to assimilative capacity at worst affected receptor (per cent)
TSP	Annual average (with veneering)	7.9	48.4	90	46	9
	Annual average (without veneering)	28.3	68.8	90	24	31
PM_{10}	24 hour maximum (with veneering)	7.4	26.1	50	48	15
	24 hour maximum (without veneering)	23.7	42.4	50	15	47
	Annual average (with veneering)	4.5	20.7	25	17	18
	Annual average (without veneering)	14.6	30.8	25	-23	58
$PM_{2.5}$	24 hour maximum (with veneering)	4.1	10.5	25	58	16
	24 hour maximum (without veneering)	5.4	11.8	25	53	22
	Annual average (with veneering)	1.5	7.2	8	10	19
	Annual average (without veneering)	3.1	8.8	8	-10	39
NO_2	1 Hour	149.0	176.0	250	30	60
	Annual	16.6	24.4	62	61	27

Table notes:

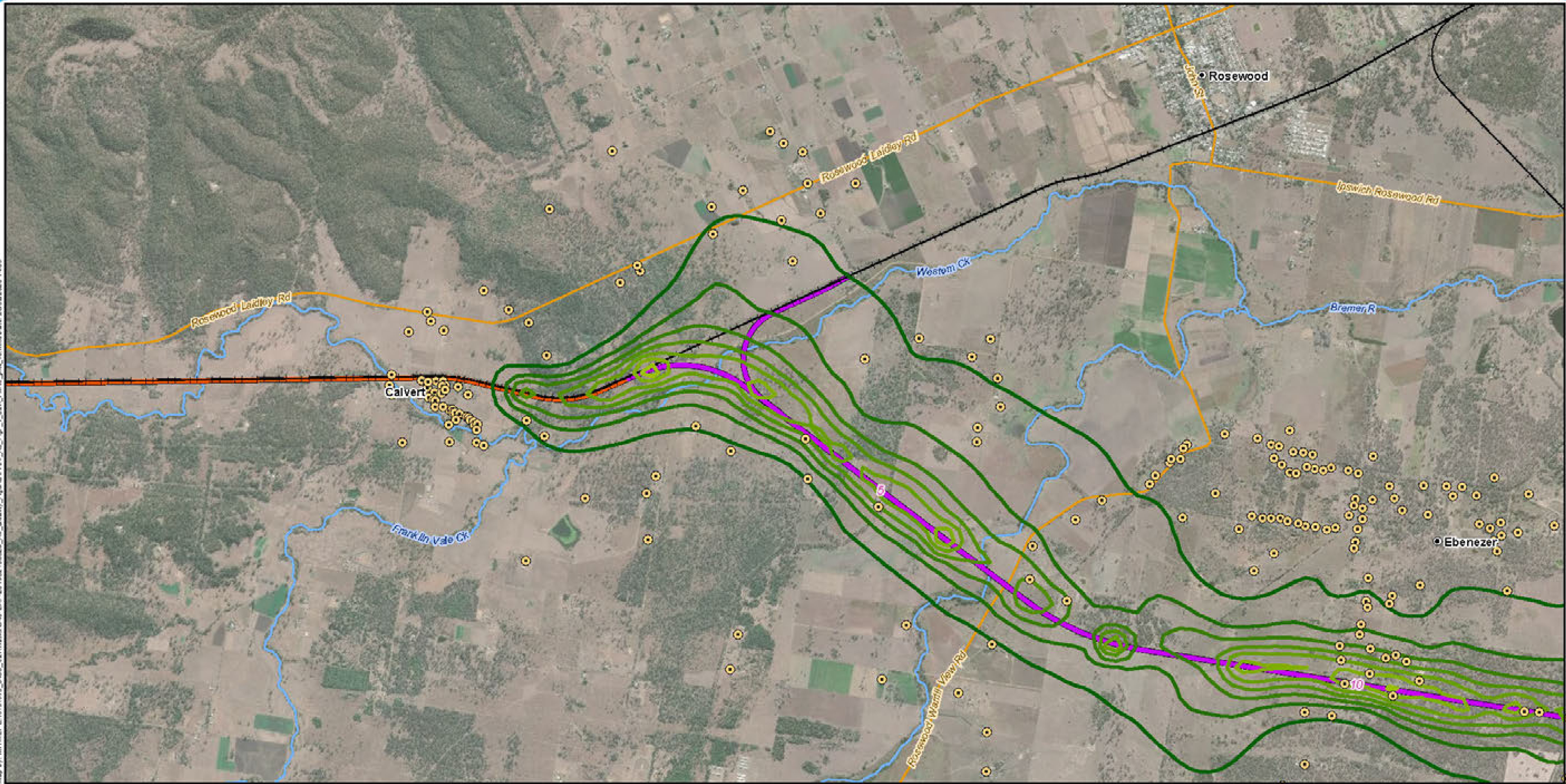
a The remaining assimilative capacity of the receiving environment at the worst affected receptor considering contributions from the operation of the Project.

b Negative percentage values occur for pollutants where the goal is exceeded.

7.1.5 Concentration contours

Predicted cumulative pollutant concentration contours for the peak train volume scenario are presented in Figure 7.1 to Figure 7.3 for PM_{10} (24 hour), $PM_{2.5}$ (annual) and NO_2 (1 hour). Predicted cumulative pollutant concentration contours for the same pollutant for the typical train volume scenario are presented in Figure 7.4 to Figure 7.6. The concentration contours presented are cumulative, and therefore can be compared directly against the Project air quality goals.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m³ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

Future Freight — Integrating Community, Environment and Engineering

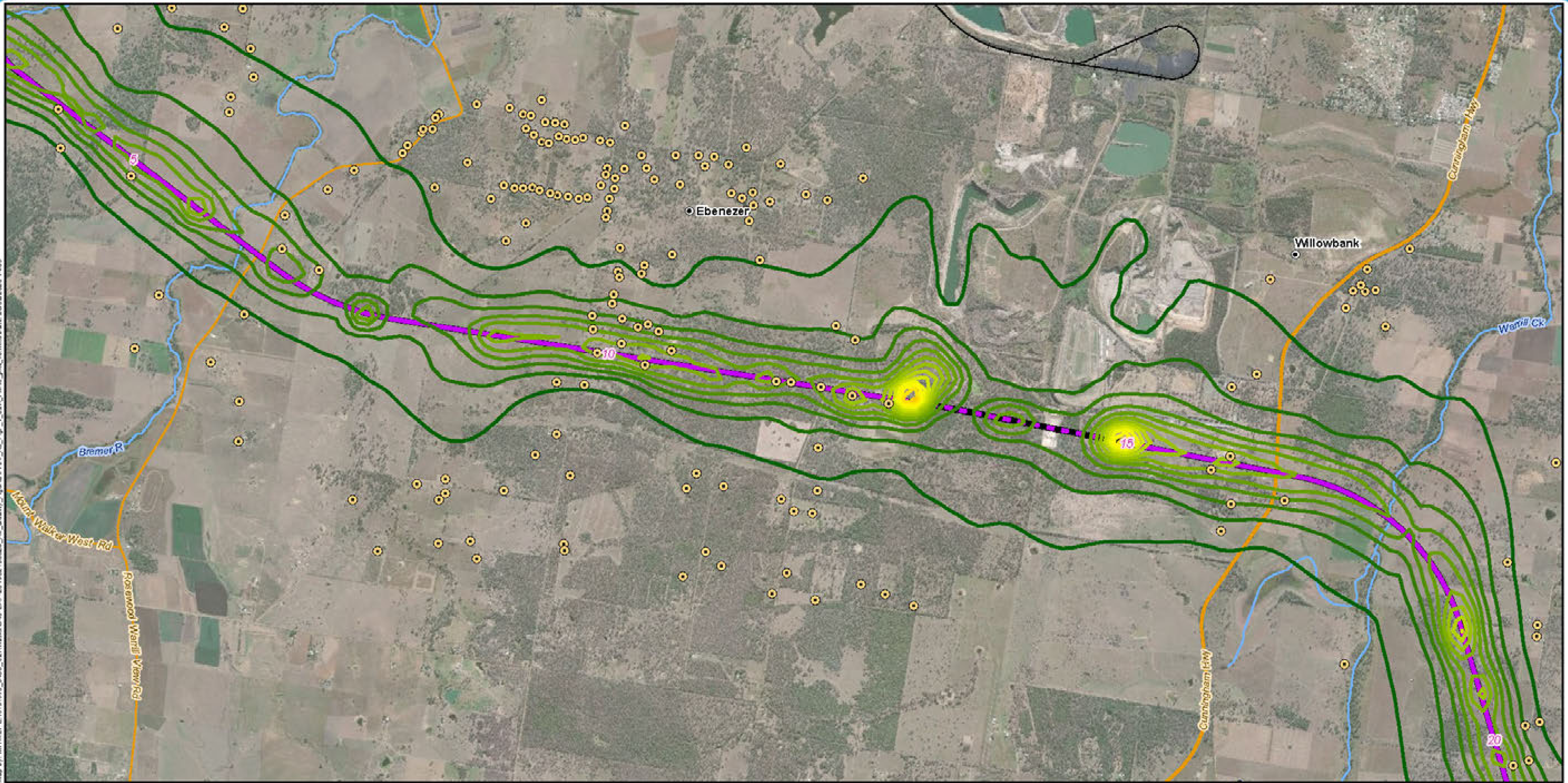
Issue date: 28/02/2020 Version: 8

Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1a: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

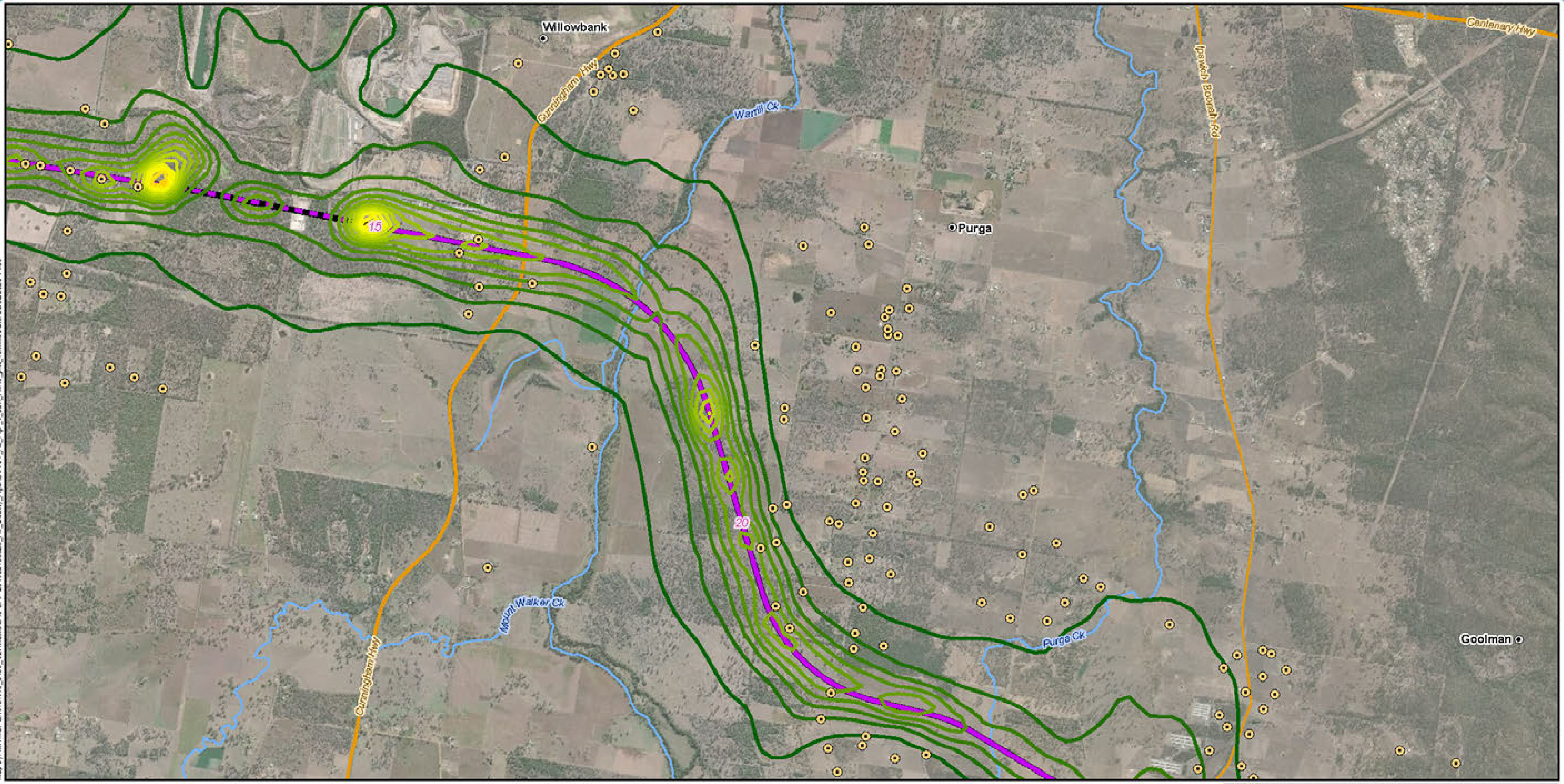
Future Freight
Integrating Community, Environment and Engineering

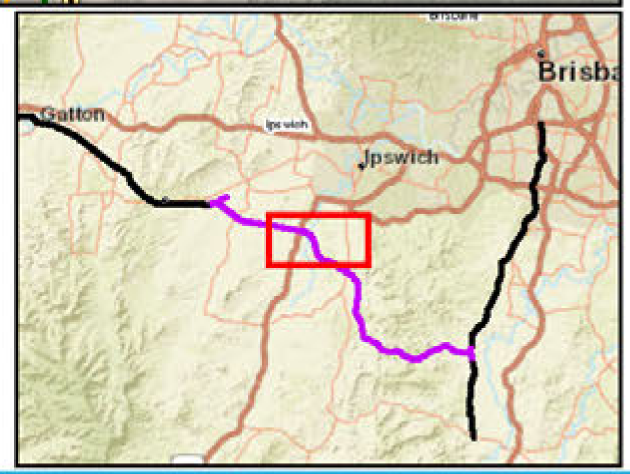
Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1b: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

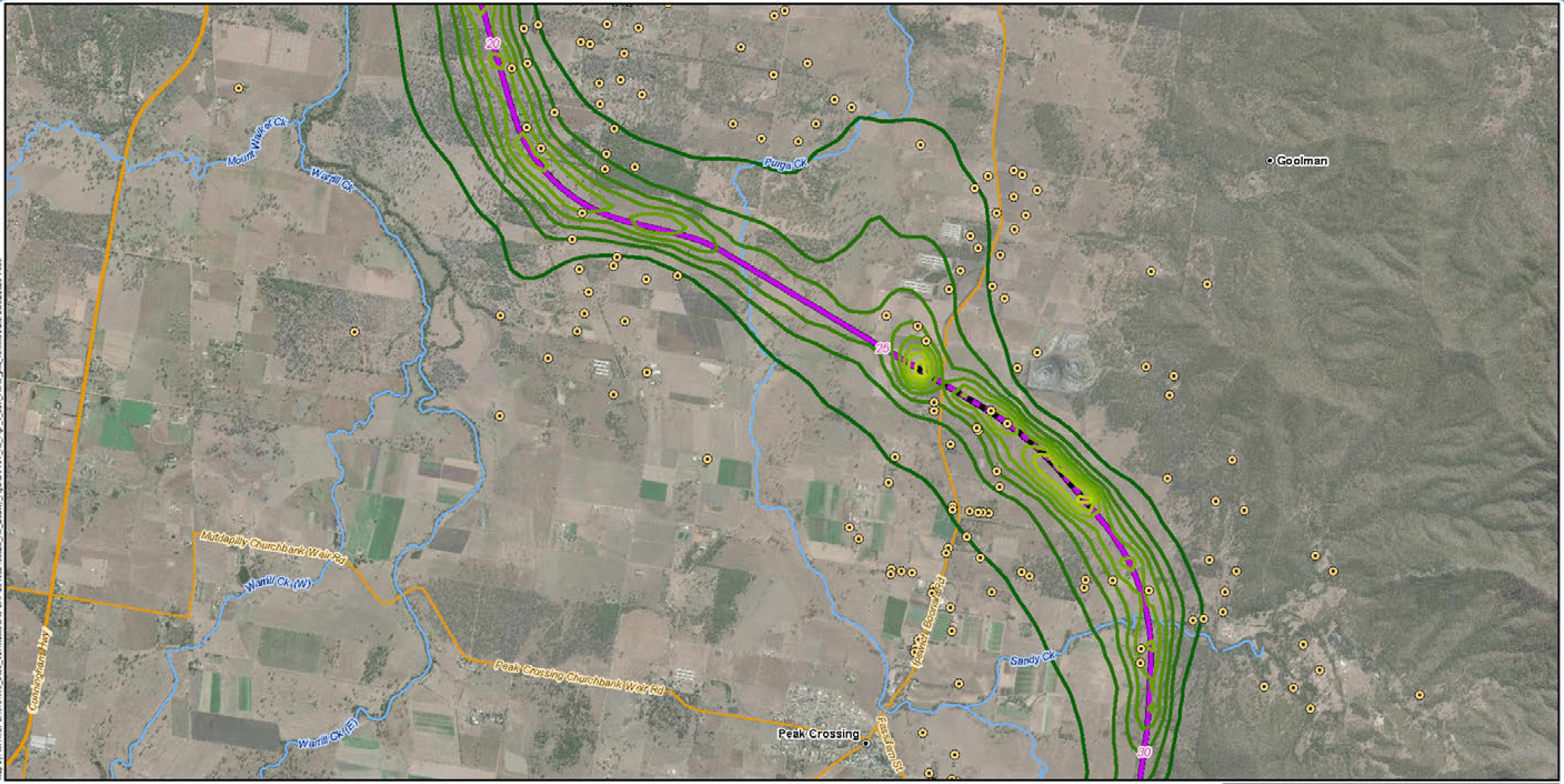
Future Freight
Integrating Community, Environment and Engineering

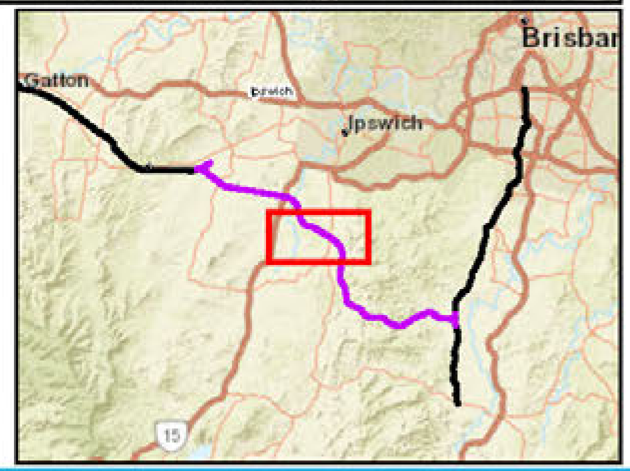
Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1c: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m³ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

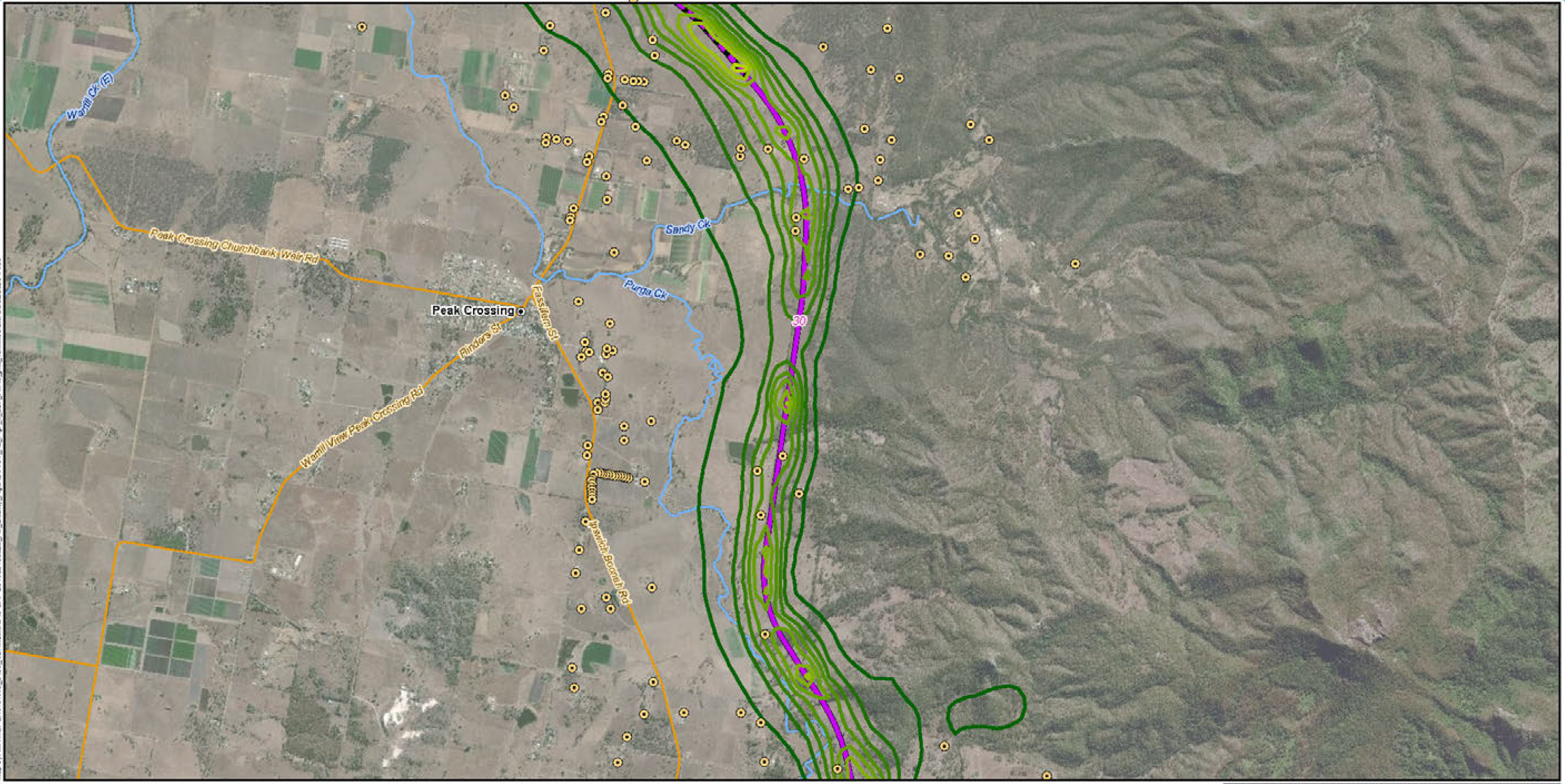
0 0.4 0.8 1.2 1.6 2km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1d: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 $\mu g/m^3$ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

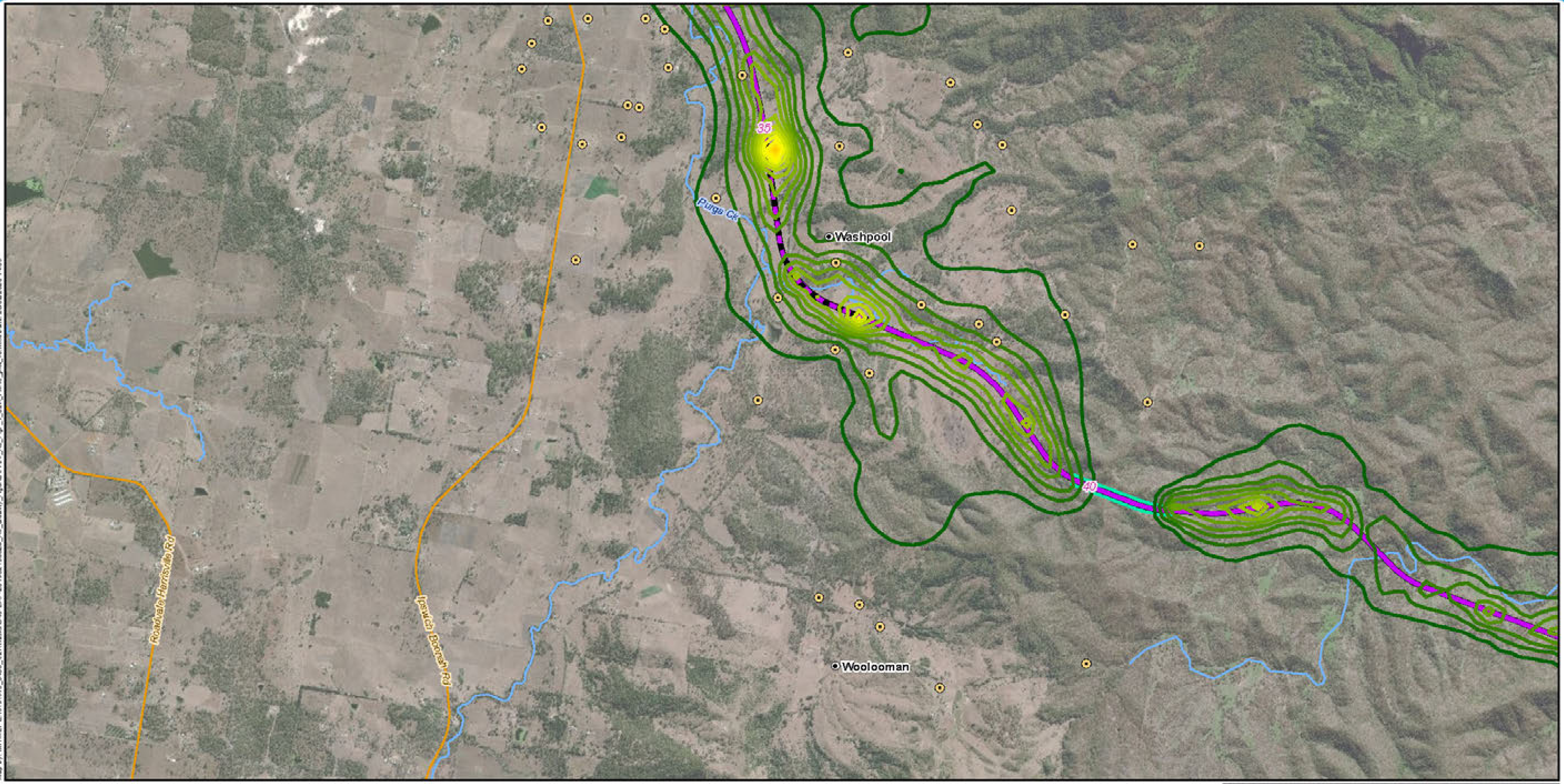
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1e: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Tunnel
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m³ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

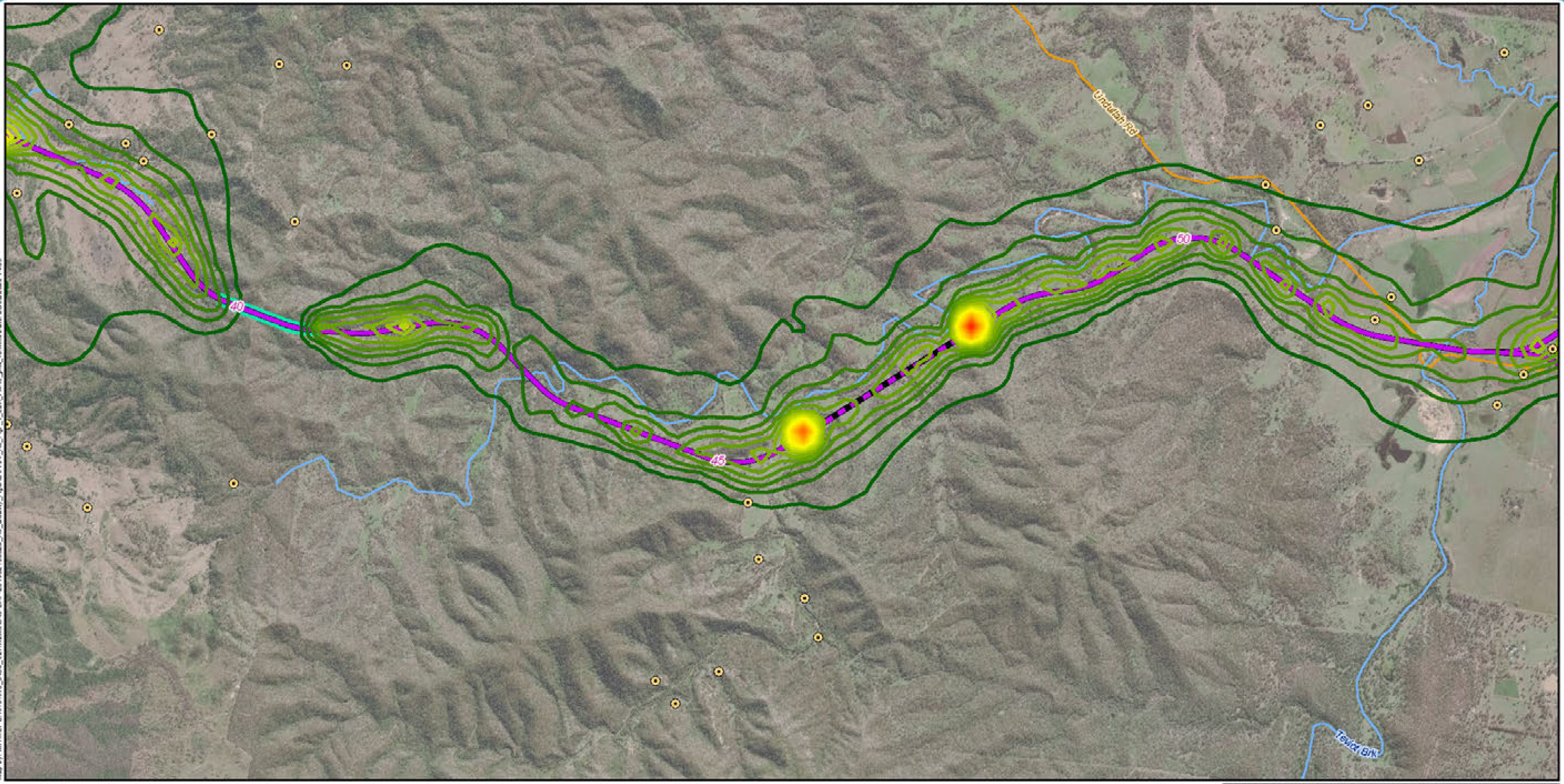
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1f: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Tunnel
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

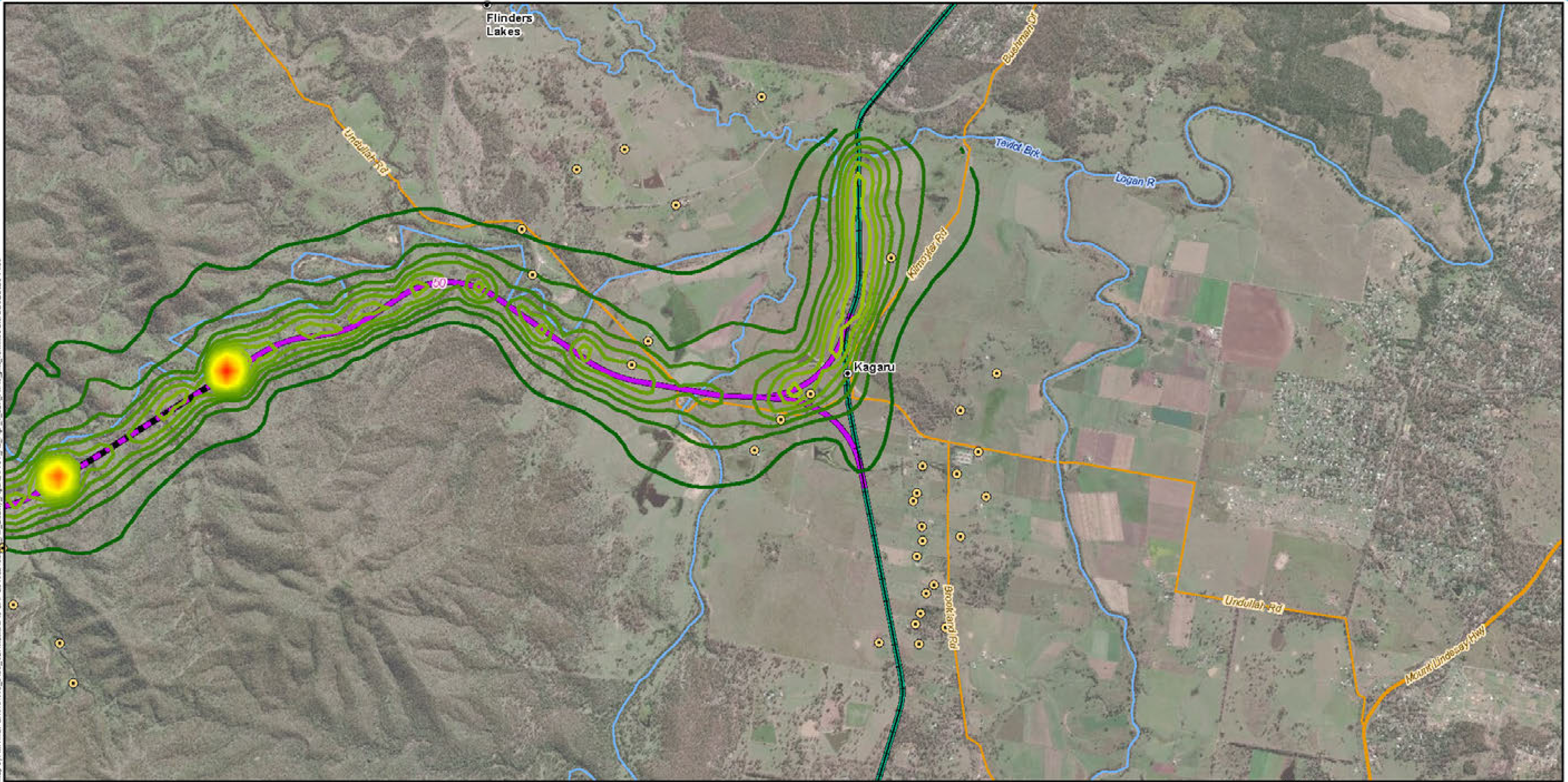
0 0.4 0.8 1.2 1.6 2km

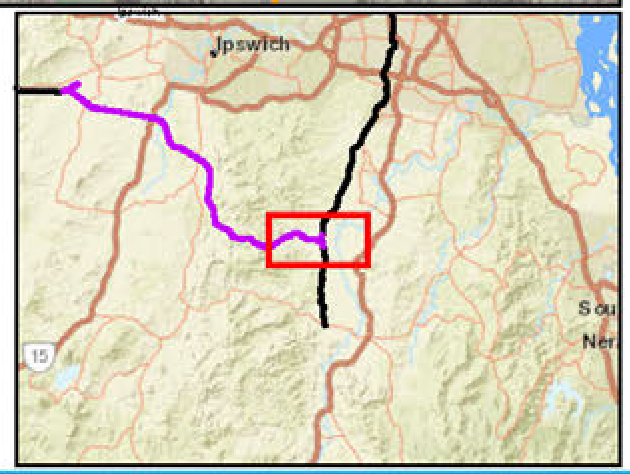
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1g: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot





Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m³ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

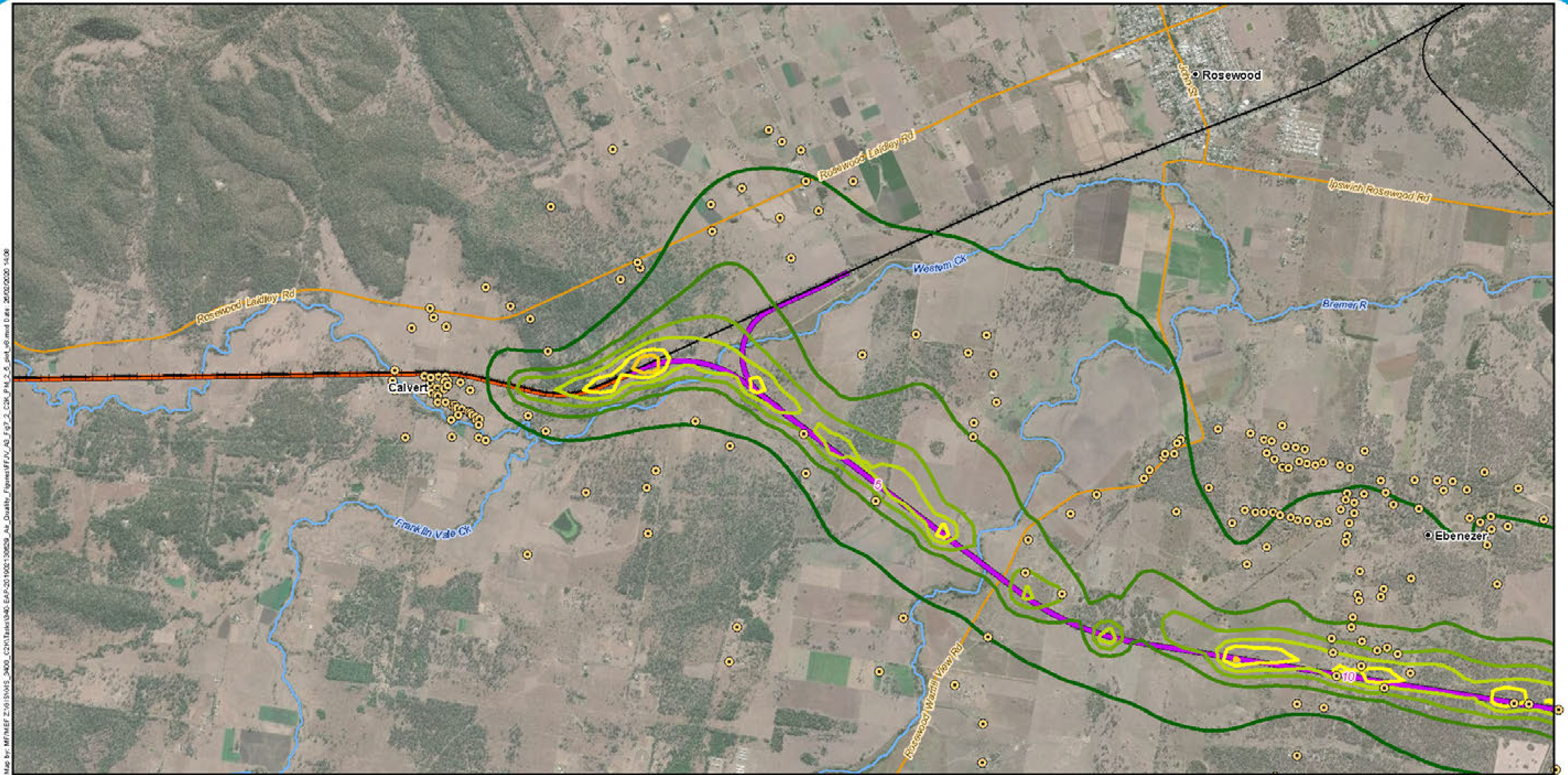
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.1h: Peak scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2km

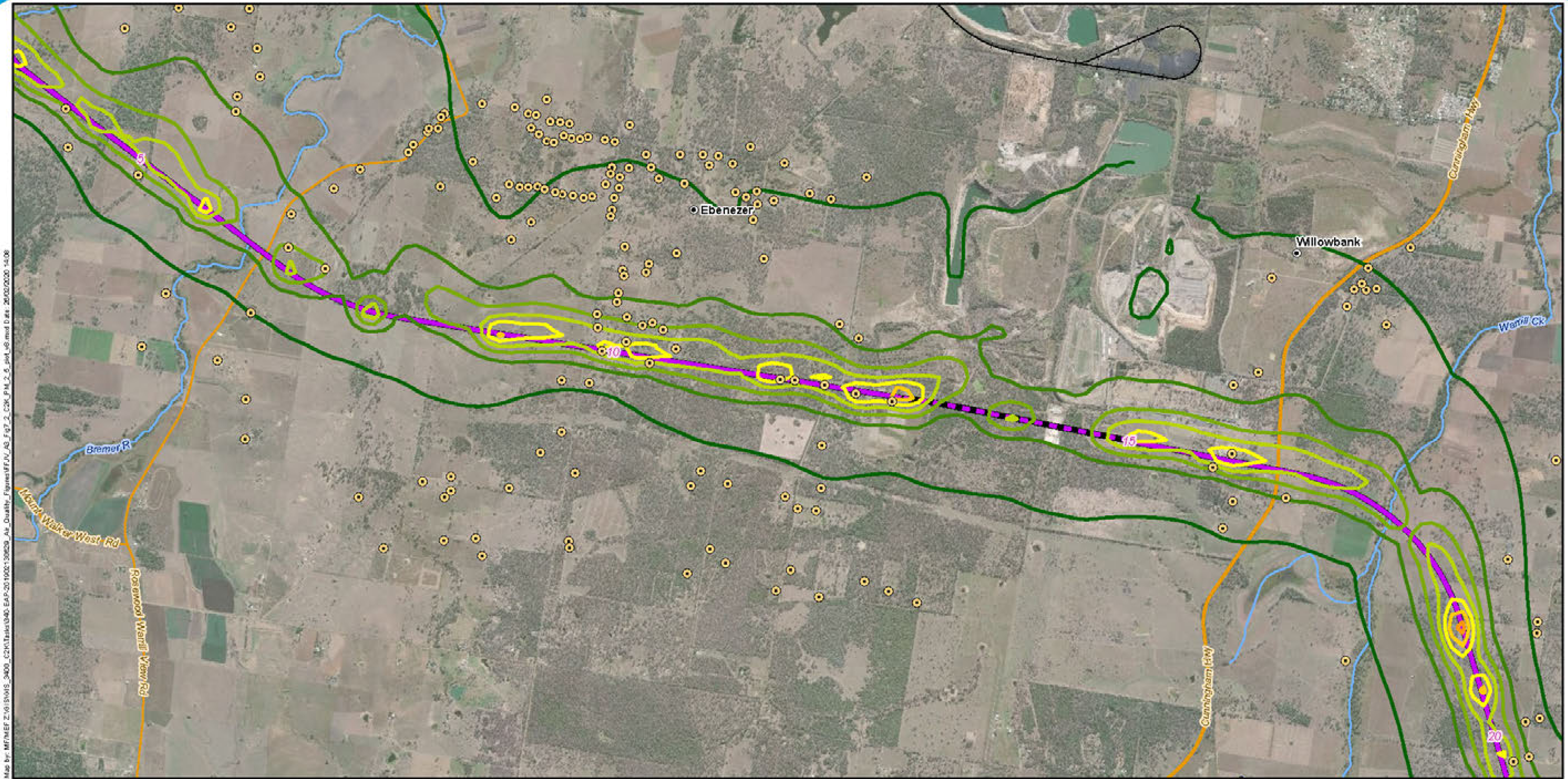
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2a: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2 km

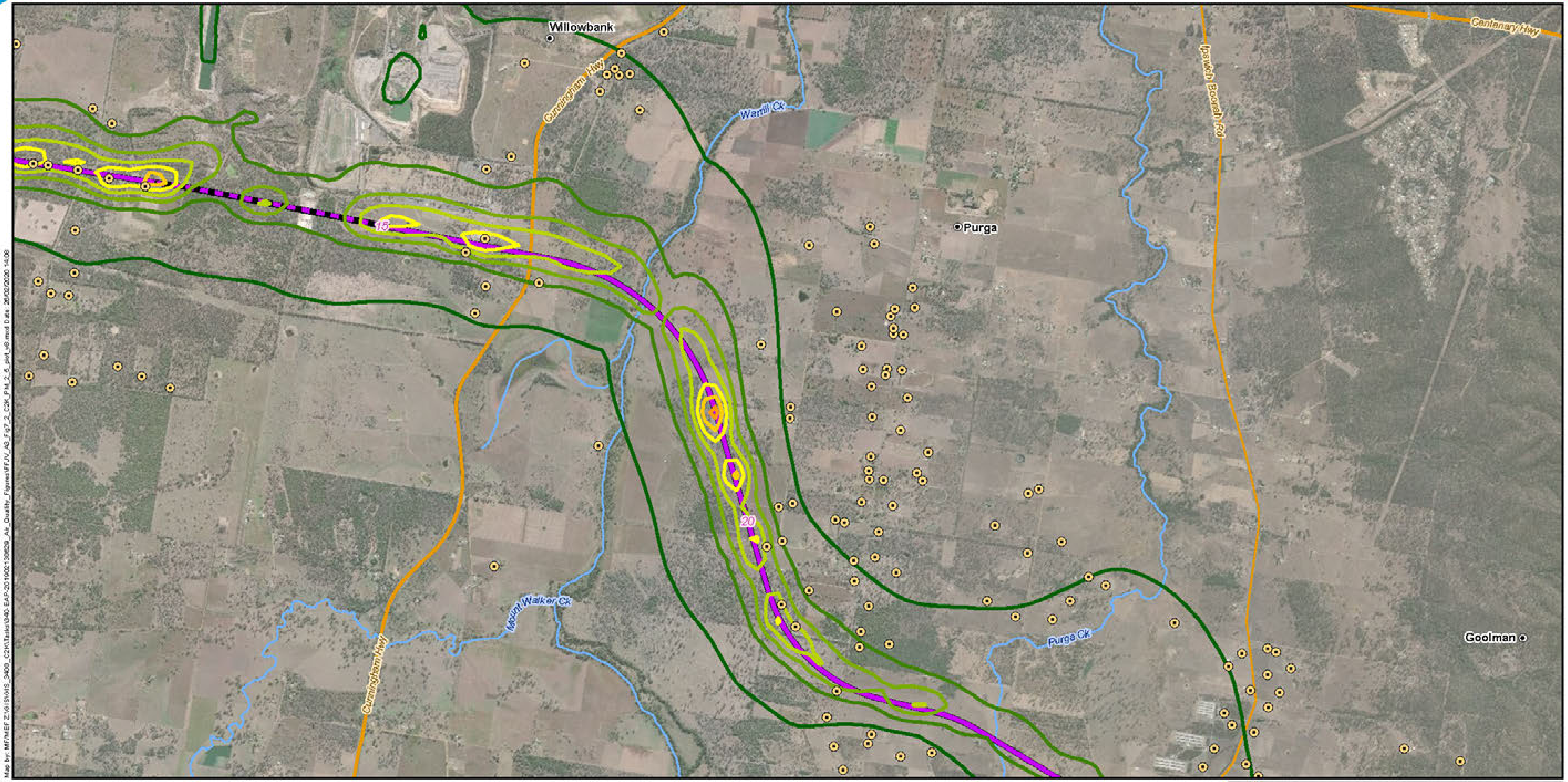
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2b: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

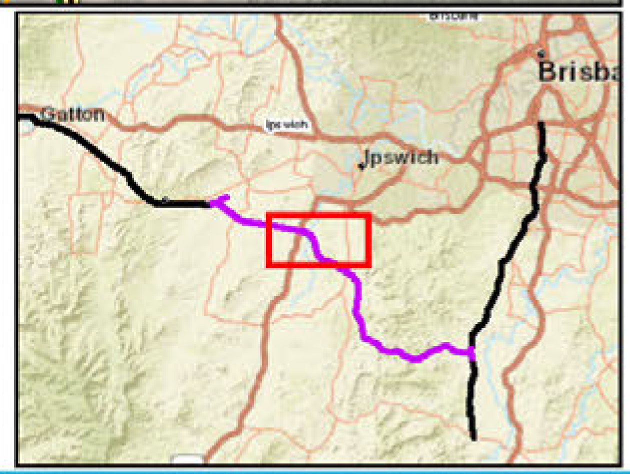


Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative PM2.5 annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4



A3 scale: 1:40,000

0 0.5 1 1.5 2 km

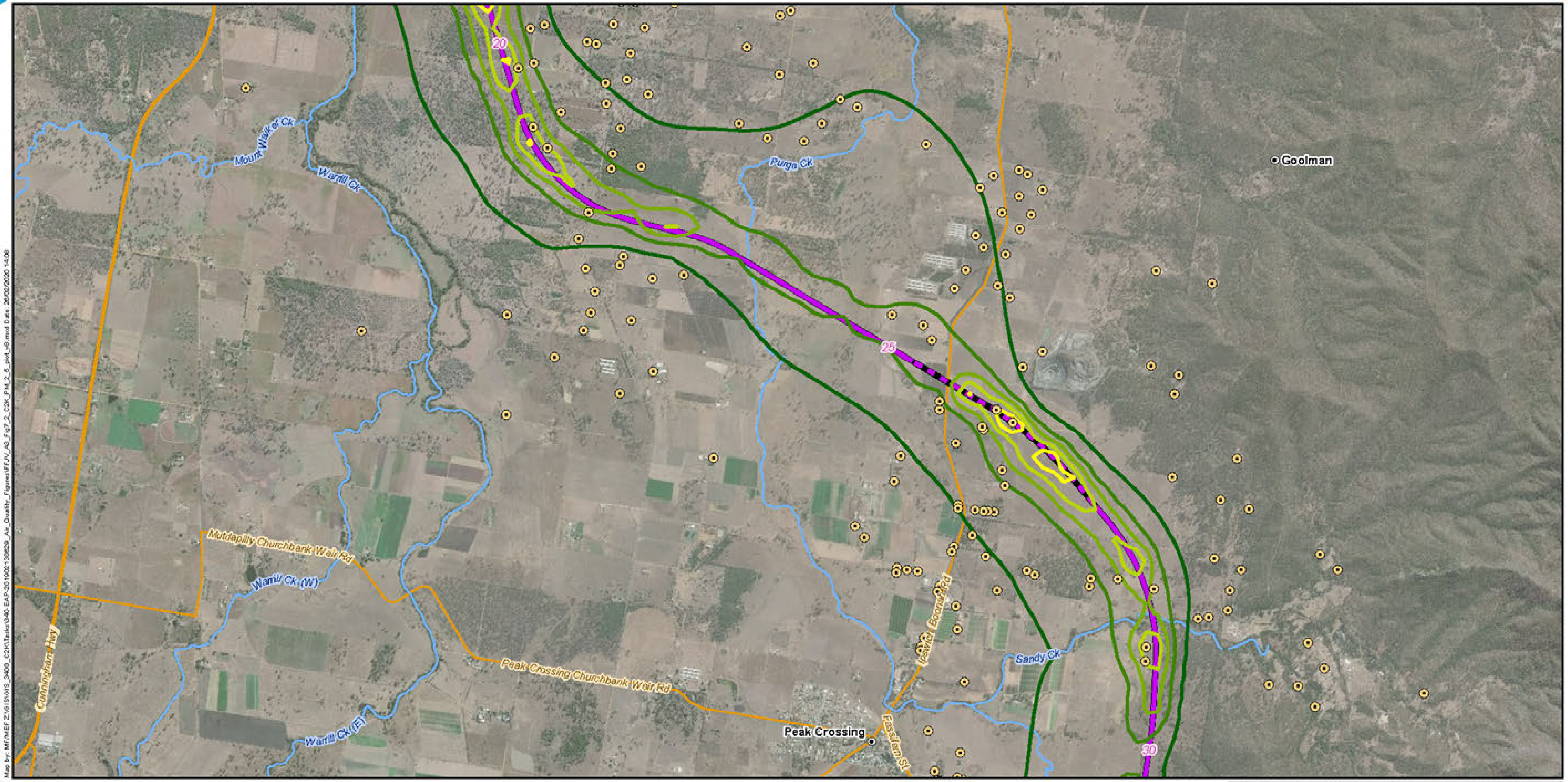
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2c: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

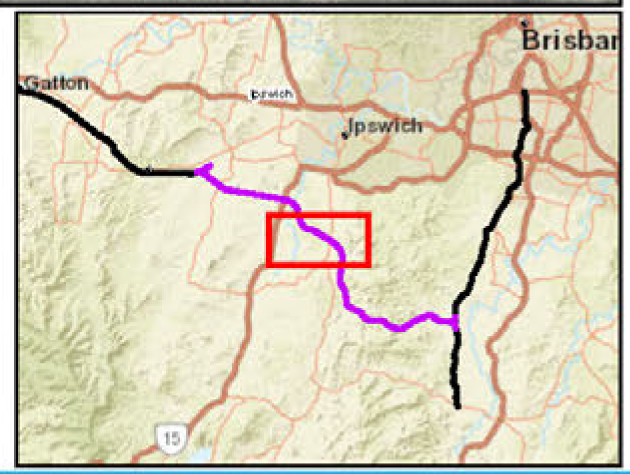


Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4



A3 scale: 1:40,000

0 0.5 1 1.5 2 km

Future Freight — Integrating Community, Environment and Engineering

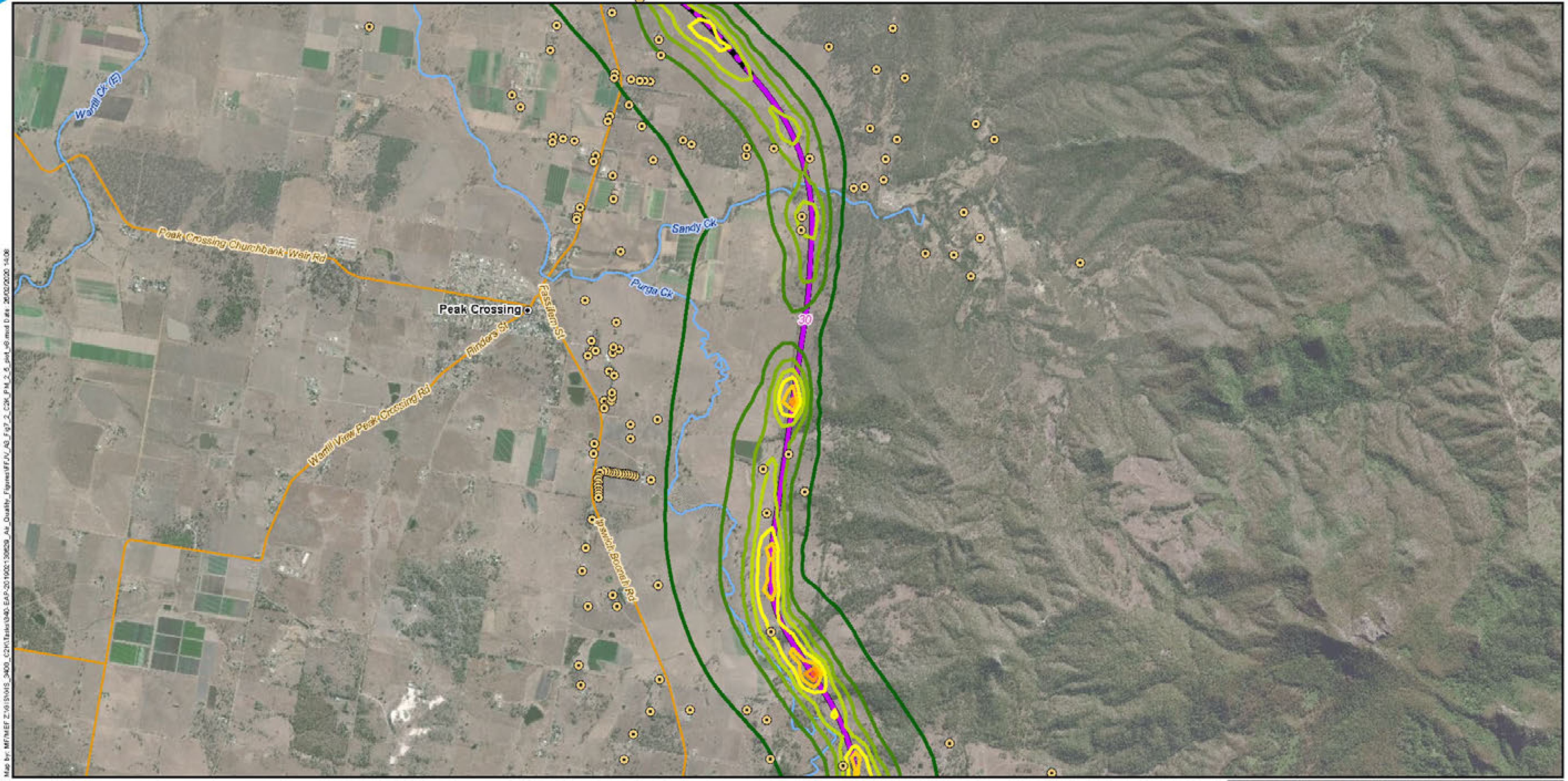
Issue date: 28/02/2020 Version: 8

Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2d: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2km

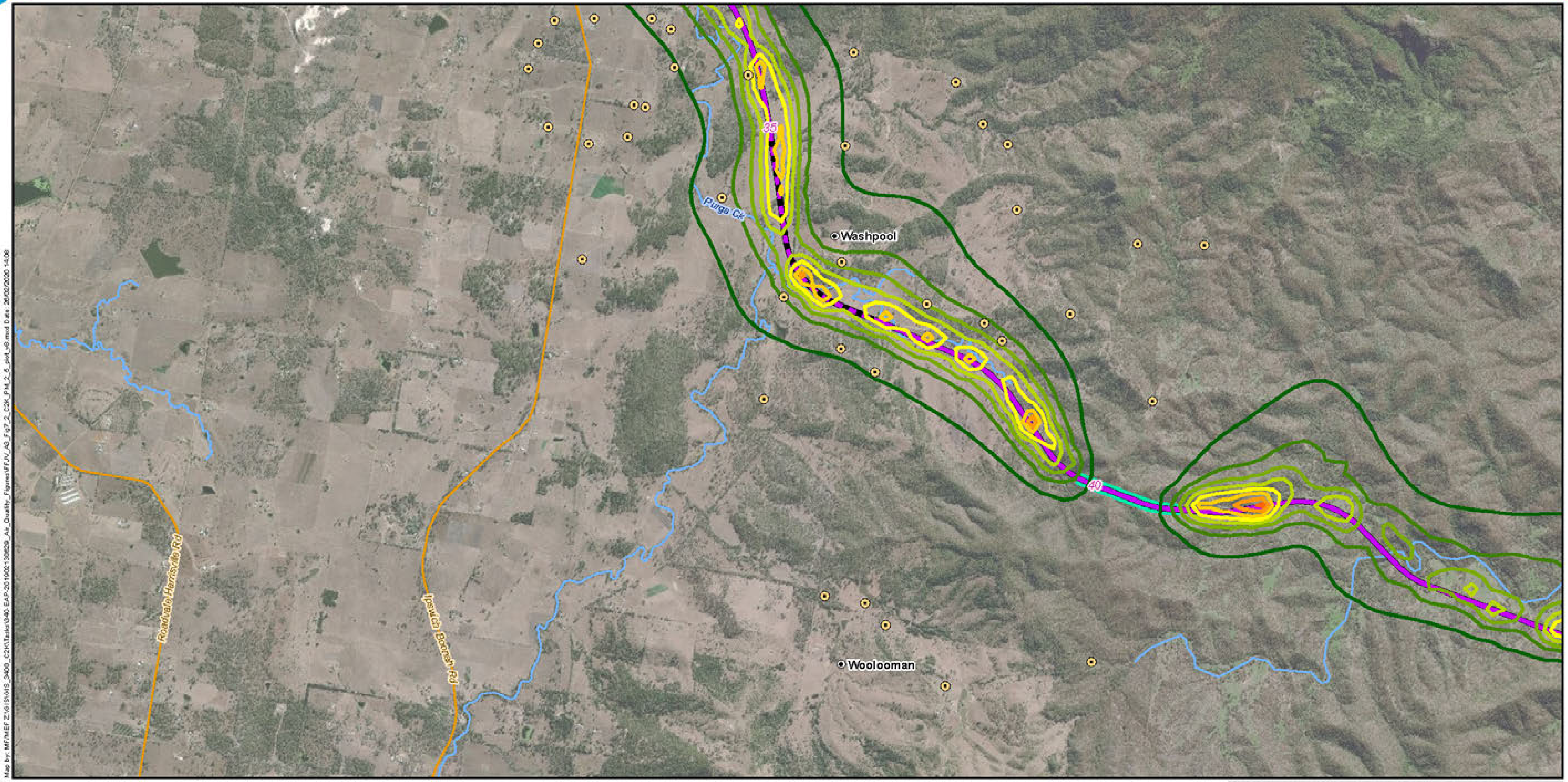
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2e: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative PM$_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2 km

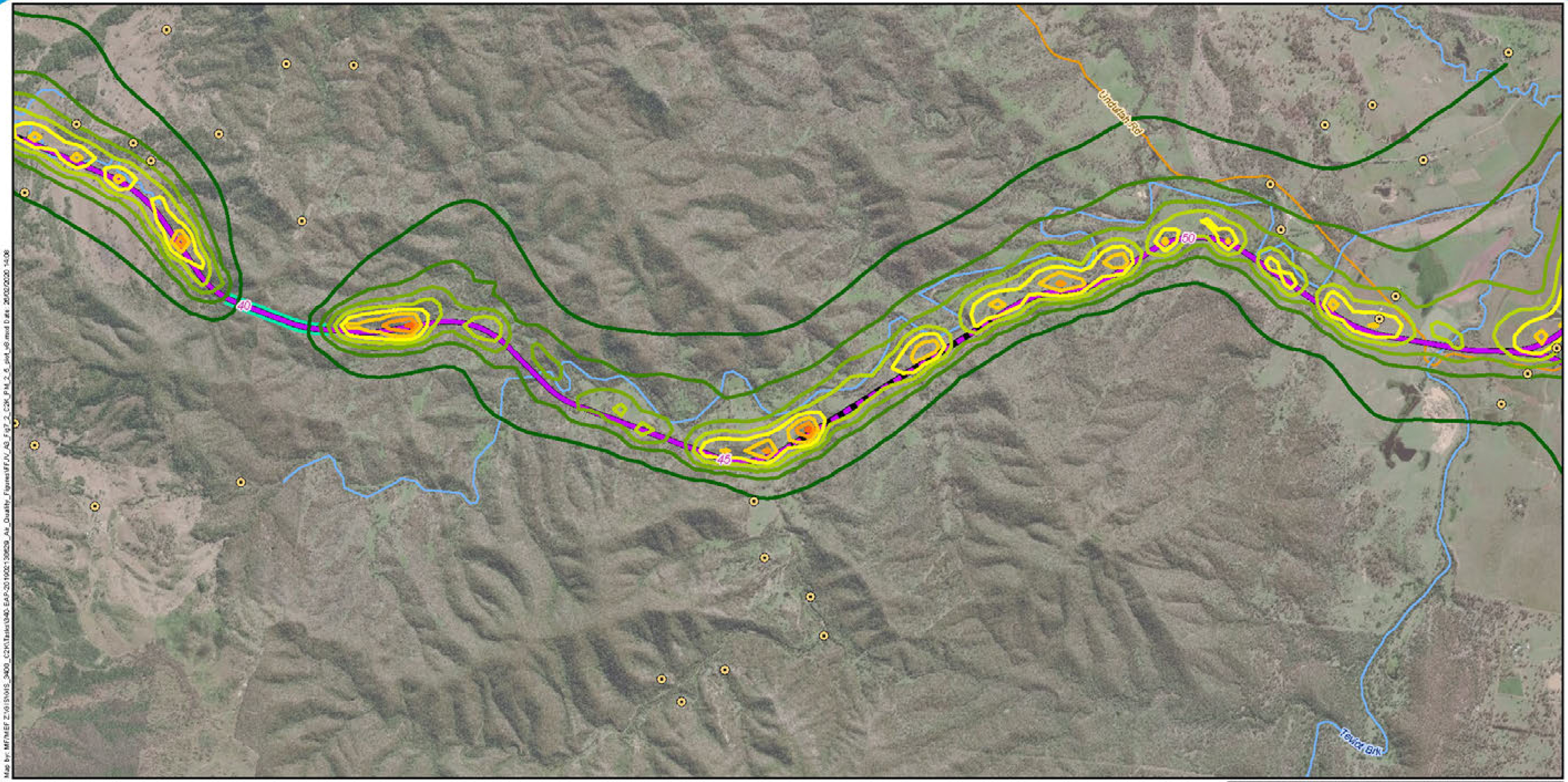
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2f: Peak scenario predicted cumulative PM$_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2km

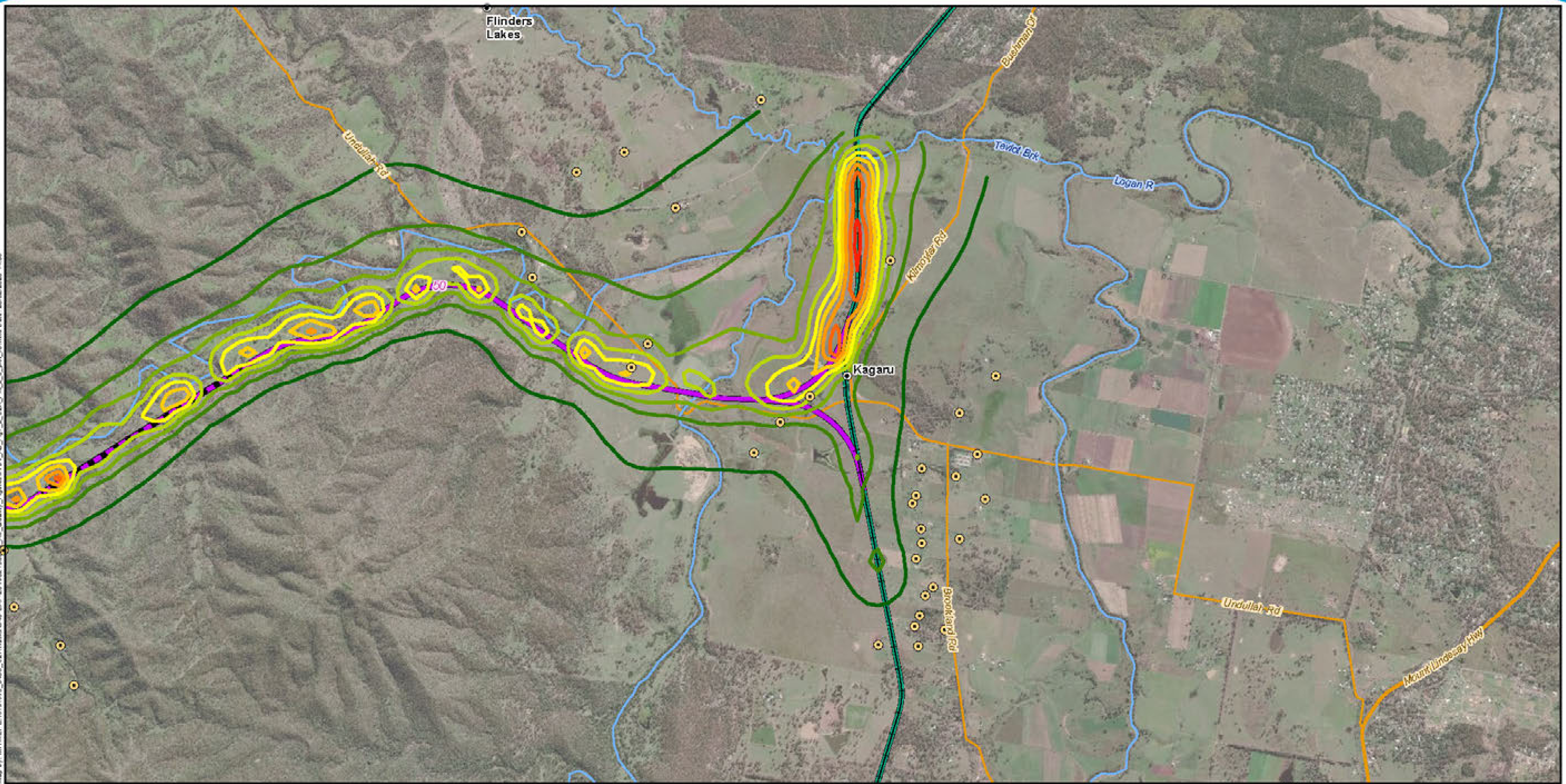
Future Freight
Integrating Community, Environment and Engineering

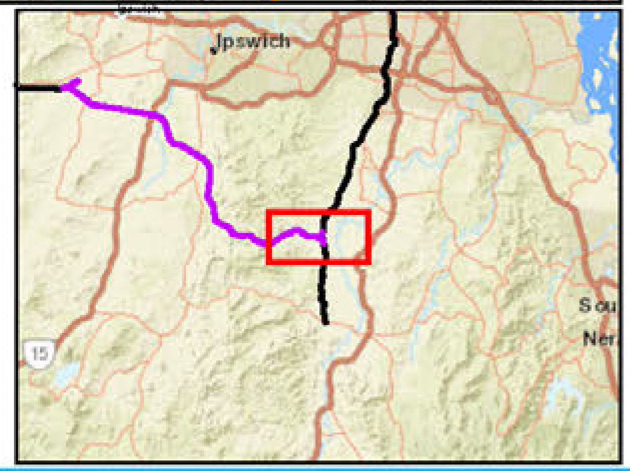
Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2g: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7
- 7.2
- 7.4

A3 scale: 1:40,000

0 0.5 1 1.5 2km

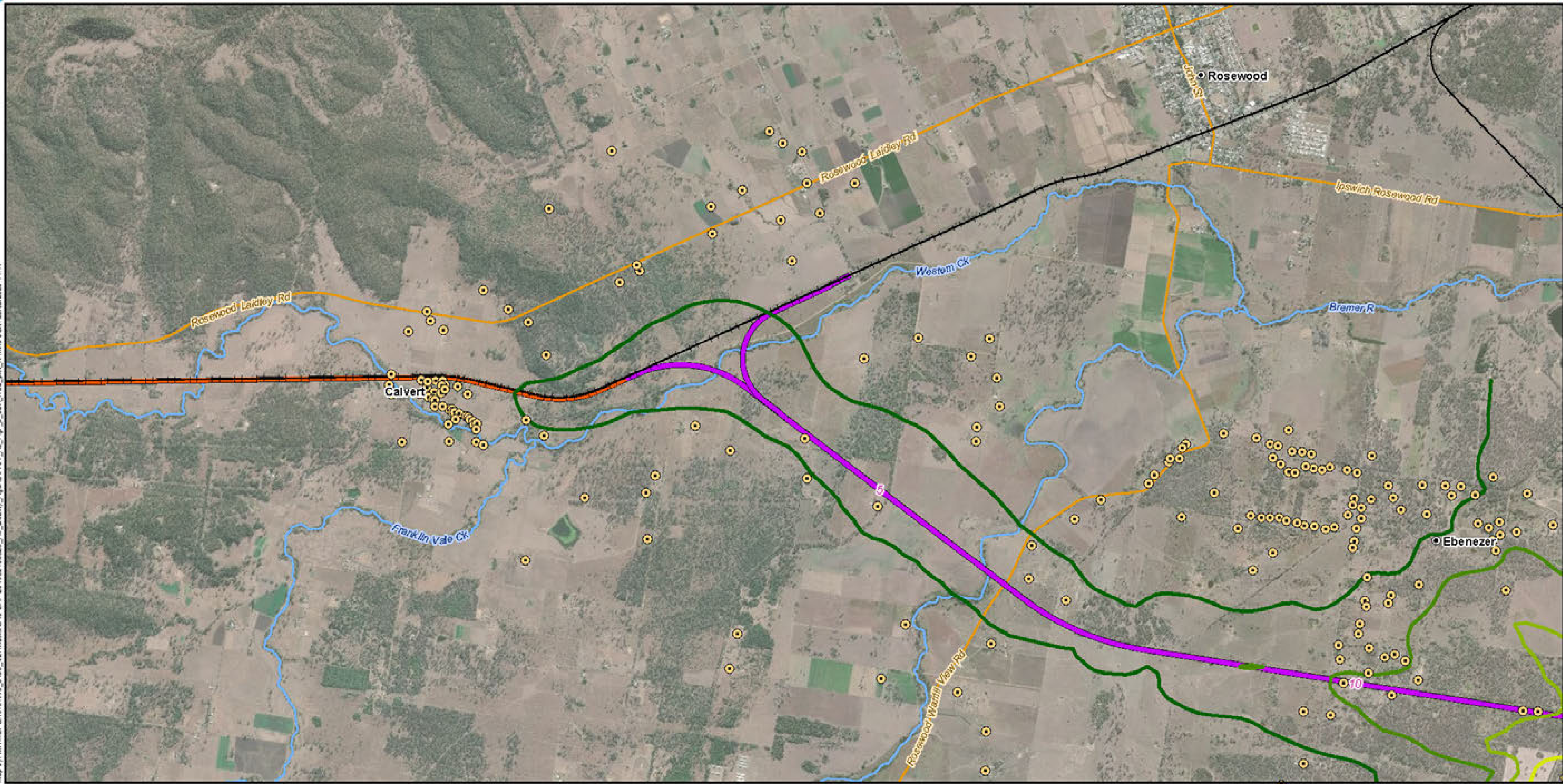
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 8
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.2h: Peak scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

70, 90, 110, 130, 150, 170, 190, 210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

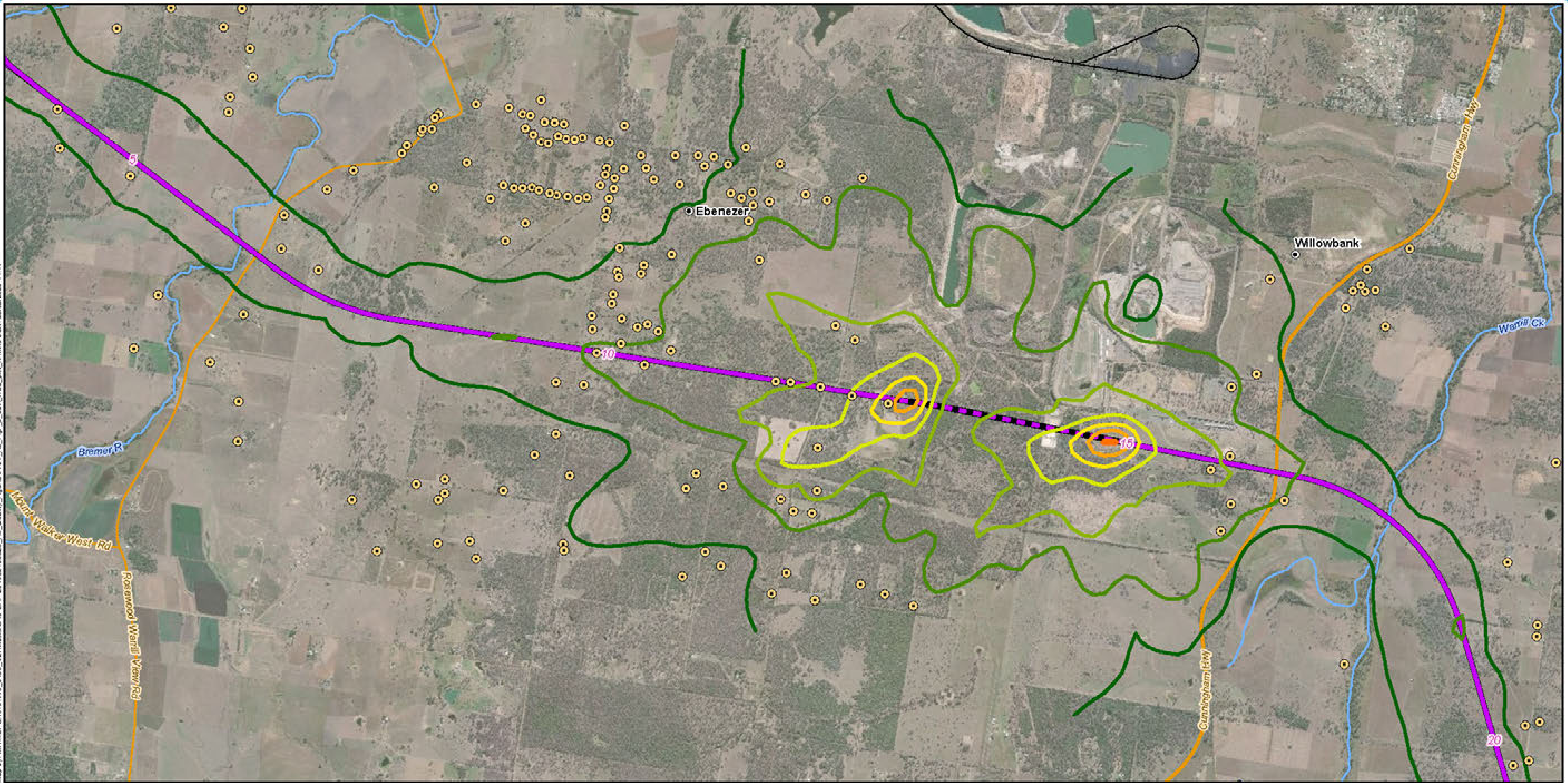
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3a: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

70	150
90	170
110	190
130	210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

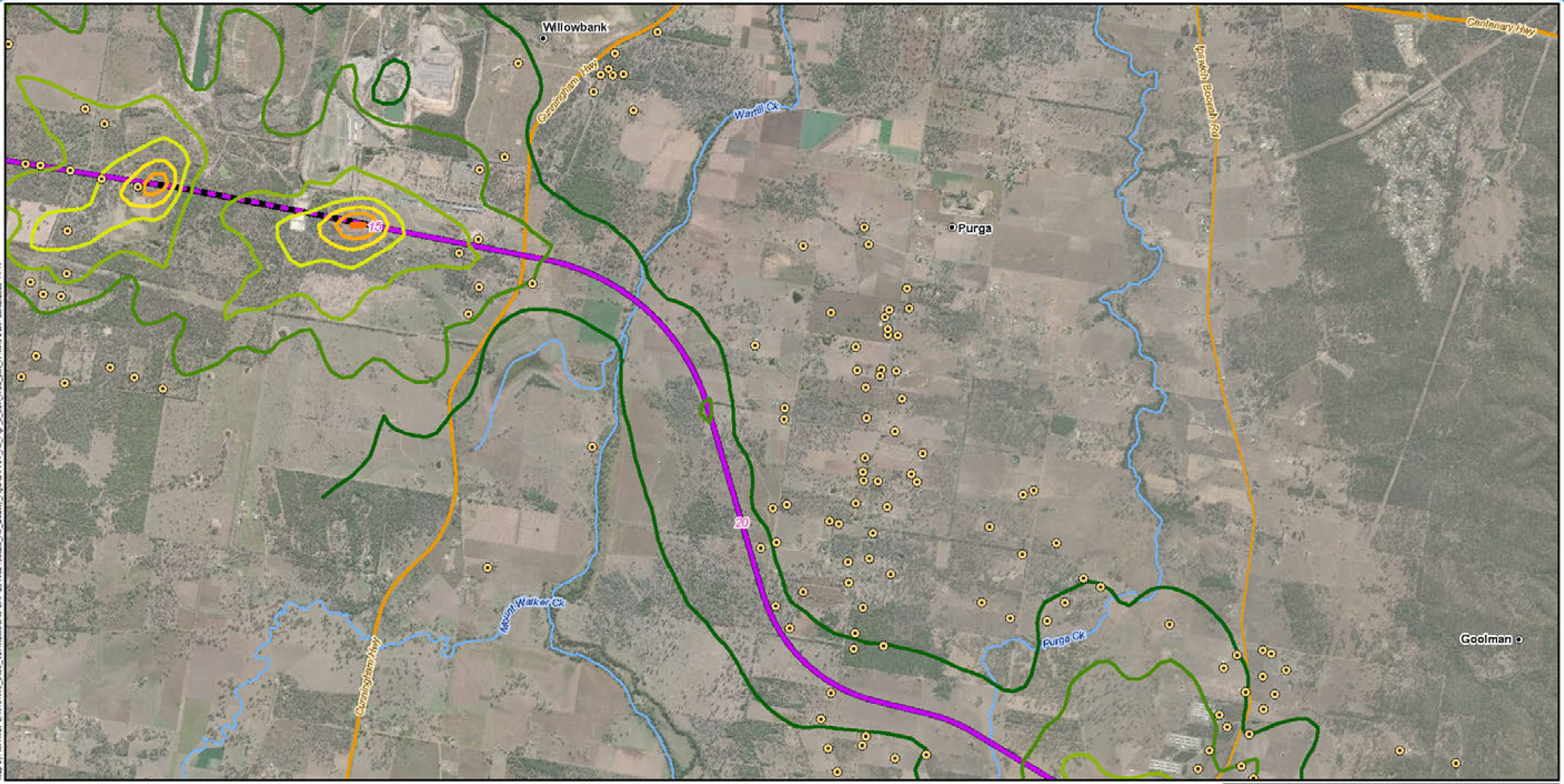
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3b: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

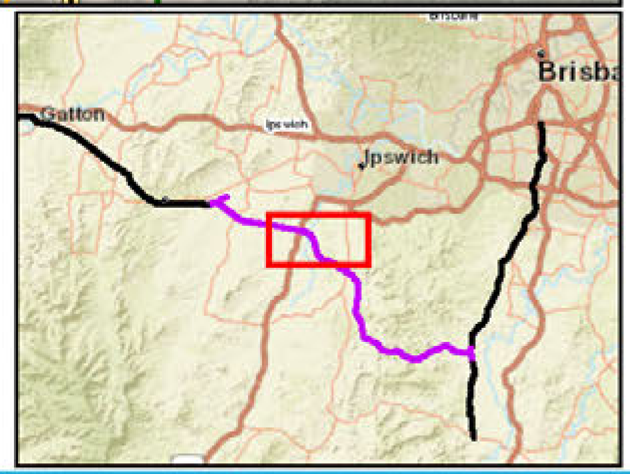


Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m³ Criterion)

70	150
90	170
110	190
130	210



A3 scale: 1:40,000

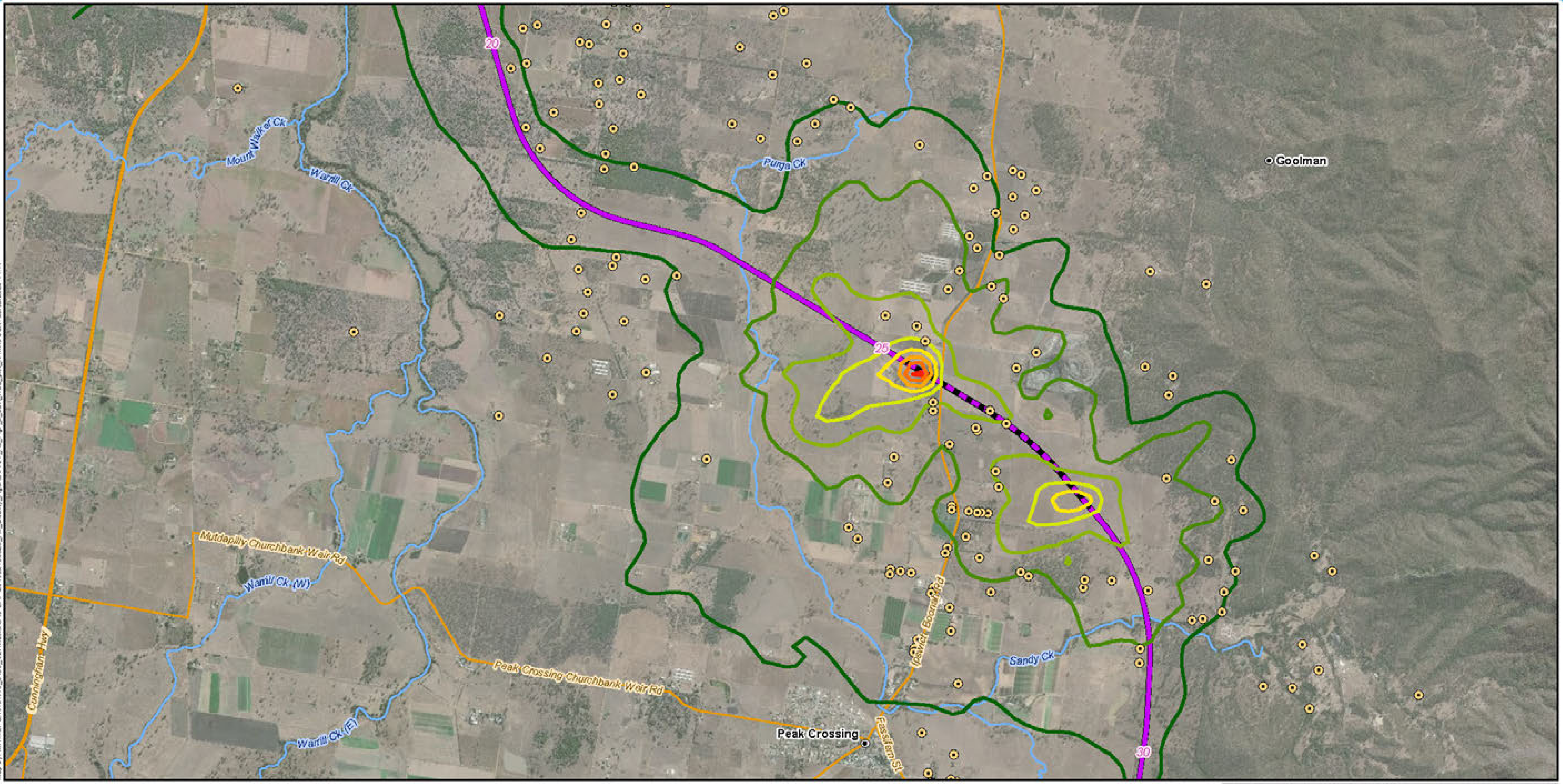
0 0.5 1 1.5 2km

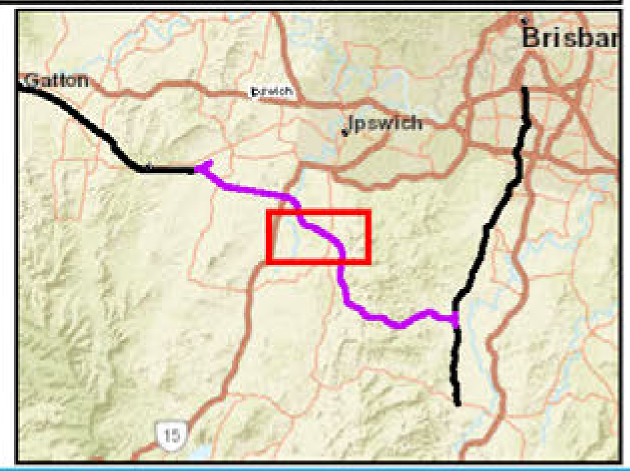
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3c: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot





Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

70	150
90	170
110	190
130	210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

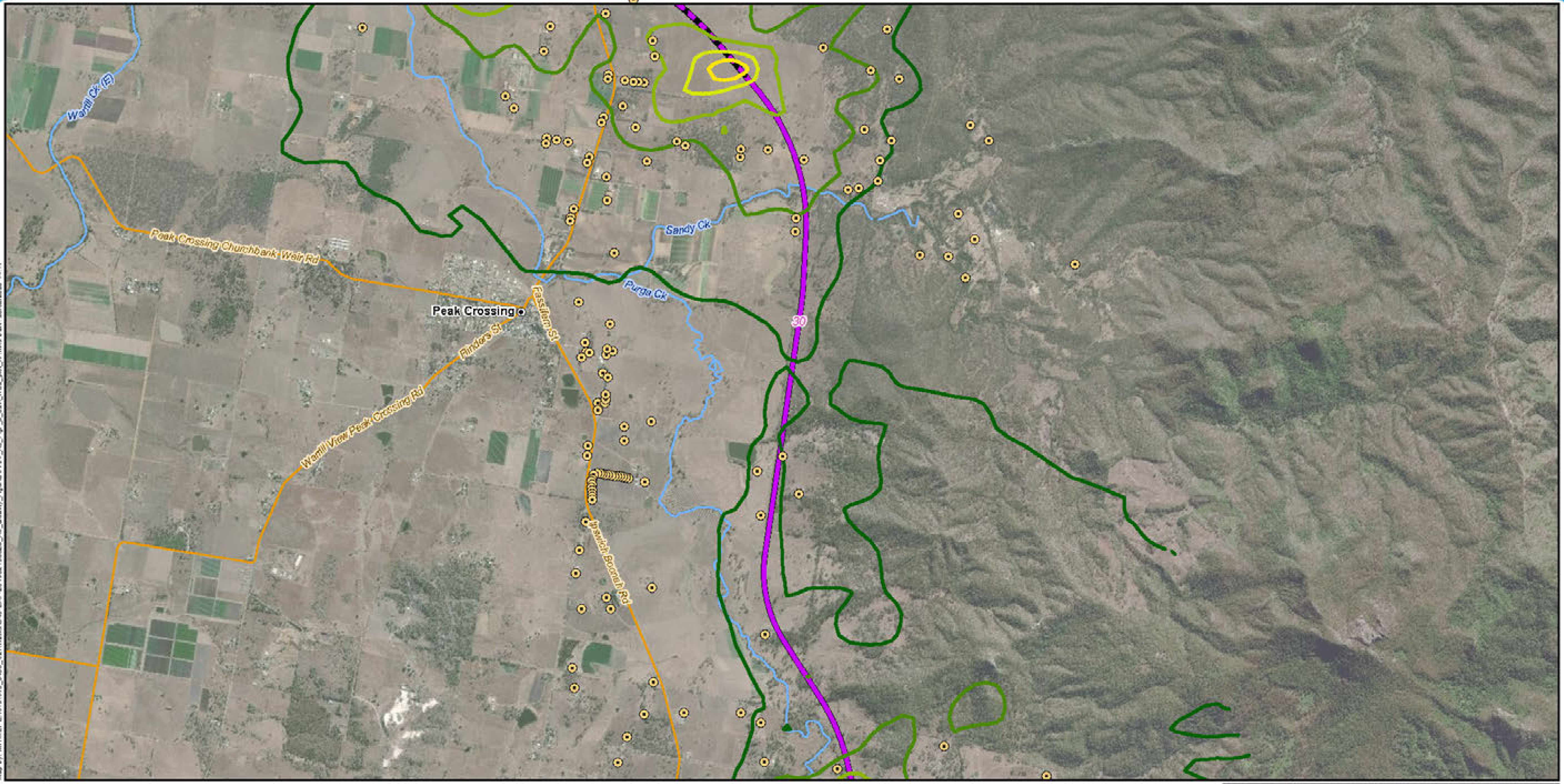
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3d: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

70	150
90	170
110	190
130	210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

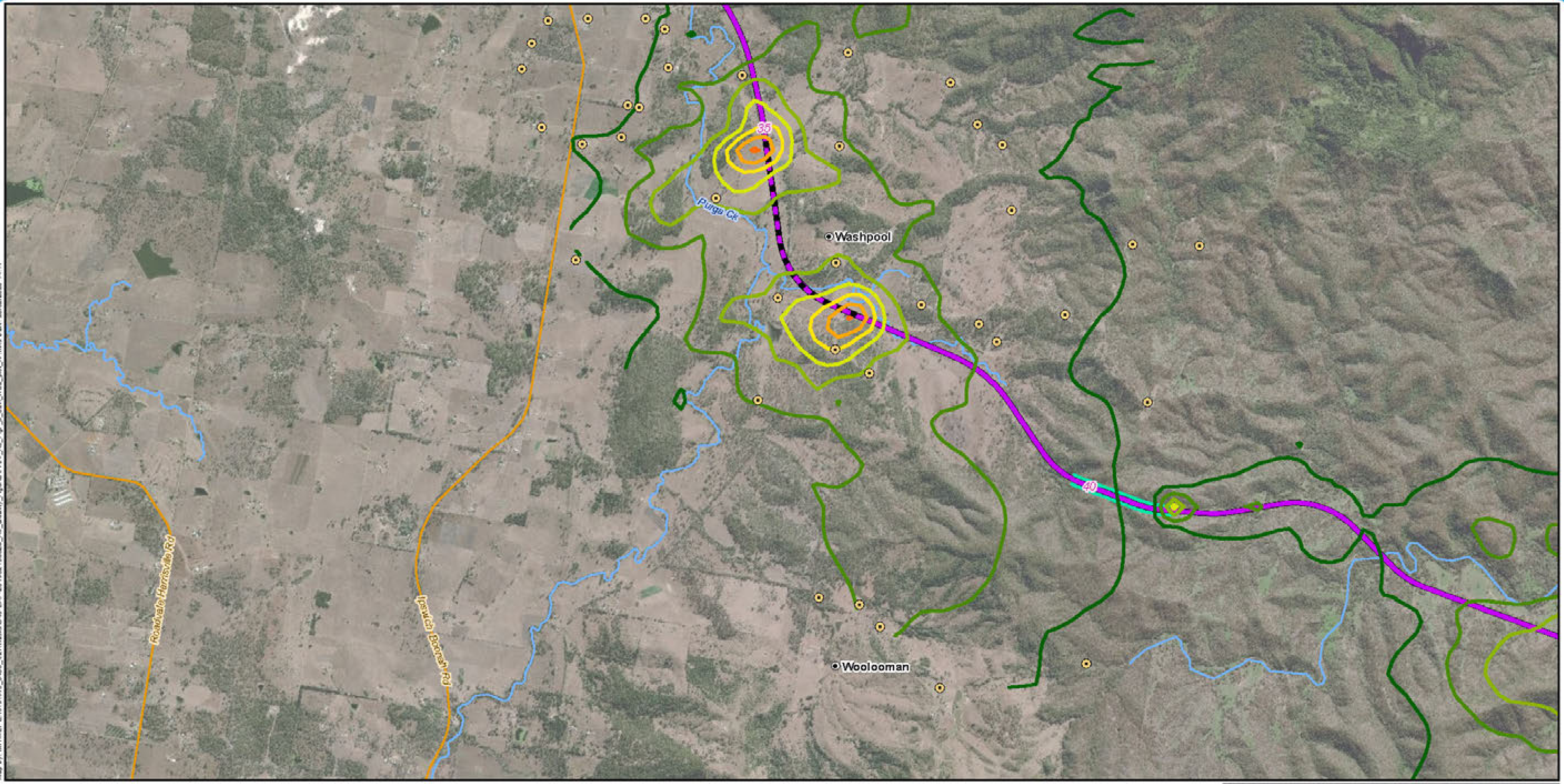
Future Freight
Integrating Community, Environment and Engineering

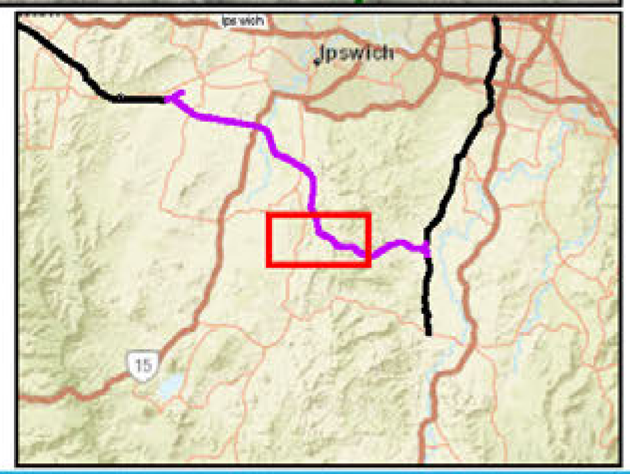
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3e: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

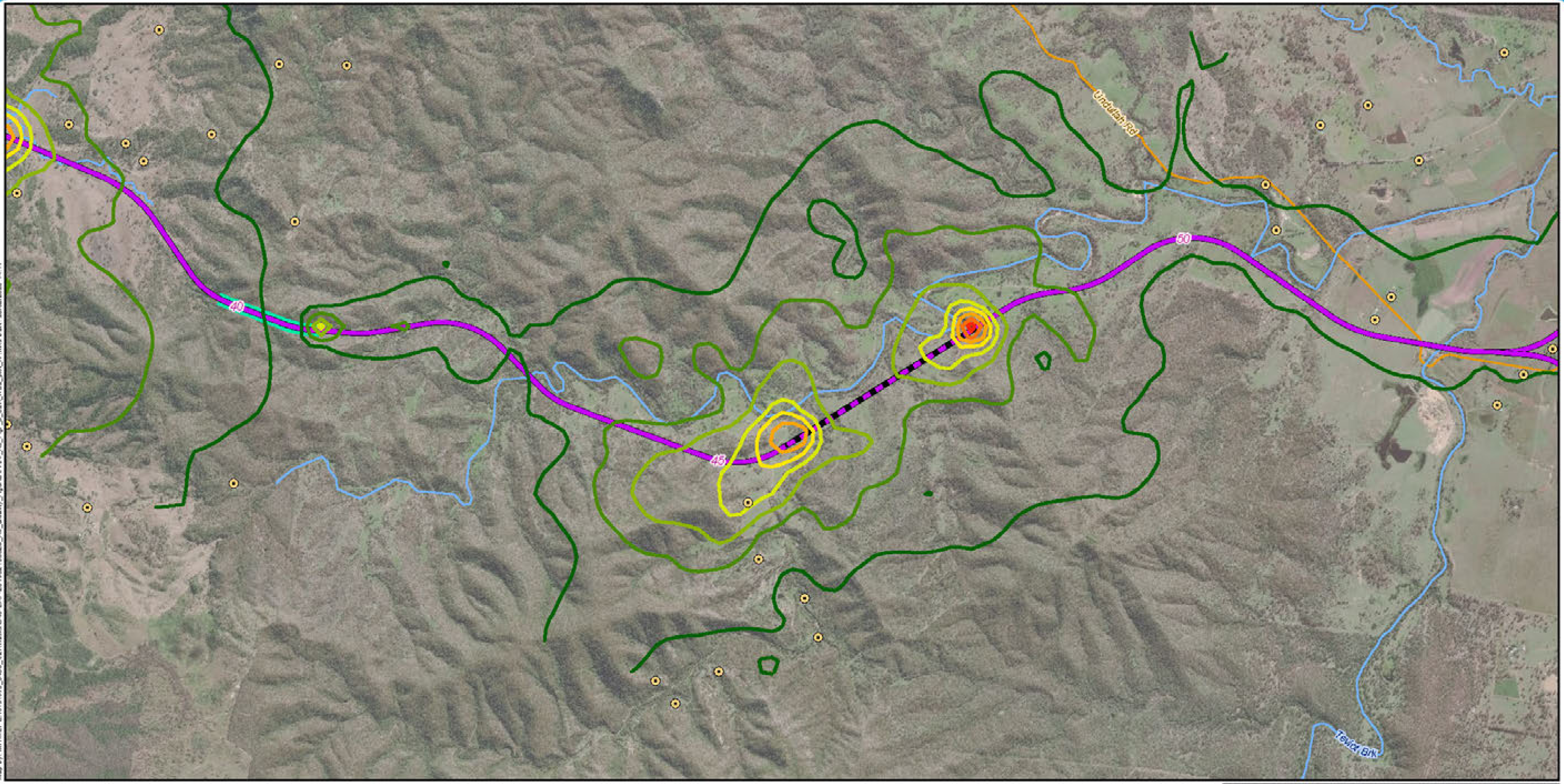
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3f: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

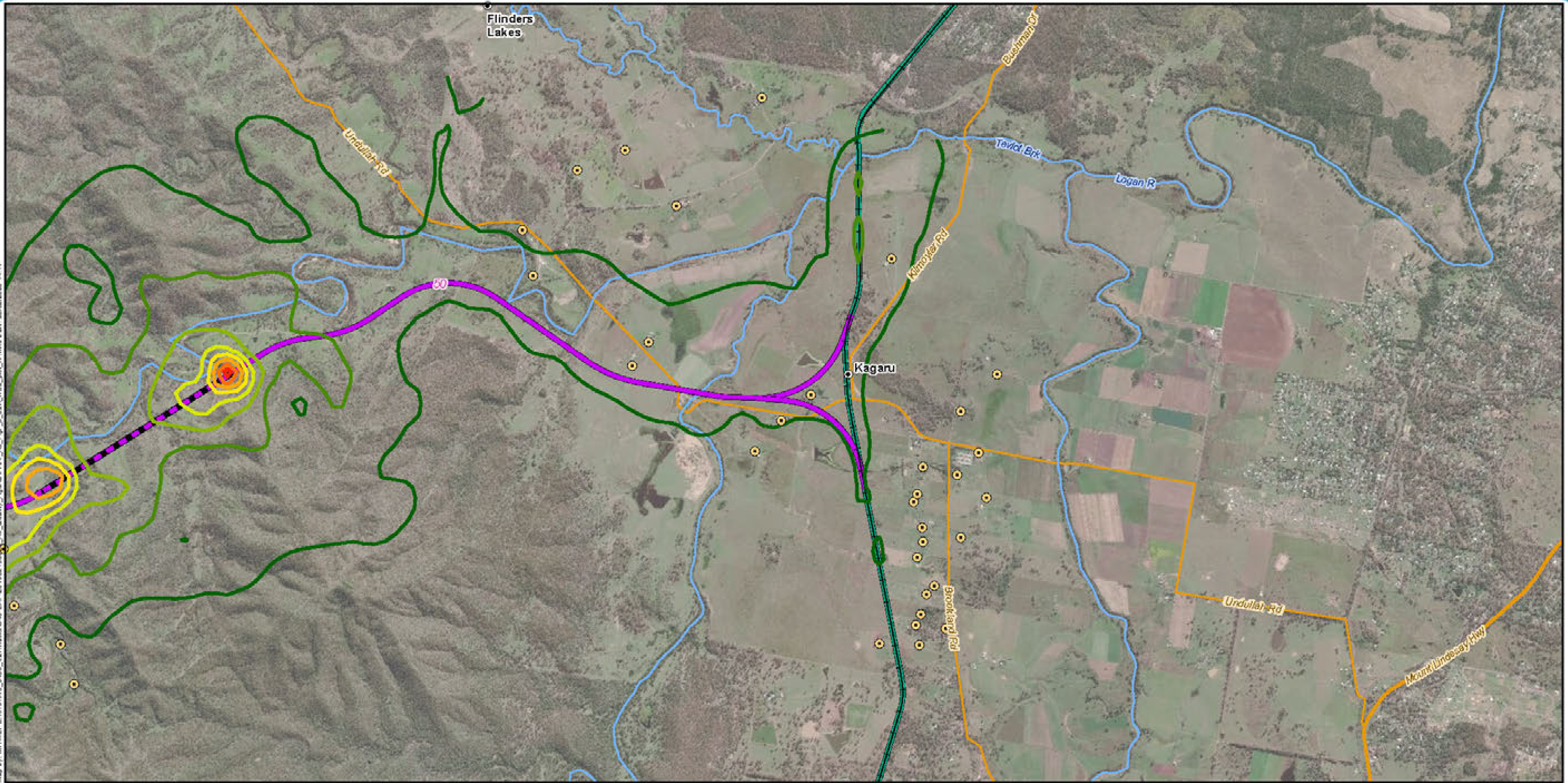
Future Freight
Integrating Community, Environment and Engineering

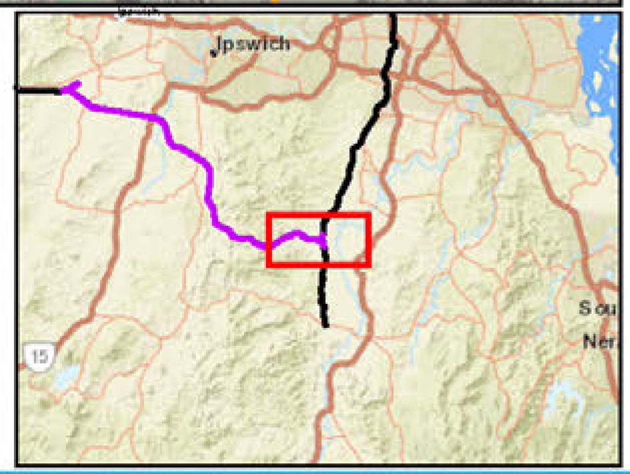
Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3g: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

70	150
90	170
110	190
130	210

A3 scale: 1:40,000

0 0.5 1 1.5 2km

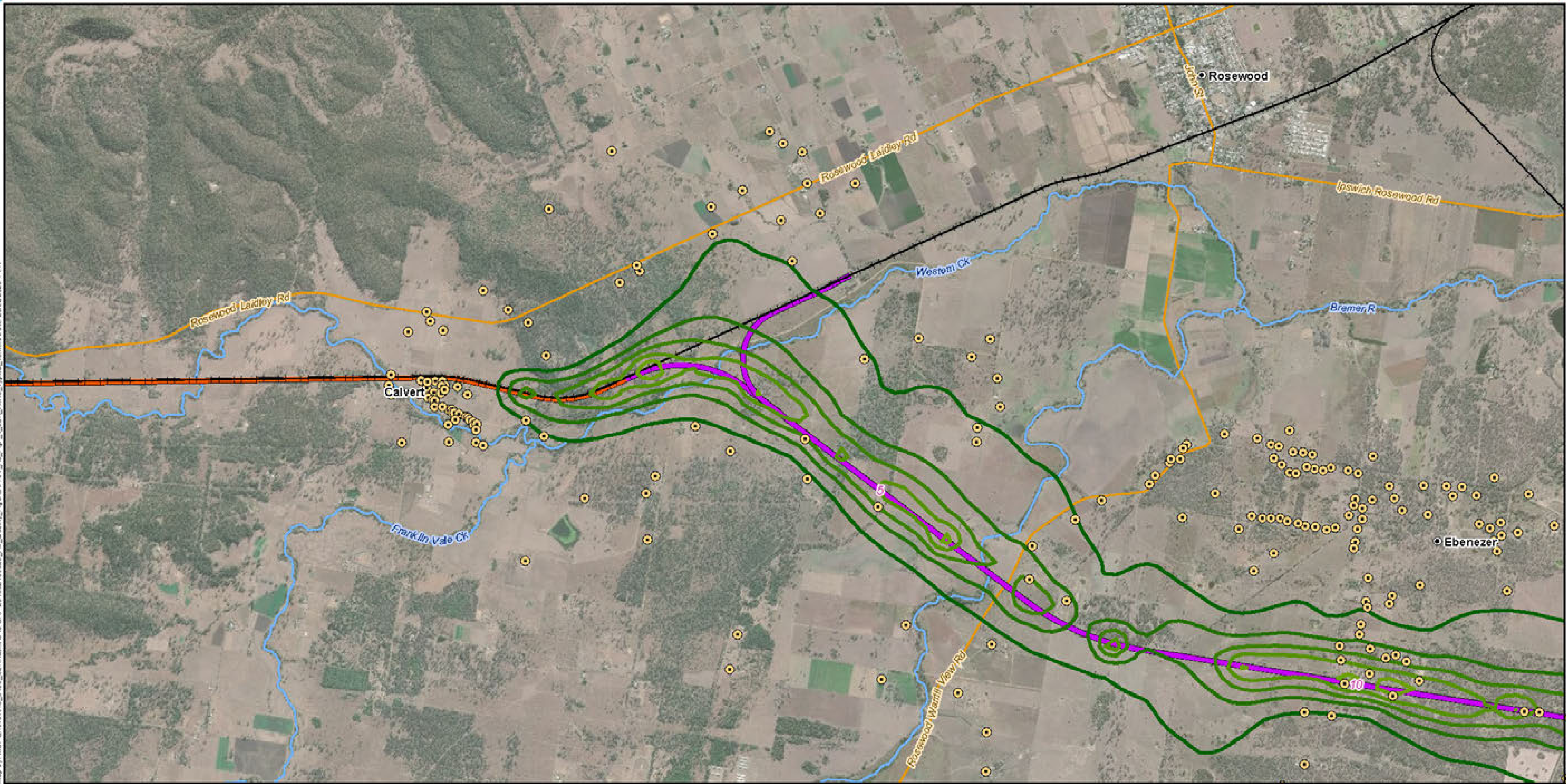
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 7
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.3h: Peak scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

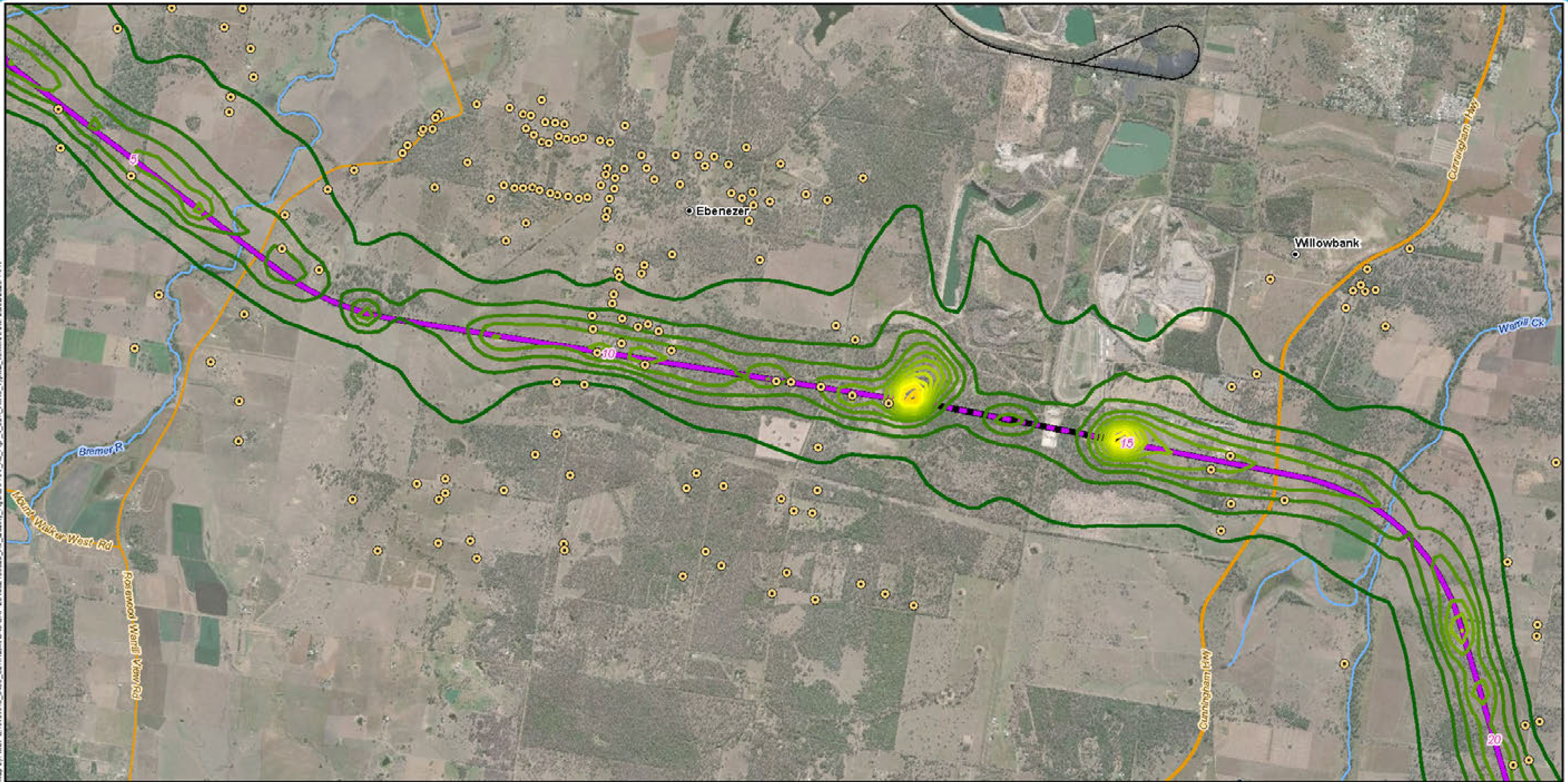
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4a:Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

A3 scale: 1:40,000

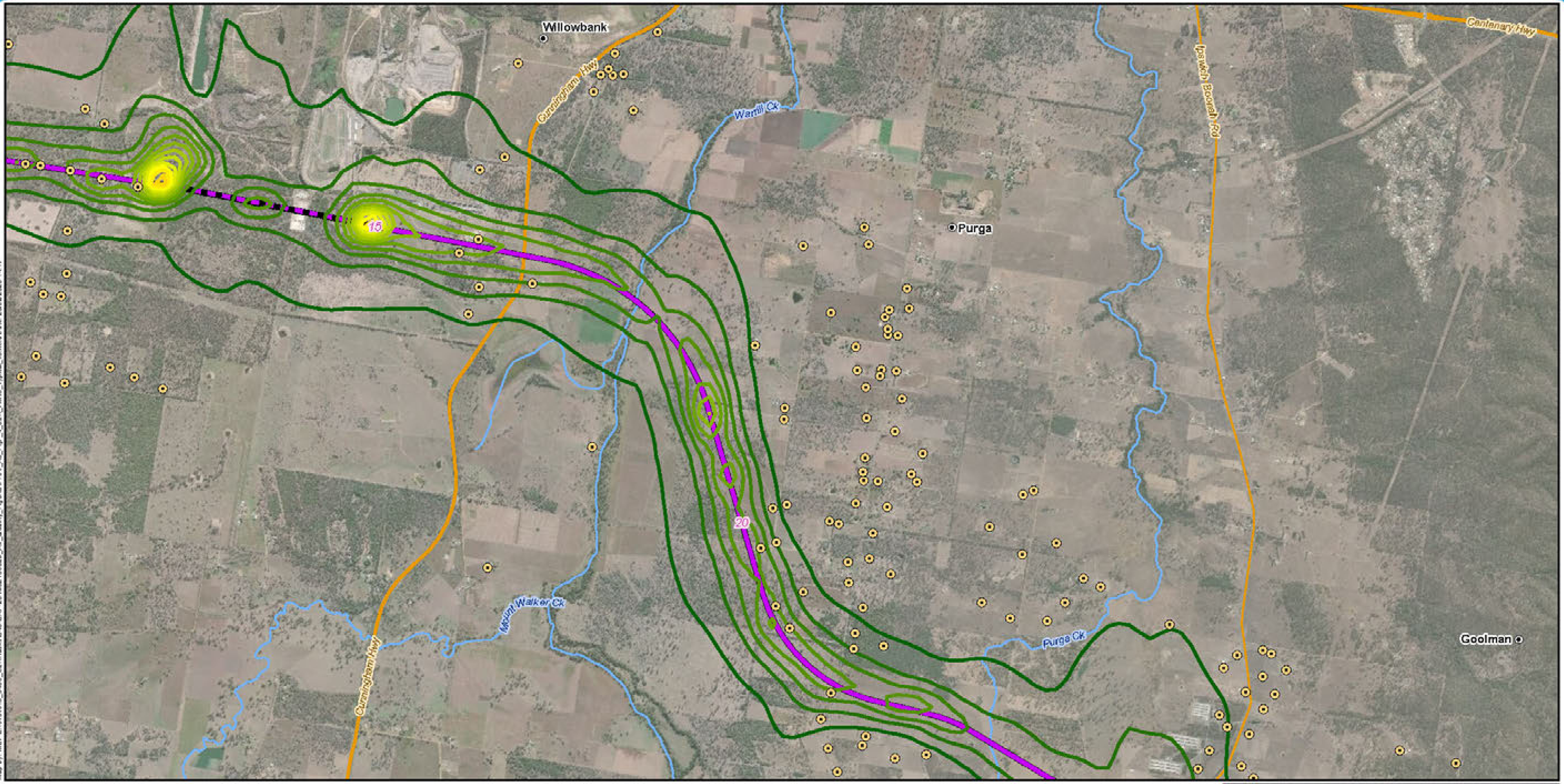
0 0.4 0.8 1.2 1.6 2km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4b: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

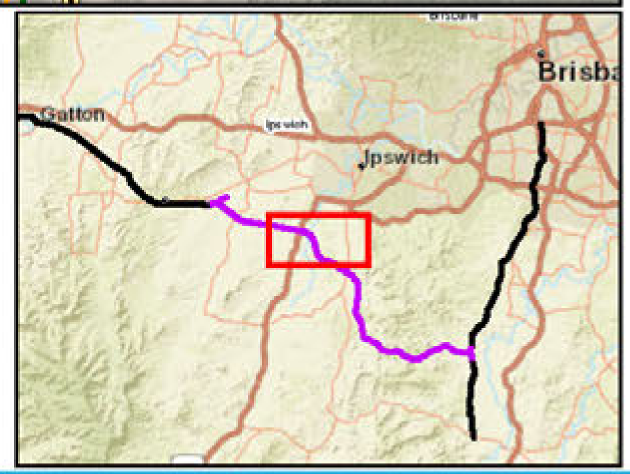


Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38



A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

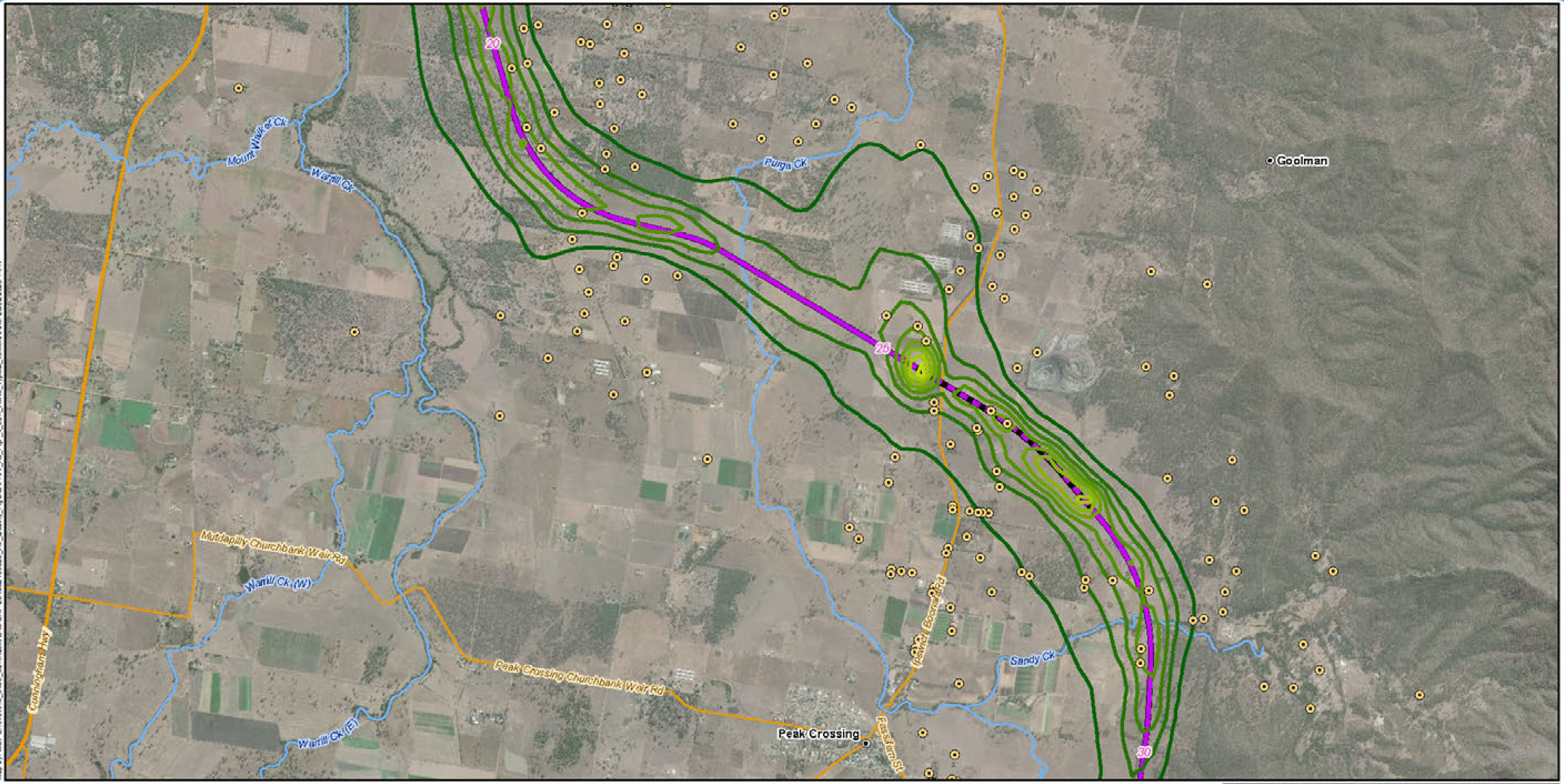
Future Freight
Integrating Community, Environment and Engineering

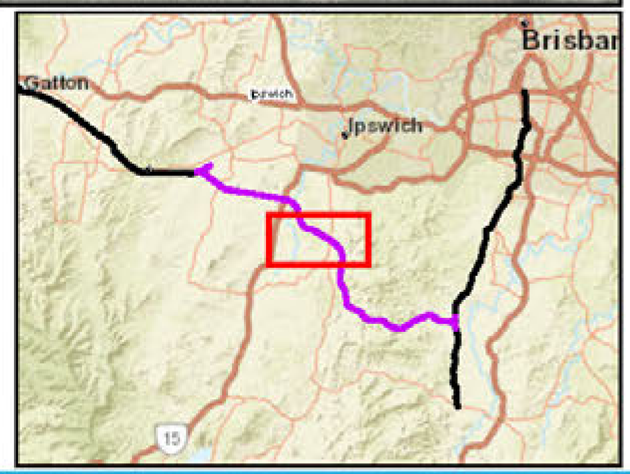
Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4c: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

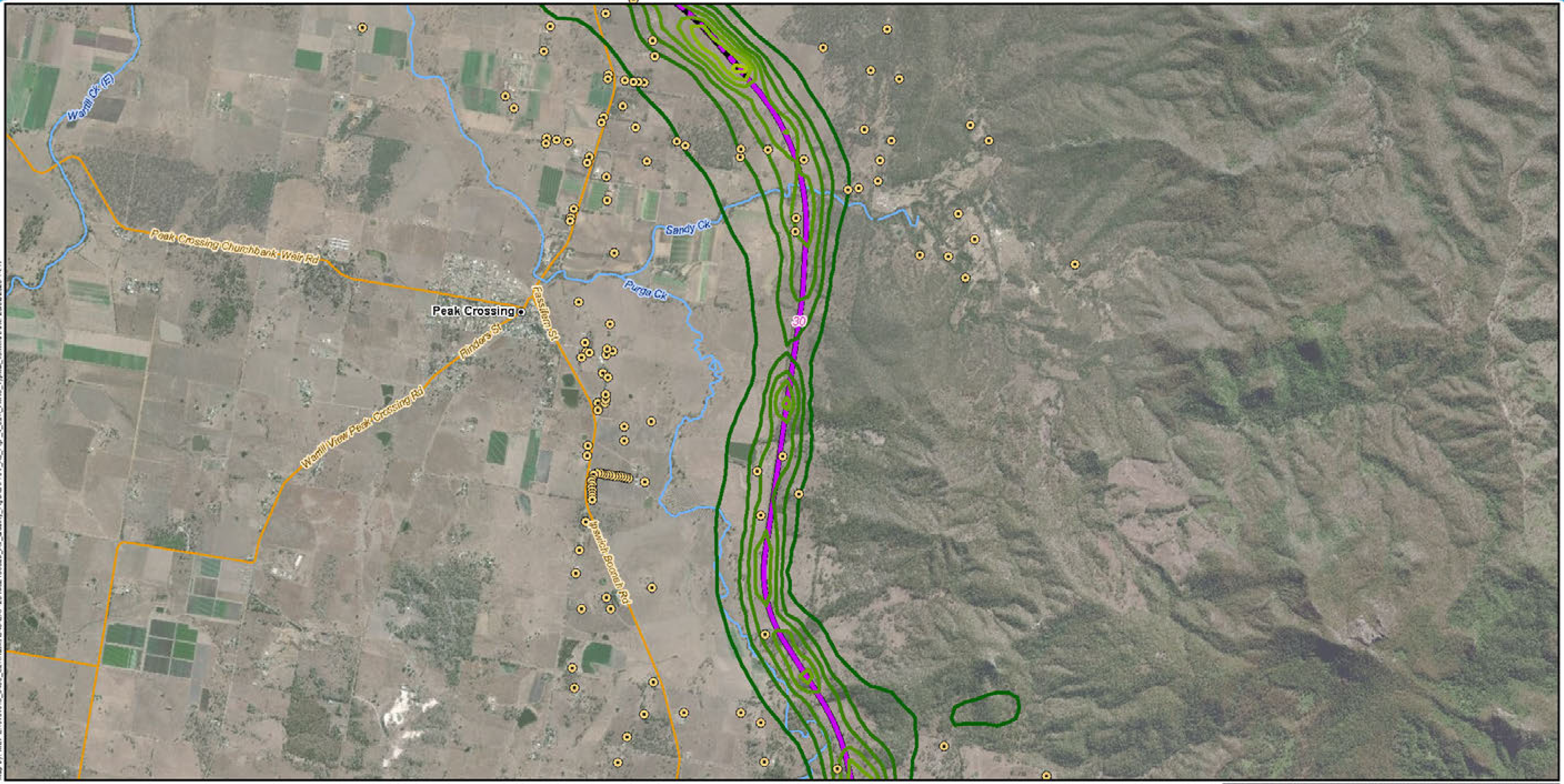
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4d: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

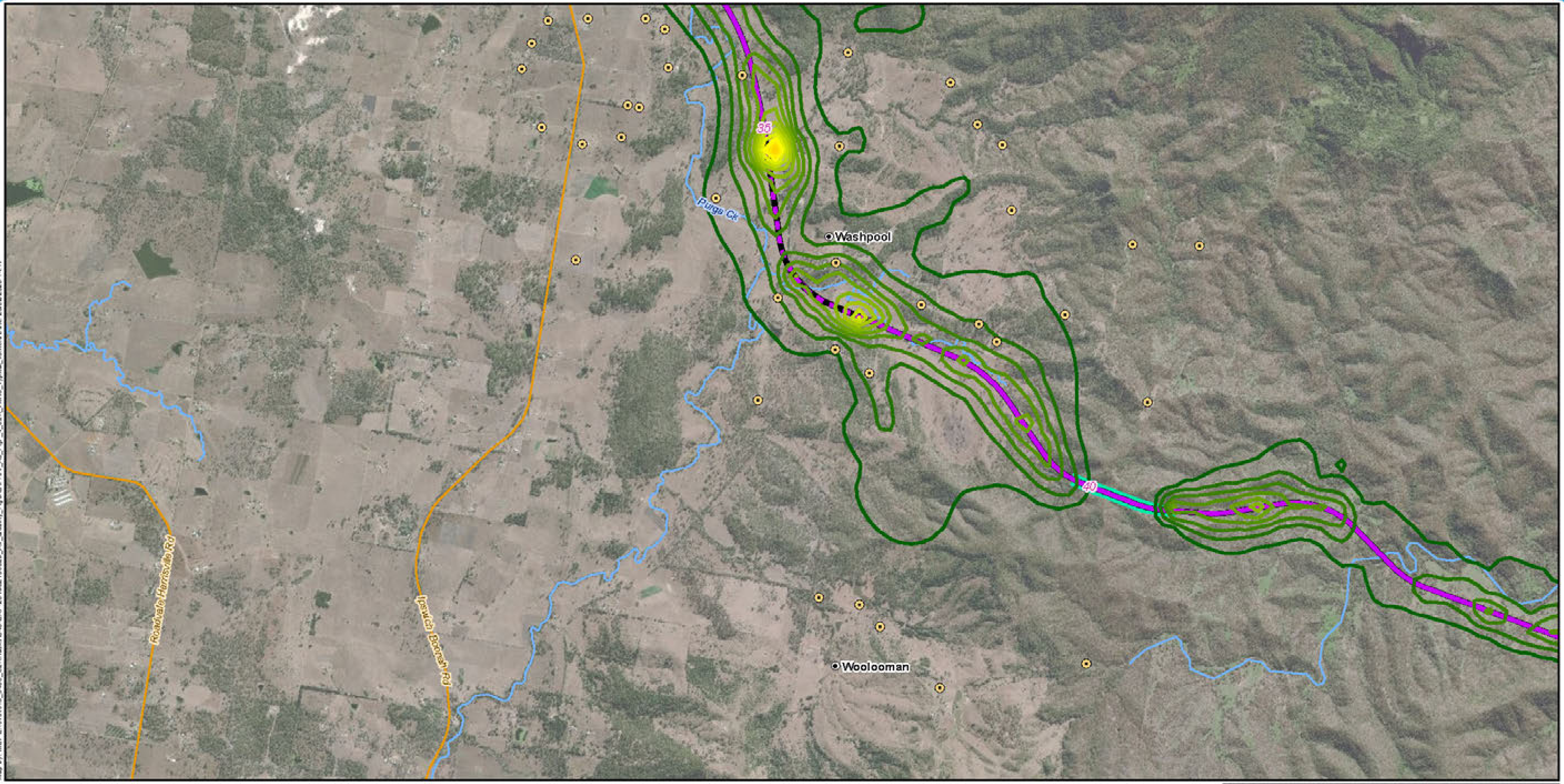
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4e: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

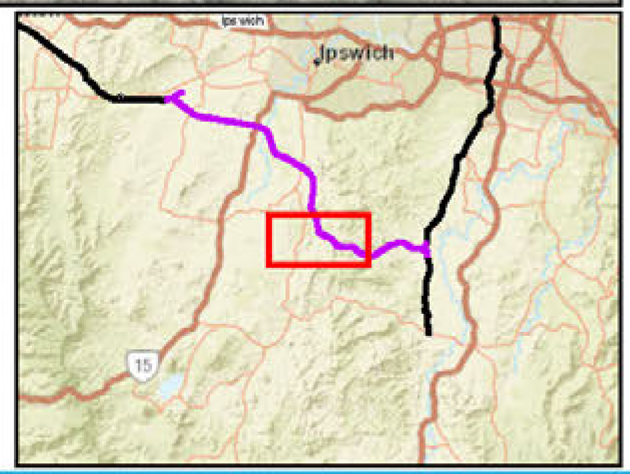


Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Tunnel
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m³ Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38



A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

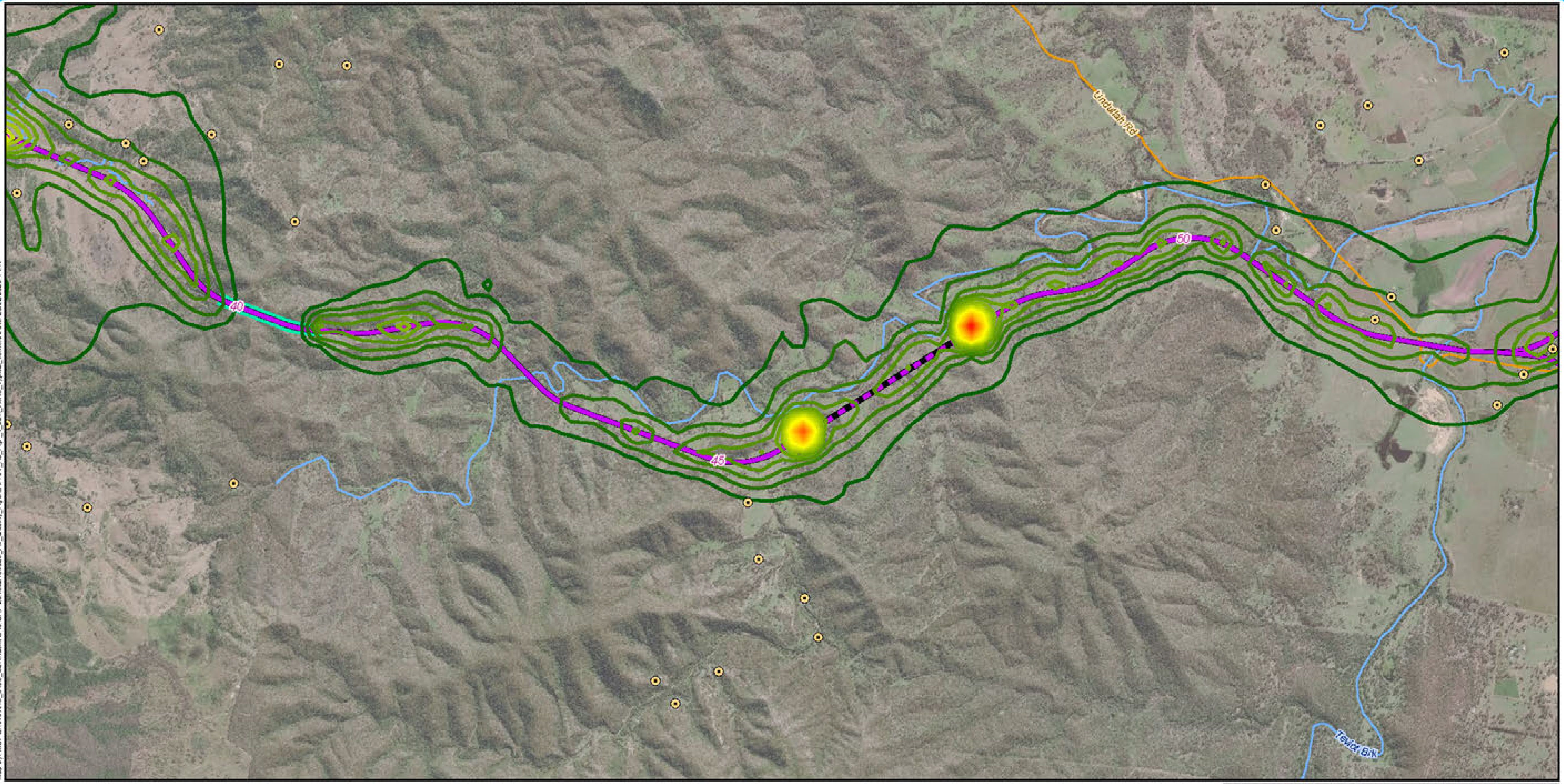
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4f: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Tunnel
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

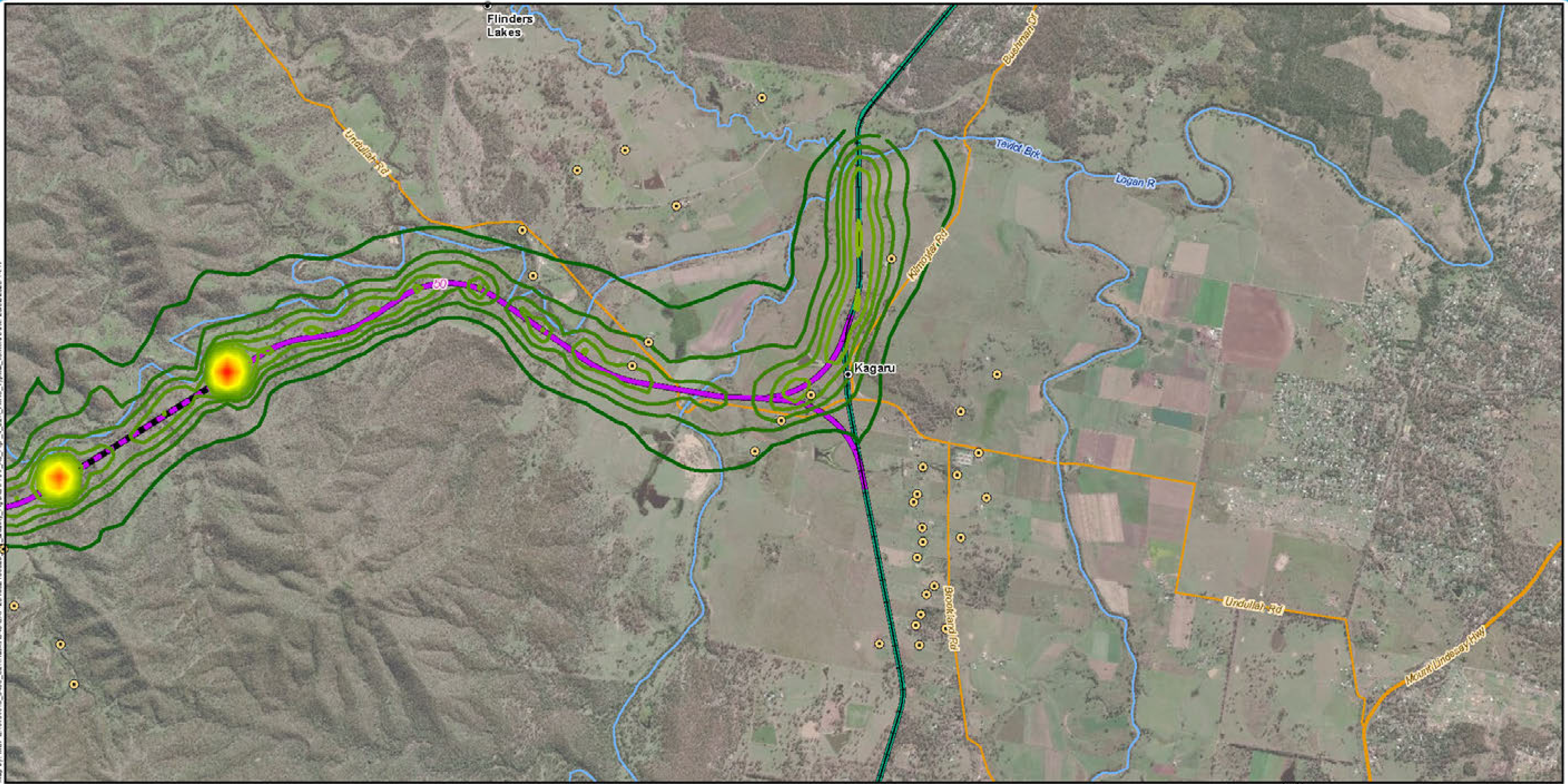
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4g: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

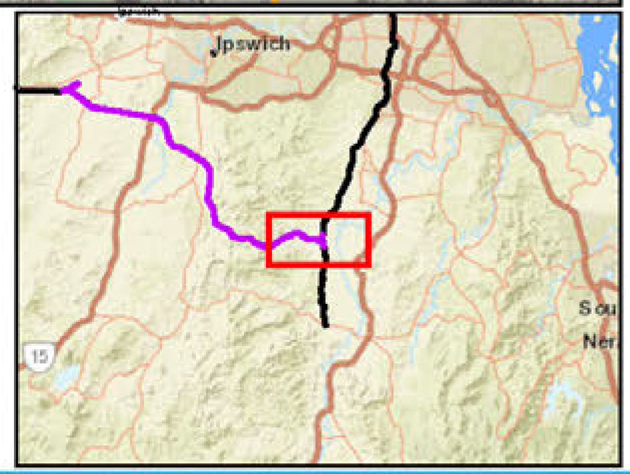


Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative maximum PM_{10} 24-hour average (50 µg/m^3 Criterion)

20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38



A3 scale: 1:40,000

0 0.4 0.8 1.2 1.6 2km

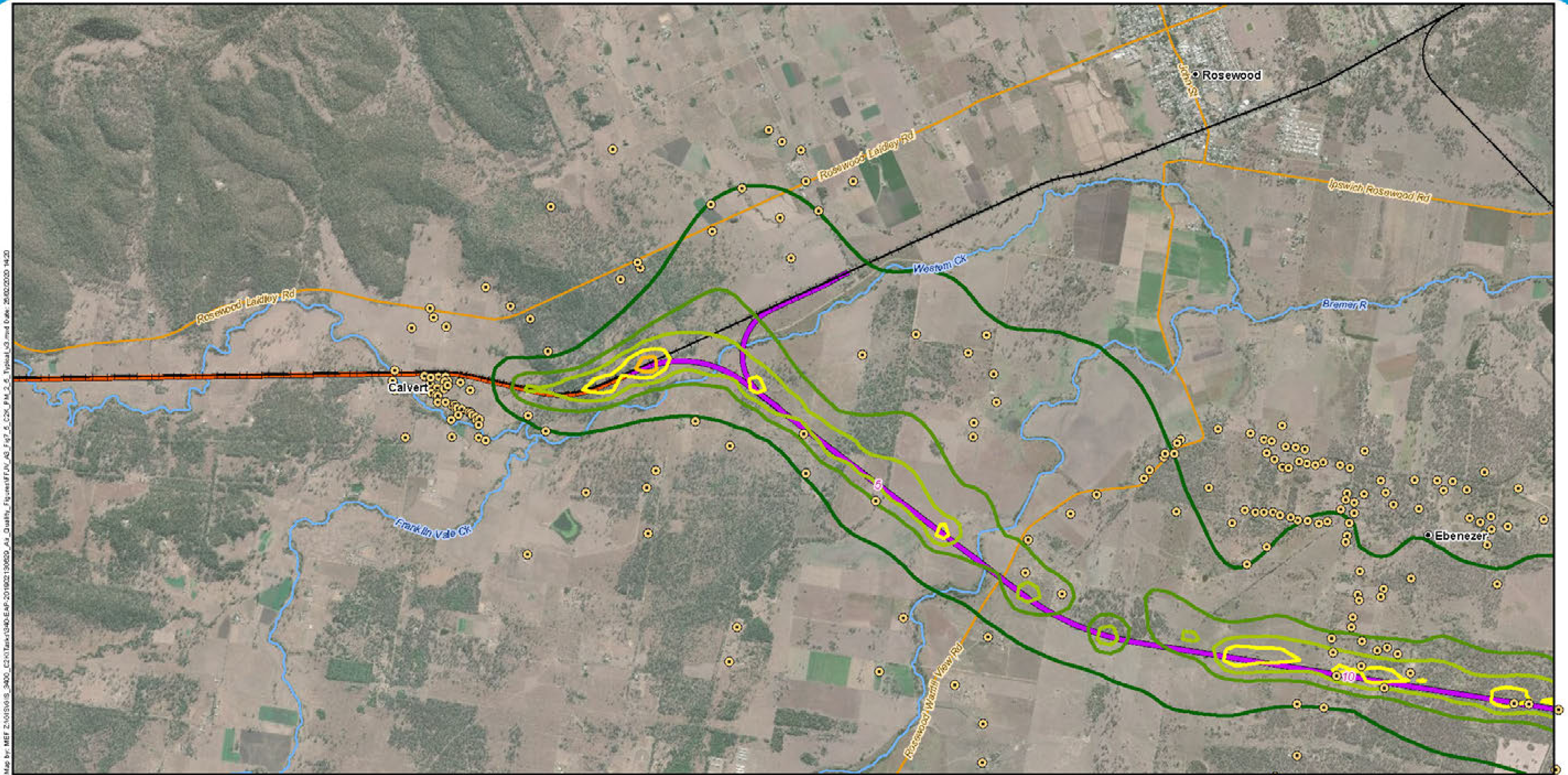
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.4h: Typical scenario predicted cumulative maximum PM_{10} 24-hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2 km

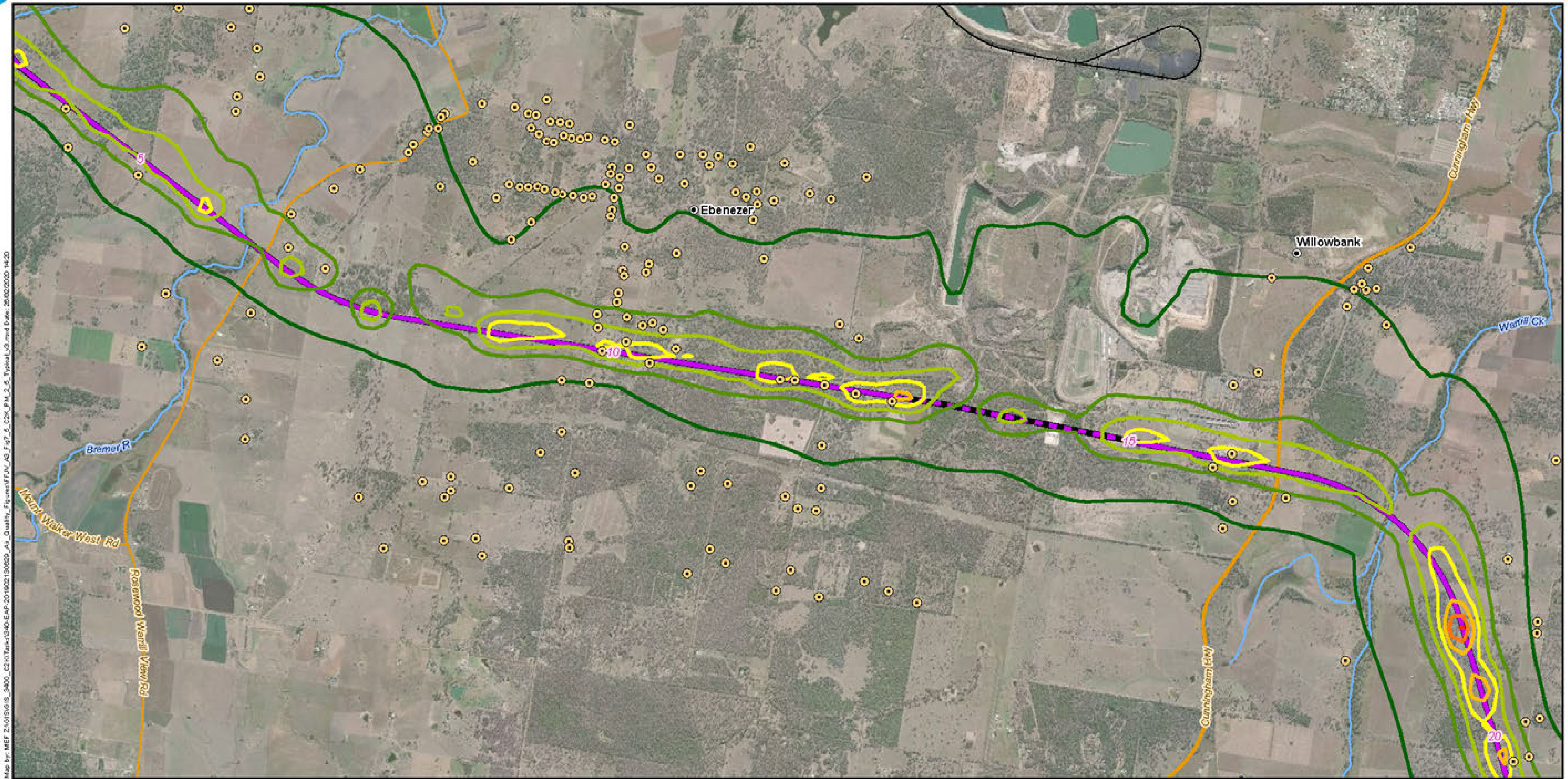
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5a: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2km

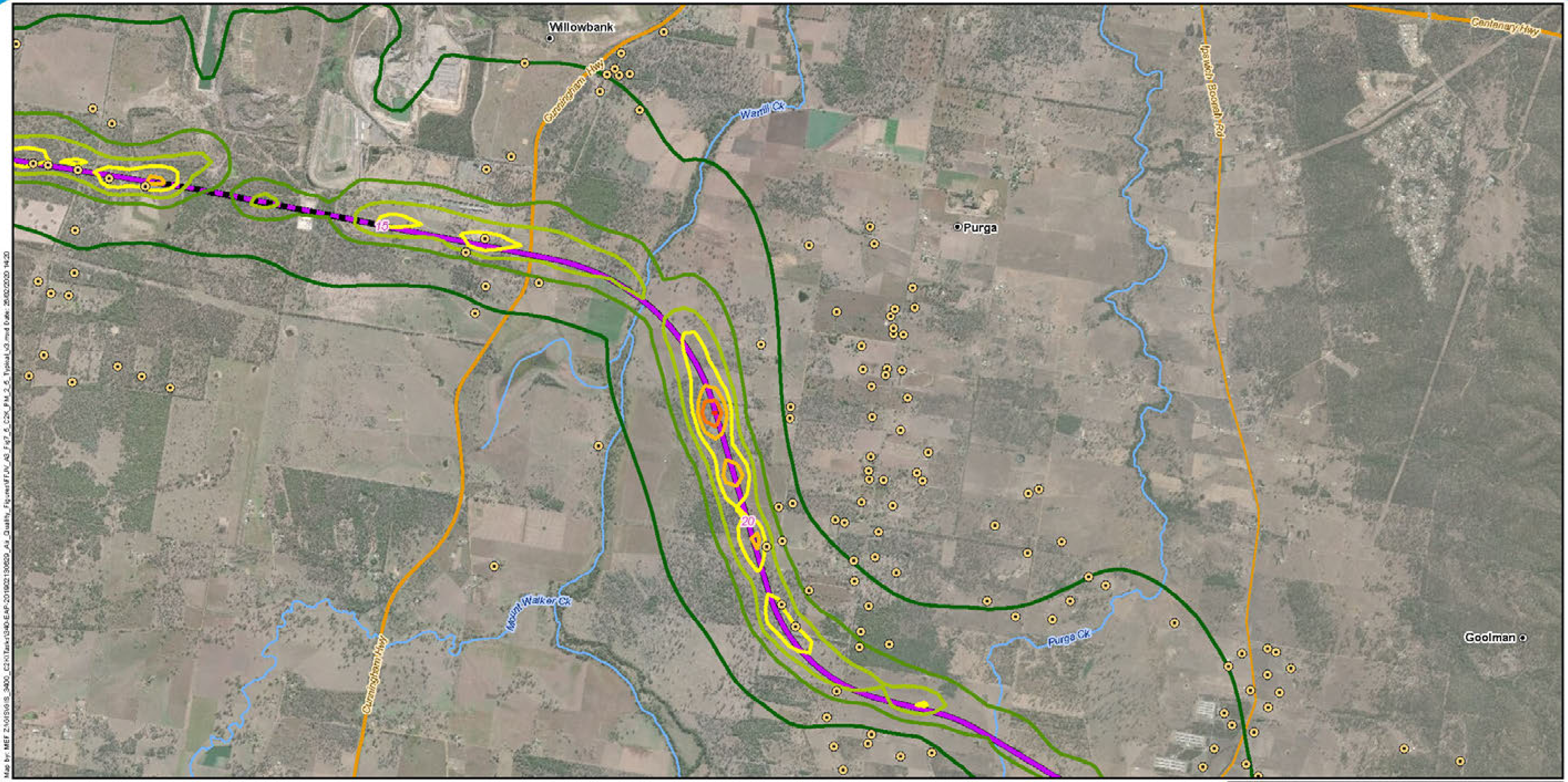
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5b: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

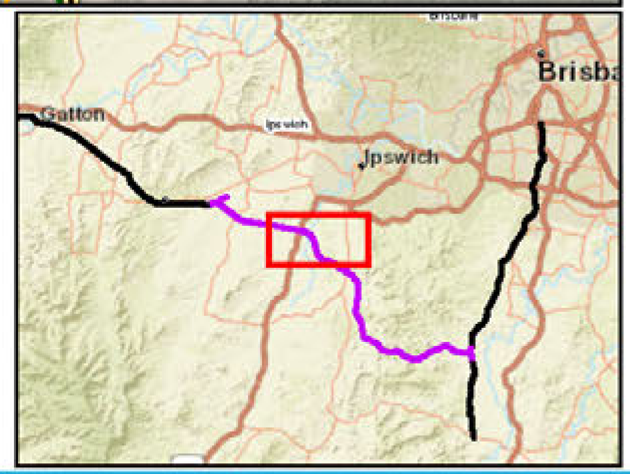


Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7



A3 scale: 1:40,000

0 0.5 1 1.5 2 km

Future Freight
Integrating Community, Environment and Engineering

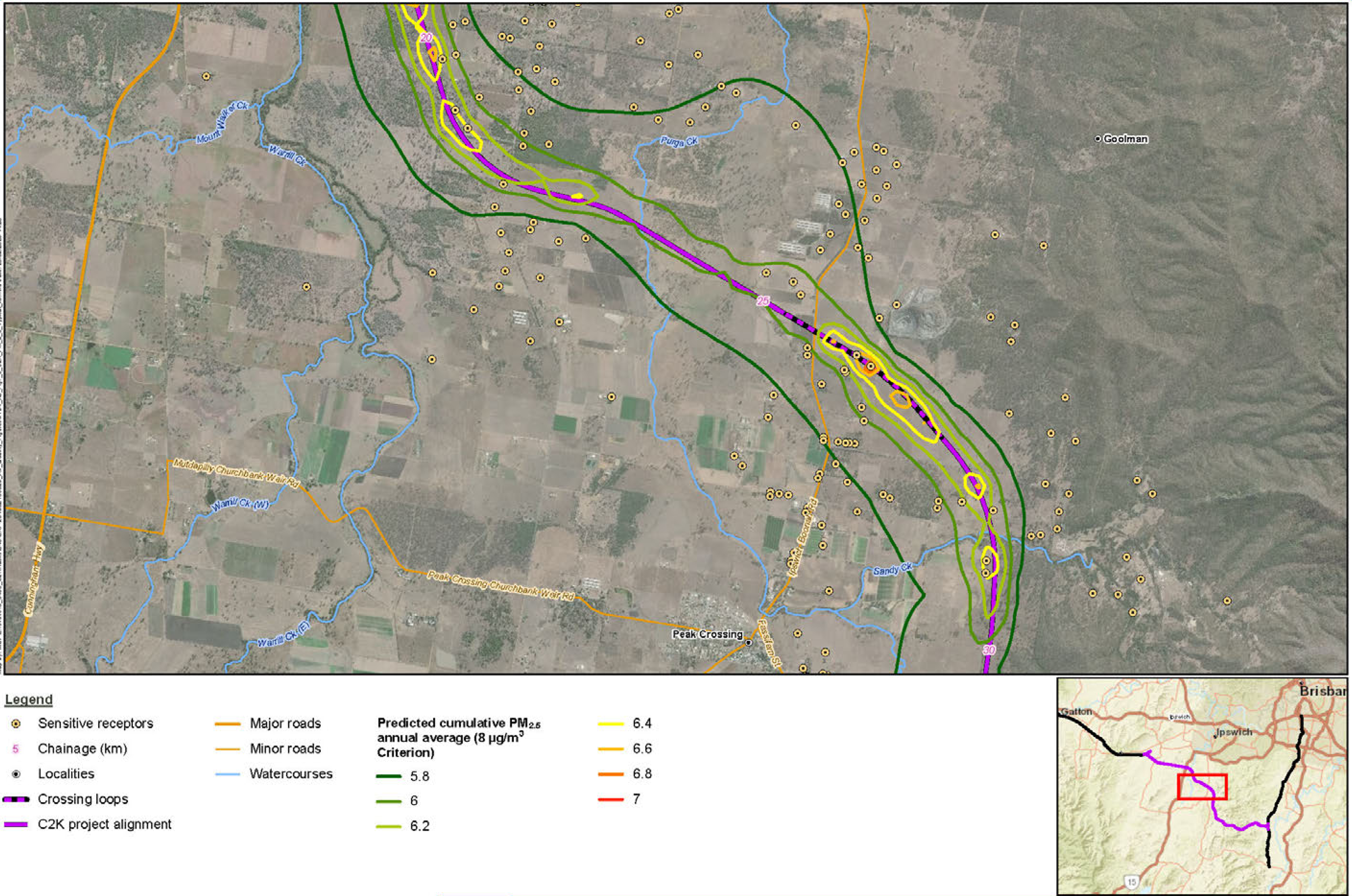
Issue date: 26/02/2020 Version: 3

Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5c: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 $\mu g/m^3$ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2km

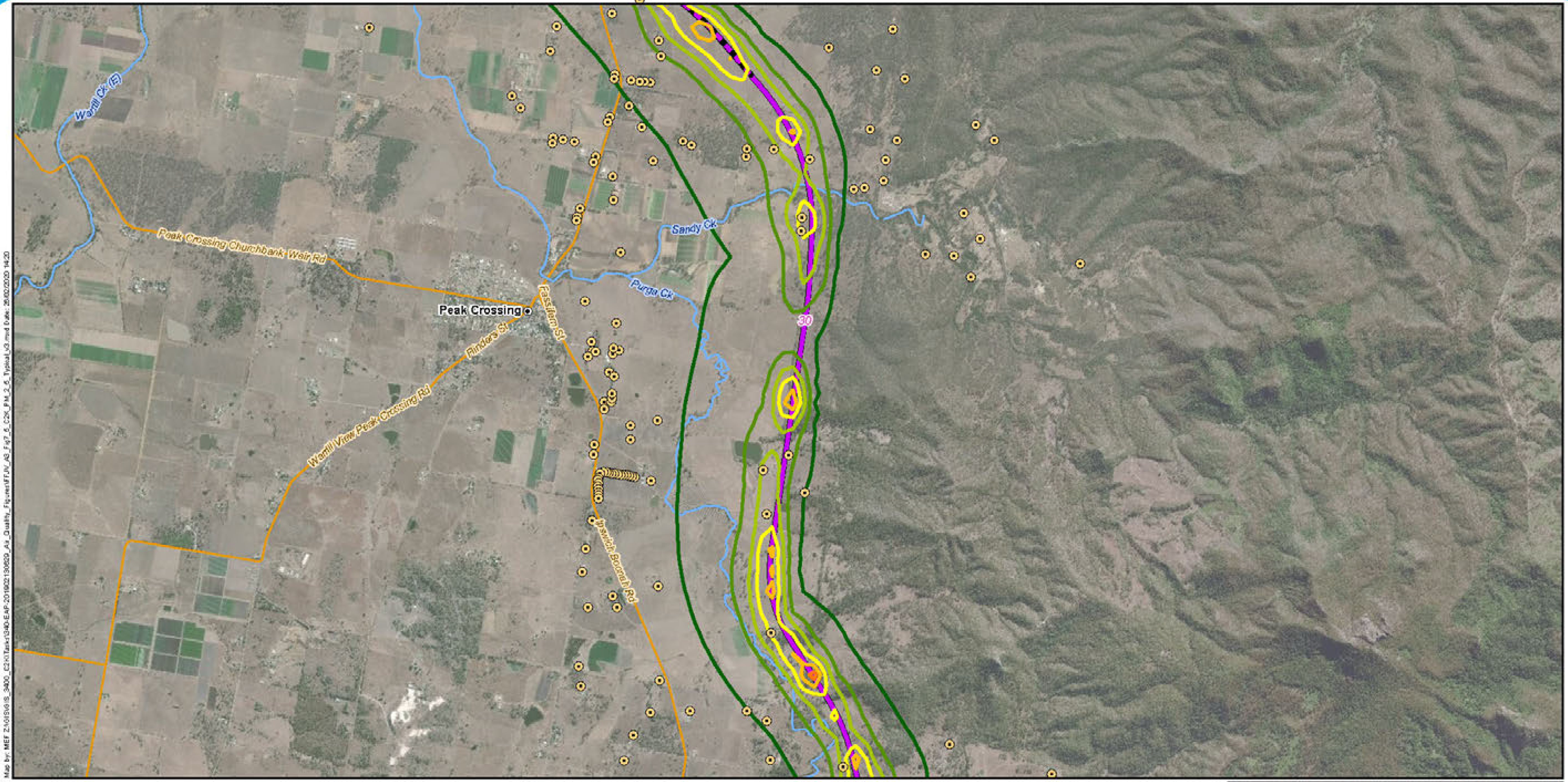
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5d: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2km

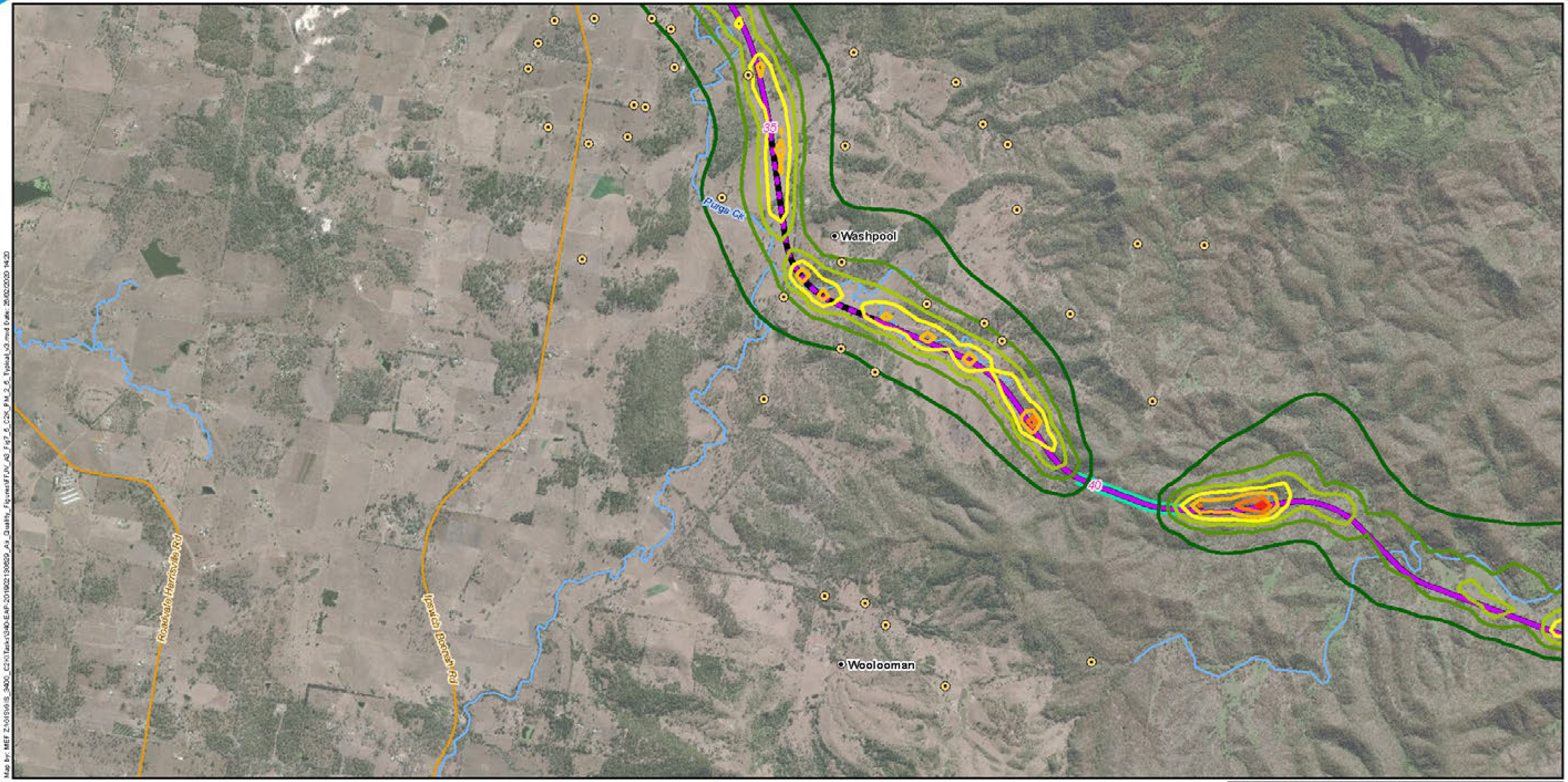
Future Freight
Integrating Community, Environment and Engineering

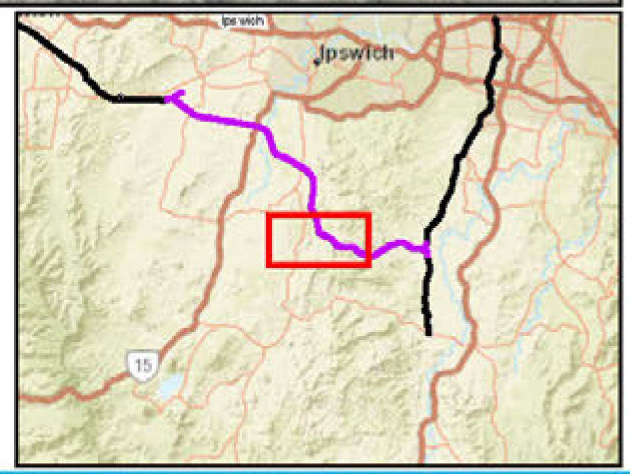
Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5e: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2 km

Future Freight — Integrating Community, Environment and Engineering

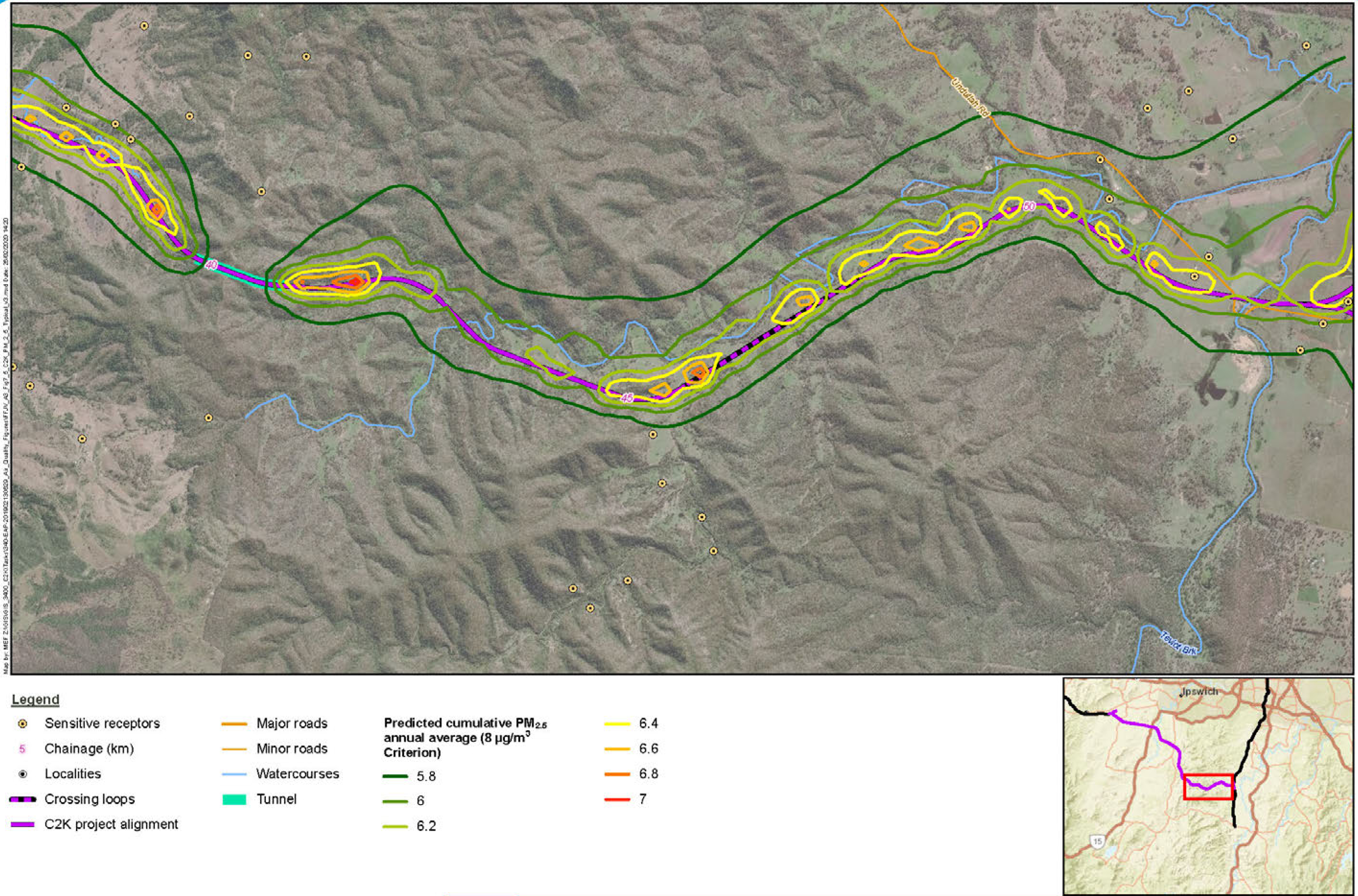
Issue date: 28/02/2020 Version: 3

Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5f: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative $PM_{2.5}$ annual average (8 µg/m³ Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2km

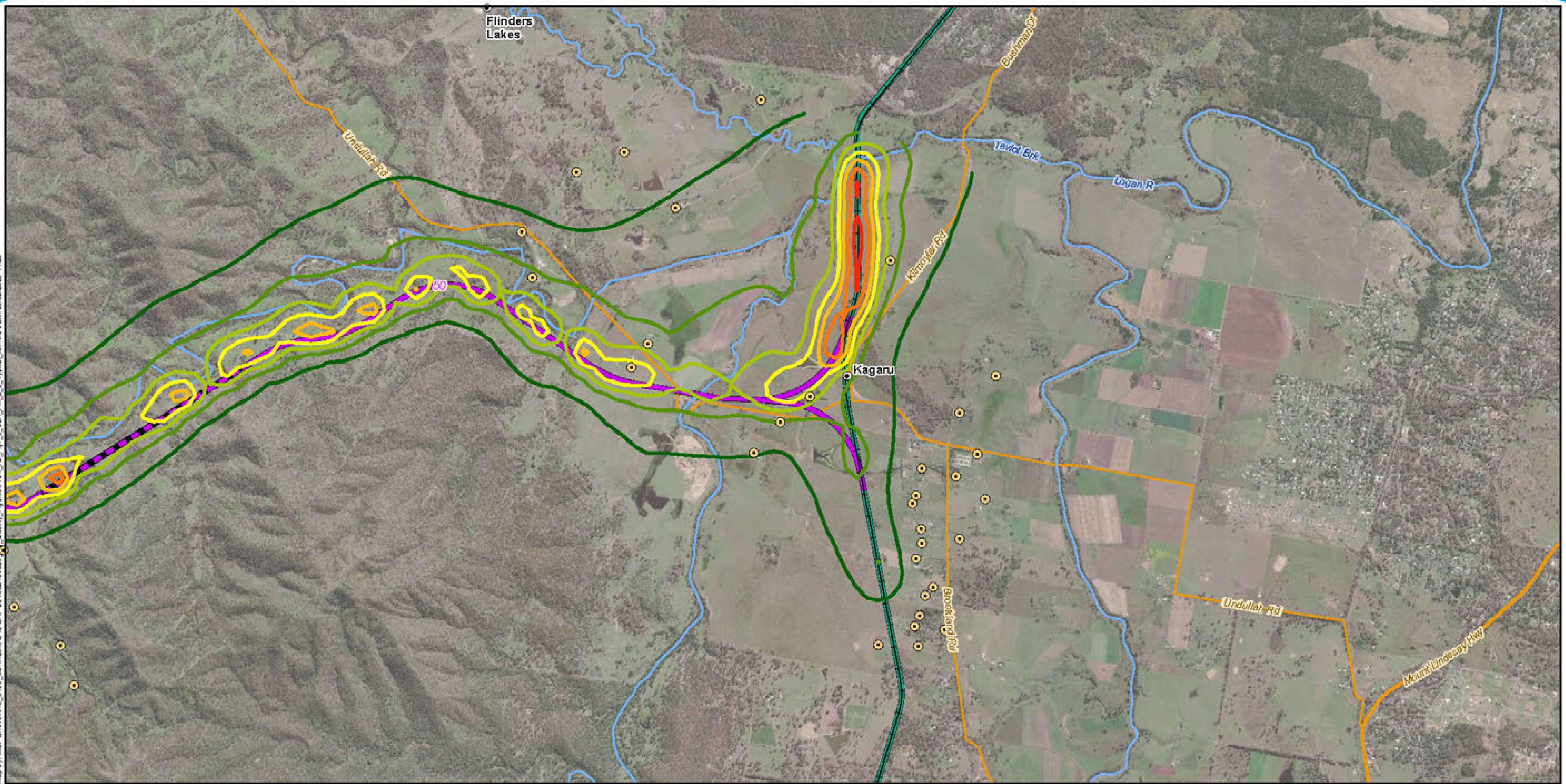
Future Freight
Integrating Community, Environment and Engineering

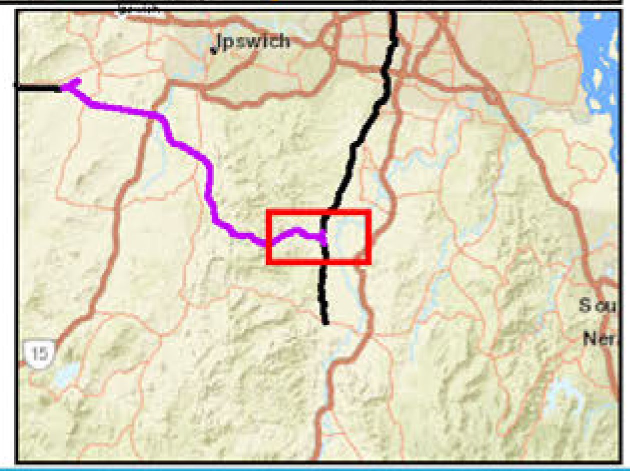
Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5g: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative $PM_{2.5}$ annual average (8 μg/m^3 Criterion)

- 5.8
- 6
- 6.2
- 6.4
- 6.6
- 6.8
- 7

A3 scale: 1:40,000

0 0.5 1 1.5 2km

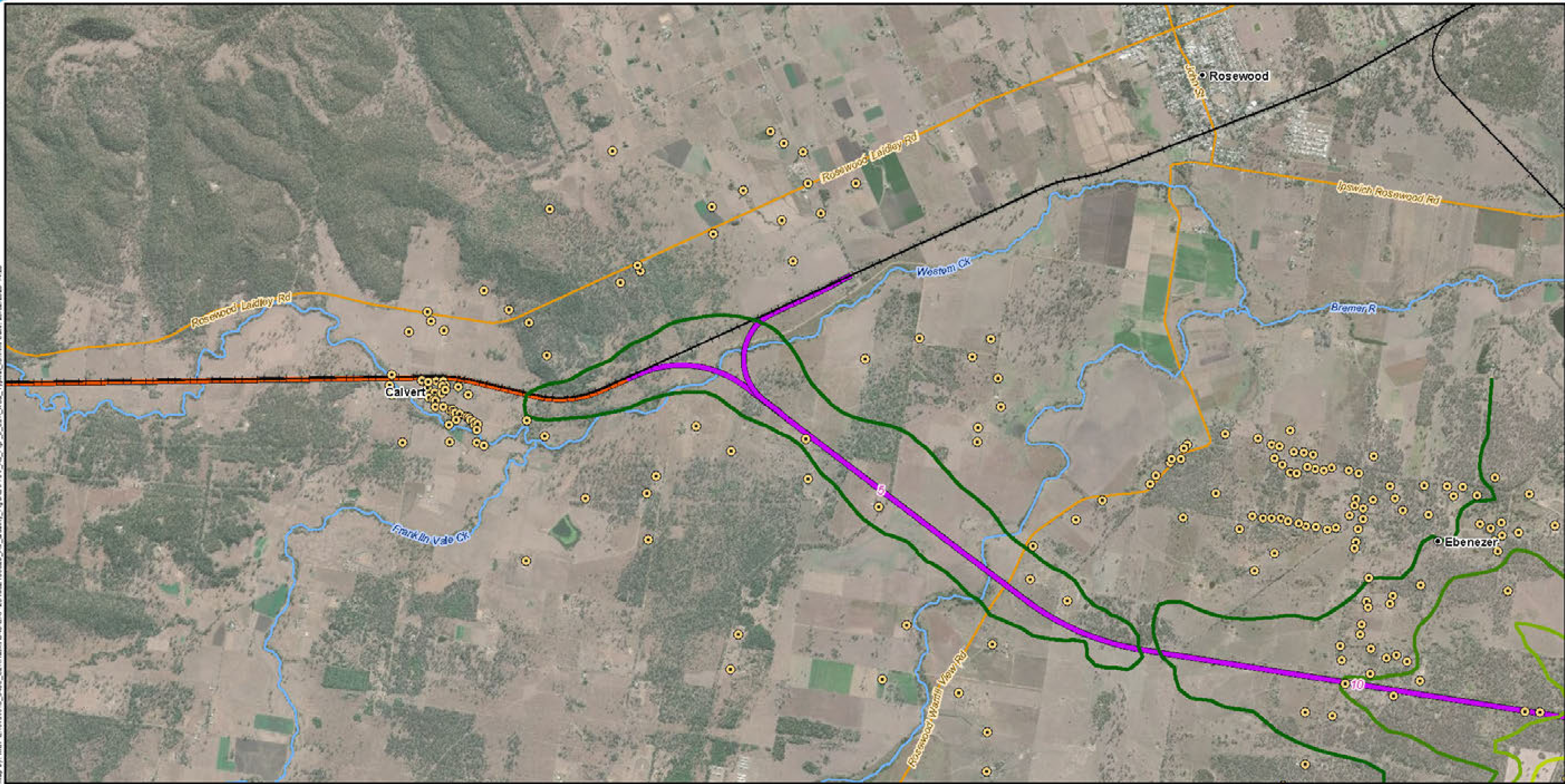
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.5h: Typical scenario predicted cumulative $PM_{2.5}$ annual average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210
- 230

A3 scale: 1:40,000

0 0.5 1 1.5 2km

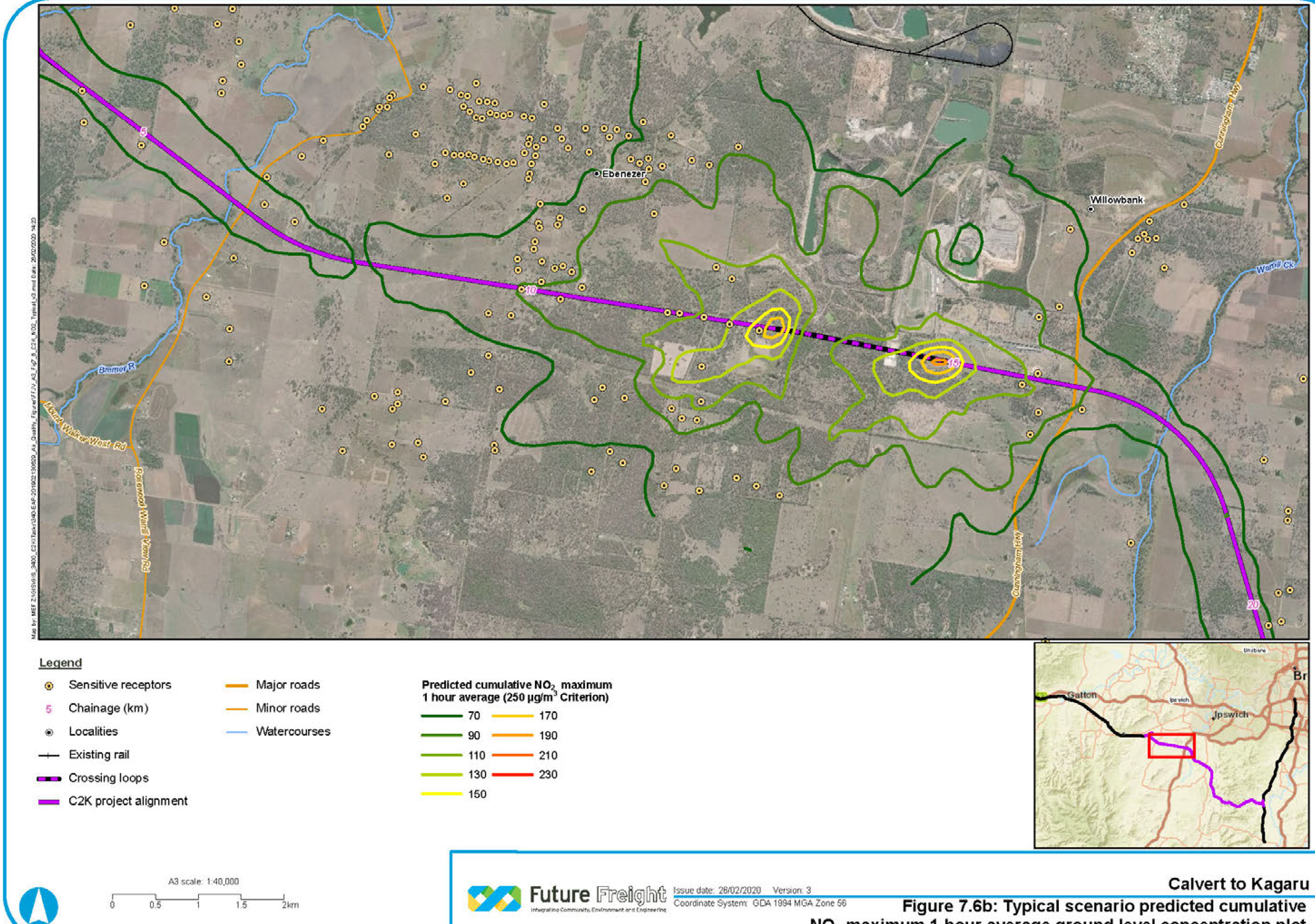
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6a: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



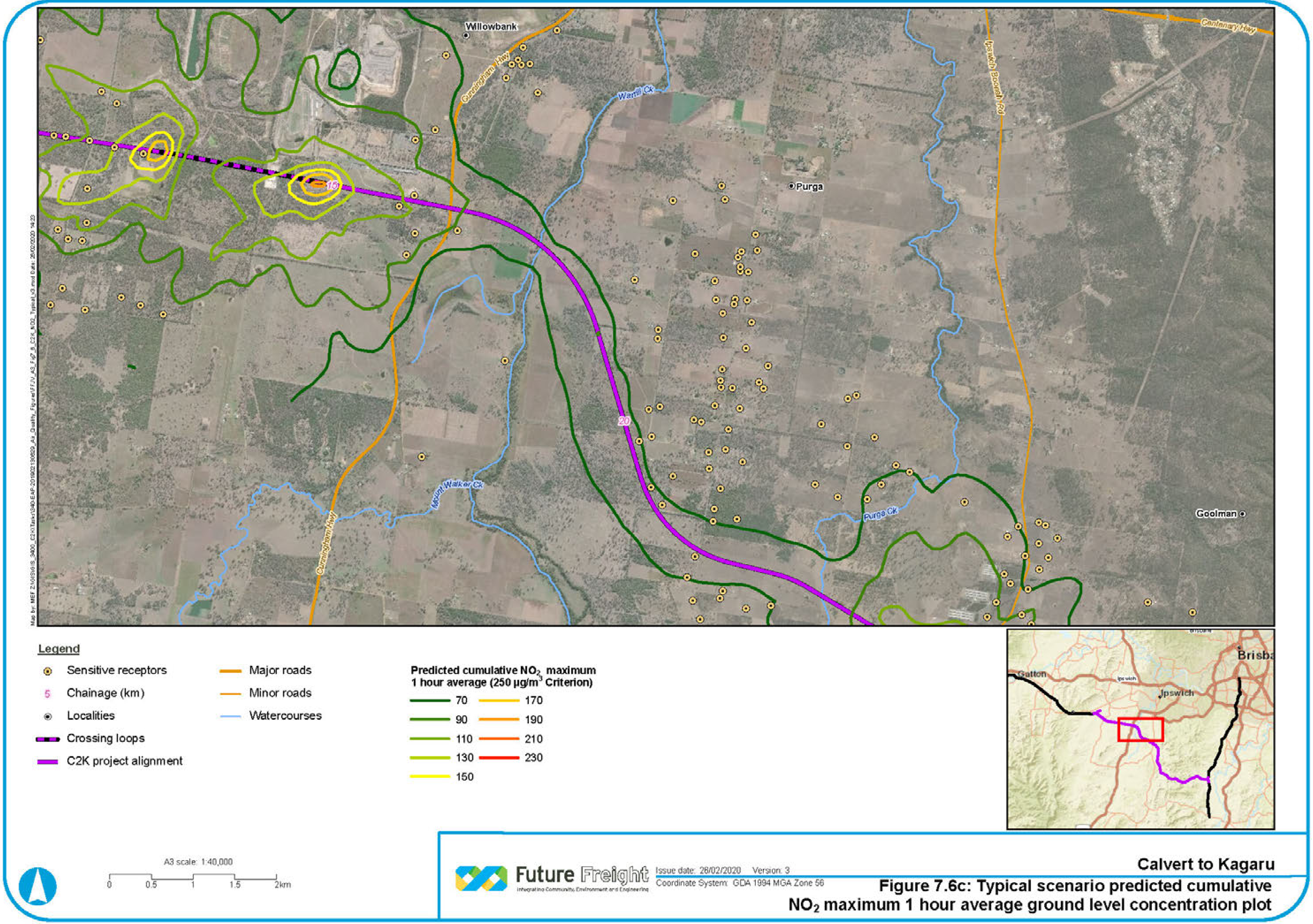
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6b: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Future Freight

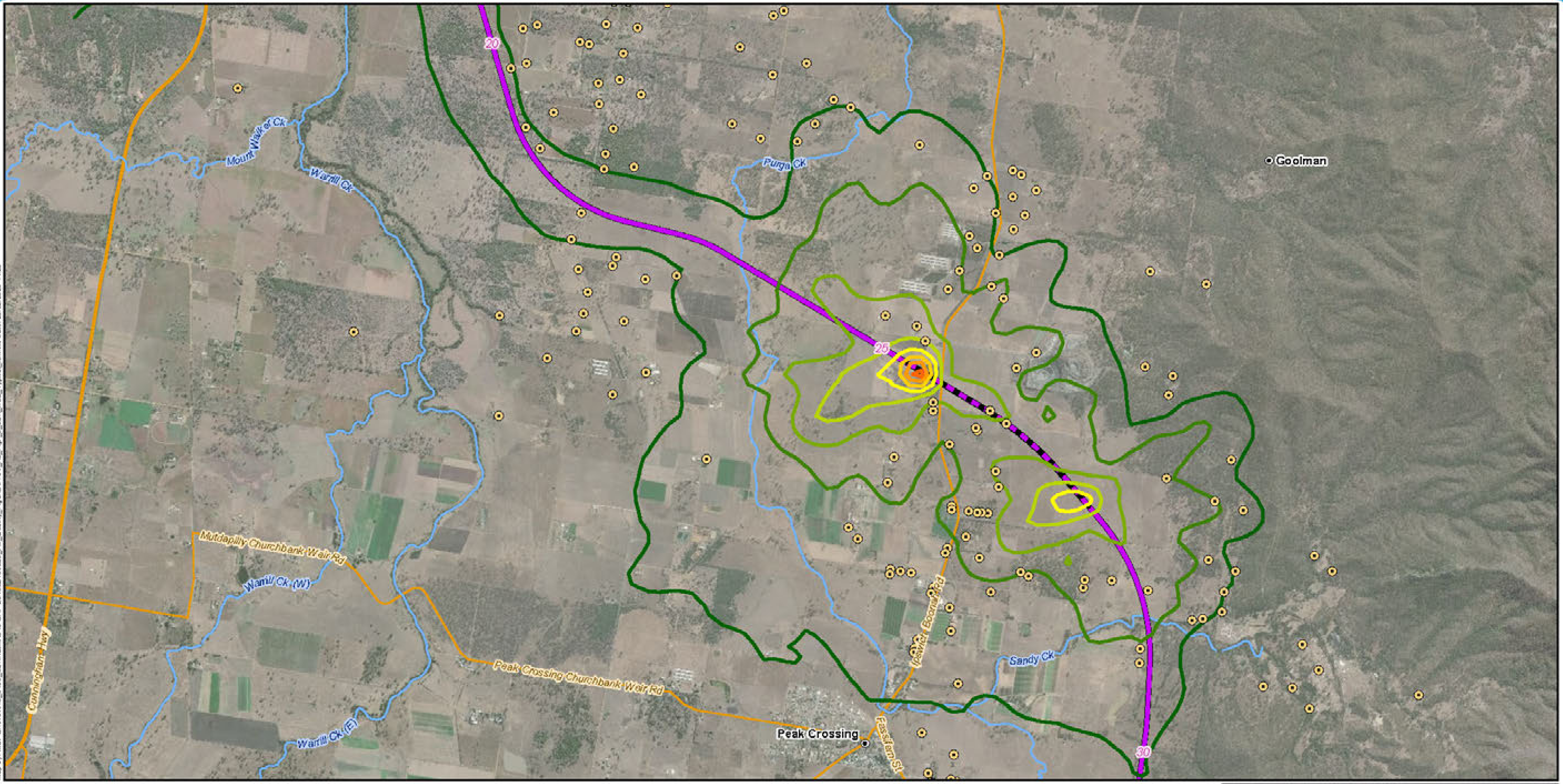
Issue date: 28/02/2020 Version: 3

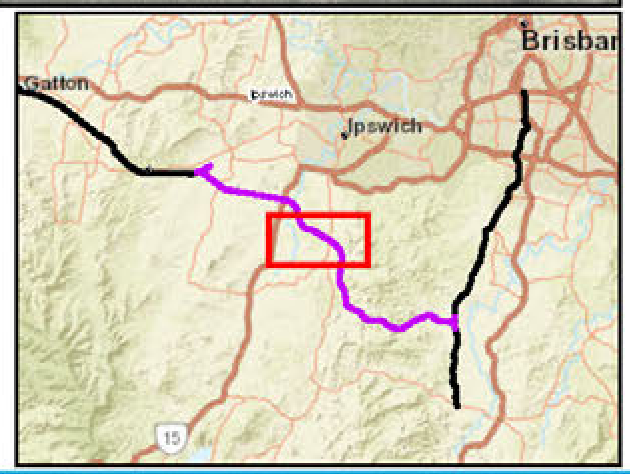
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6c: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210
- 230

A3 scale: 1:40,000

0 0.5 1 1.5 2km

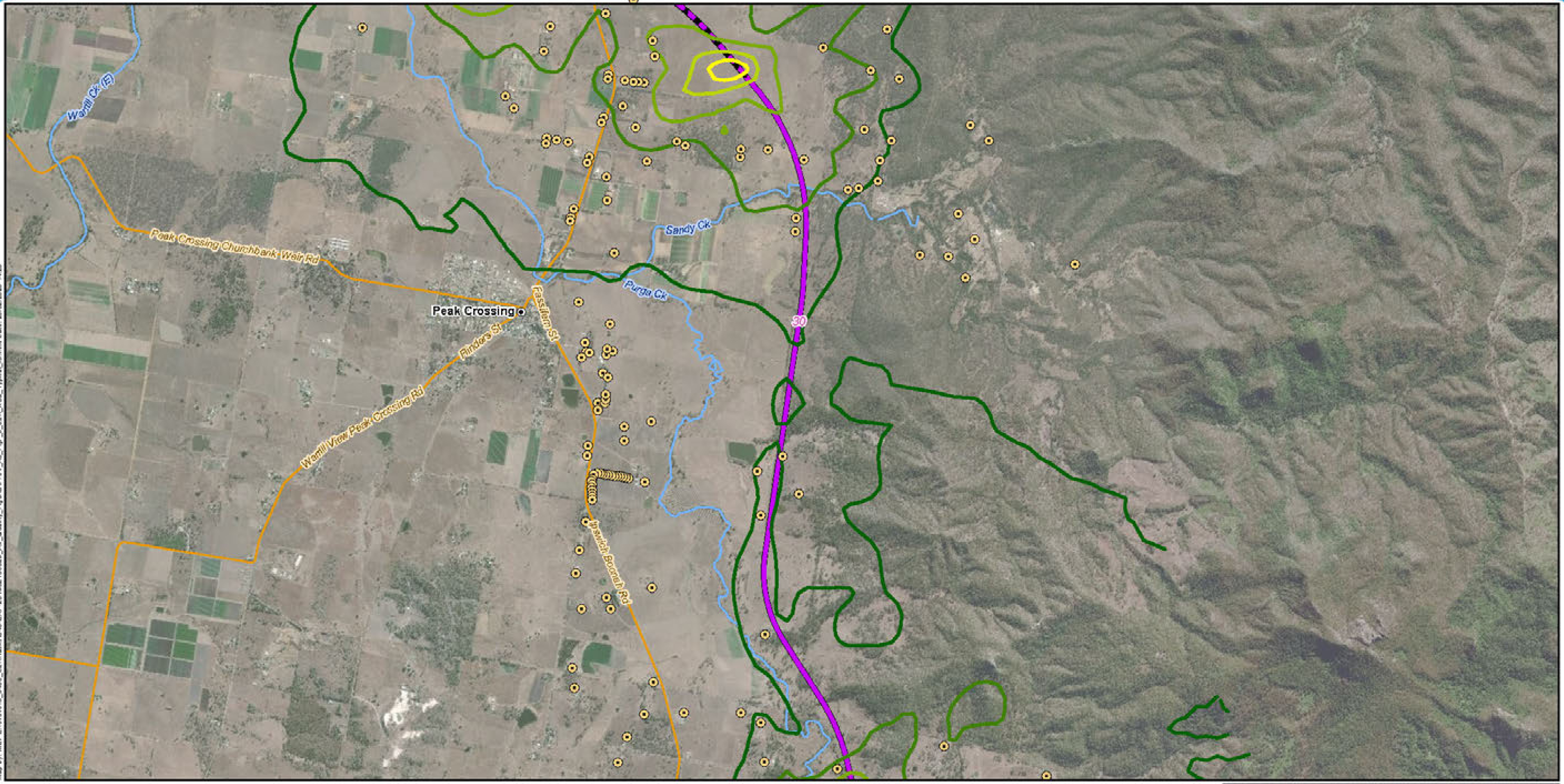
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6d: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210
- 230

A3 scale: 1:40,000

0 0.5 1 1.5 2km

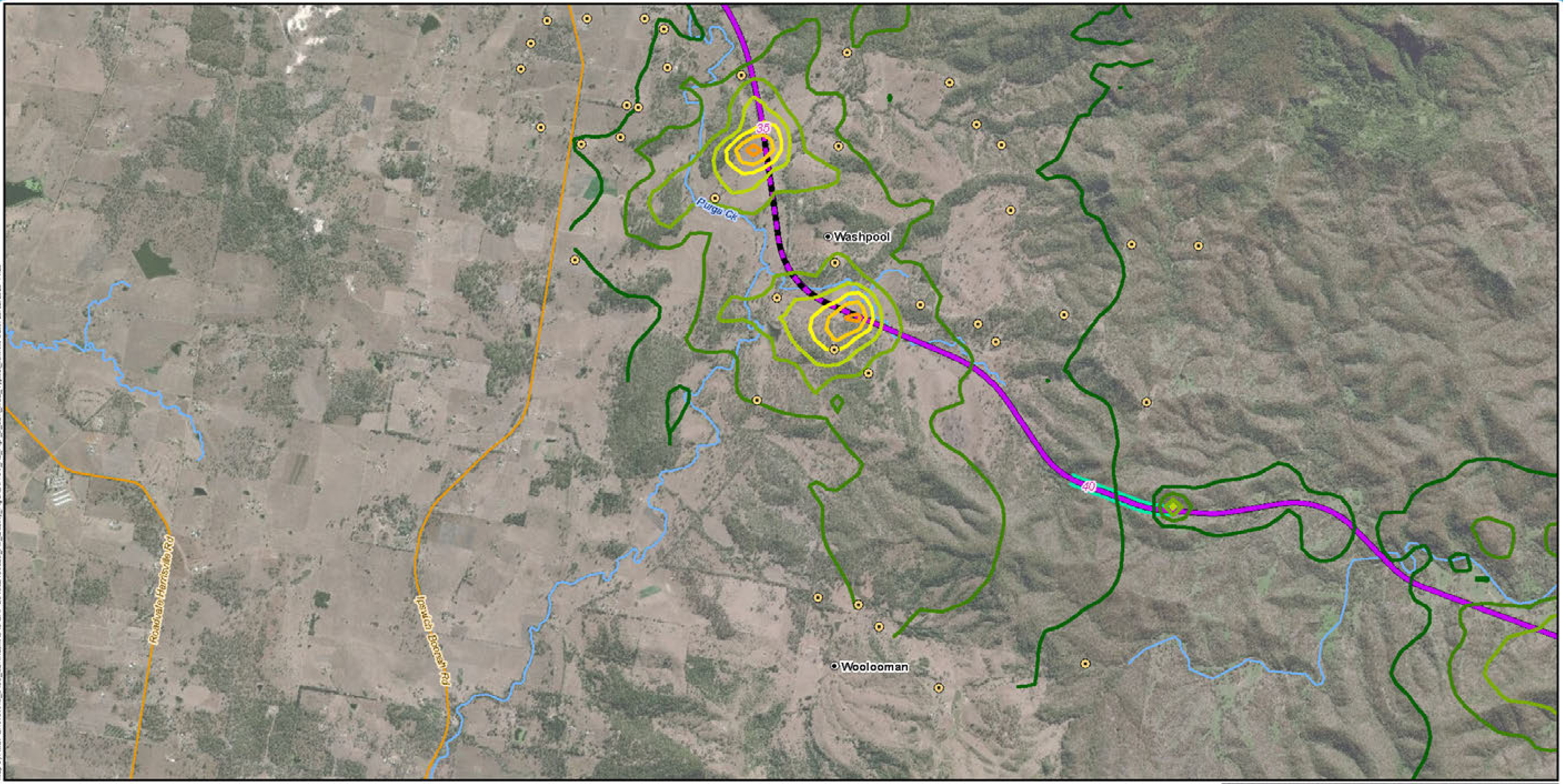
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6e: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210
- 230

A3 scale: 1:40,000

0 0.5 1 1.5 2km

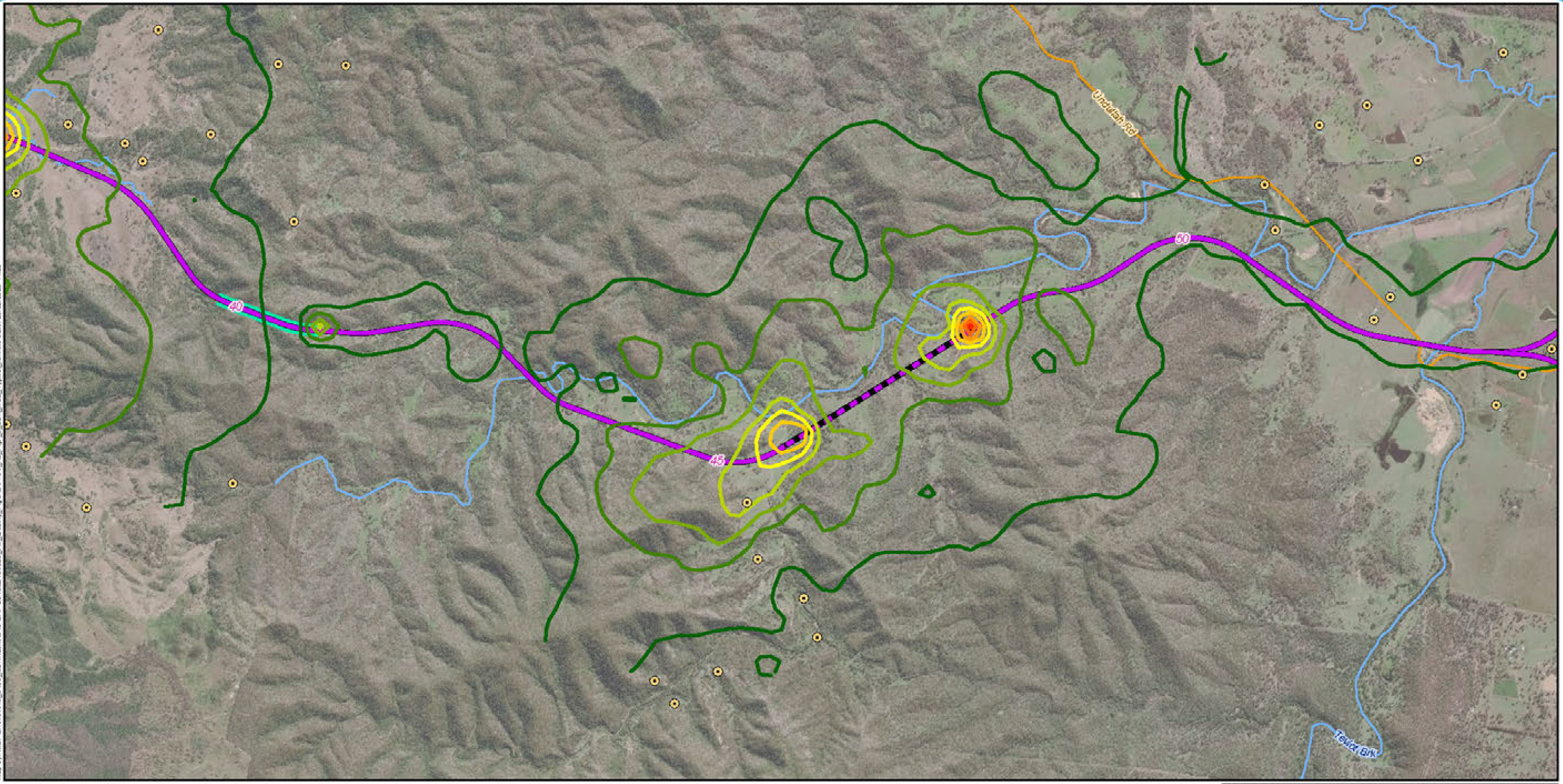
Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6f: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Crossing loops
- C2K project alignment
- Major roads
- Minor roads
- Watercourses
- Tunnel

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m^3 Criterion)

- 70
- 90
- 110
- 130
- 150
- 170
- 190
- 210
- 230

A3 scale: 1:40,000

0 0.5 1 1.5 2km

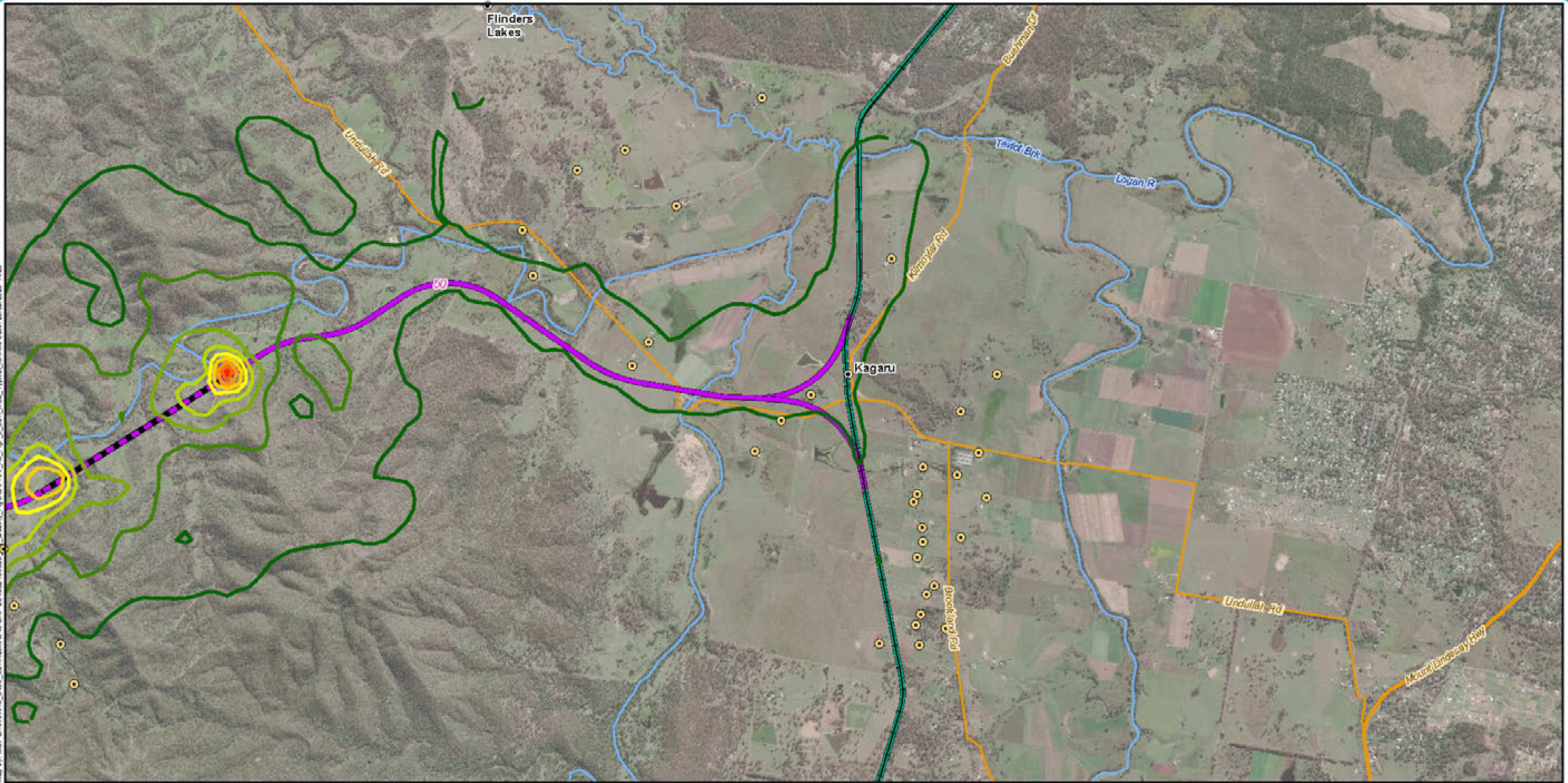
Future Freight
Integrating Community, Environment and Engineering

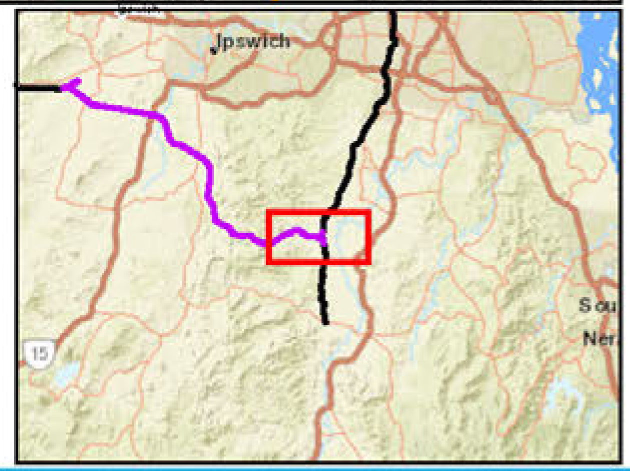
Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6g: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





Legend

- Sensitive receptors
- Chainage (km)
- Localities
- Existing rail
- Crossing loops
- C2K project alignment
- K2ARB project alignment
- Major roads
- Minor roads
- Watercourses

Predicted cumulative NO_2 maximum 1 hour average (250 µg/m³ Criterion)

70	170
90	190
110	210
130	230
150	

A3 scale: 1:40,000

0 0.5 1 1.5 2km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 28/02/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 7.6h: Typical scenario predicted cumulative NO_2 maximum 1 hour average ground level concentration plot

7.2 Impacts to tank water quality

Table 7.6 and Table 7.7 present the predicted pollutant concentrations for the water tank of the worst affected sensitive receptor for the peak and typical train operation scenarios. Table 7.6 and Table 7.7 also presents the drinking water guideline values prescribed by the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (2018).

Table 7.6 and Table 7.7 shows that at the worst affected receptor for both the peak and typical train volume scenarios compliance is predicted for all pollutants by a significant margin.

As compliance with the drinking water guideline values prescribed by the National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (2018) is predicted by a significant margin, the residual impact to drinking water is expected to be insignificant.

Table 7.6 Highest predicted water tank concentrations at sensitive receptors (peak operations)

Pollutant	Maximum predicted annual deposition rate ($\mu g/m^2/s$)	Estimated roof area (m^2)	Maximum predicted total deposited mass (µg)	Tank water volume (L)	Highest predicted concentration (mg/L)	Criteria (mg/L)[c]
Arsenic	5.3×10^{-12}	200[a.]	0.034	1,000[b.]	3.4×10^{-8}	0.01
Cadmium	5.3×10^{-10}		3.4		3.4×10^{-6}	0.002
Lead	2.7×10^{-11}		0.17		1.7×10^{-7}	0.01
Nickel	3.7×10^{-9}		24		2.4×10^{-5}	0.02
Chromium VI	2.7×10^{-9}		17		1.7×10^{-5}	0.05

Table notes:

a Based upon the average surface area of a large house.

b Assumption of a 10,000 L water tank at 10 per cent capacity, with a resultant water volume of 1,000 L.

c. Source: NHMRC Australian Drinking Water Guidelines (2018)

Table 7.7 Highest predicted water tank concentrations at sensitive receptors (typical operations)

Pollutant	Maximum predicted annual deposition rate ($\mu g/m^2/s$)	Estimated roof area (m^2)	Maximum predicted total deposited mass (µg)	Tank water volume (L)	Highest predicted concentration (mg/L)	Criteria (mg/L)[c]
Arsenic	4.2×10^{-12}	200[a.]	0.026	1,000[b.]	2.6×10^{-8}	0.01
Cadmium	4.2×10^{-10}		2.6		2.6×10^{-6}	0.002
Lead	2.1×10^{-11}		0.13		1.3×10^{-7}	0.01
Nickel	2.9×10^{-9}		18		1.8×10^{-5}	0.02
Chromium VI	2.1×10^{-9}		13		1.3×10^{-5}	0.05

Table notes:

a Based upon the average surface area of a large house.

b Assumption of a 10,000 L water tank at 10 per cent capacity, with a resultant water volume of 1,000 L.c Source: NHMRC Australian Drinking Water Guidelines (2018)

8 Cumulative impact risk assessment

When numerous projects occur within close proximity to each other they can cause cumulative impacts. It is a requirement of the Project ToR that cumulative impacts associated with the Project are considered.

The environment in which the Project will be constructed and operated is likely to have a number of existing regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed. As is typical for air quality assessments, background concentrations and deposition levels have been estimated for the relevant pollutants of concern for the air quality study area and have been used in the assessment of construction and operational phase impacts (refer Section 5.2.6).

As discussed in Section 4.4, dispersion modelling undertaken for the assessment of operational phase air quality impacts has included emissions from the adjoining sections of the Inland Rail Program adjacent to the Project, namely the H2C and K2ARB sections. Assessment of the modelling results has considered the background concentrations and deposition levels estimated for the relevant pollutants to assess cumulative impacts.

Due to the location of the Boral Purga Quarry, emissions from the quarry and the potential for elevated background concentrations (for particulates) at receptors near the quarry were also considered when assessing the impact of the construction phase of the Project (refer Section 6.1). The quarry will not operate concurrently with the operation of the Project, and therefore there is no risk of cumulative impacts with the quarry for the operational phase of the Project.

Although the H2C, K2ARB and Boral Purga Quarry projects have already been considered in the assessment of the construction and operational phases of the Project, they have been included in this cumulative impact risk assessment for completeness.

The assessment matrix and the results of the cumulative impact risk assessment are discussed in the following sections.

8.1 Assessment matrix

The assessment of cumulative impacts has considered existing or proposed projects which have the potential to cause cumulative air quality impacts as a result of emissions to air anticipated to be generated during construction and operation of the identified projects, and the projects spatial and temporal relationship with the Project.

The significance of the potential cumulative impact has been determined by using professional judgement to select the most appropriate relevance factor for each aspect as identified in Table 8.1. The sum of the relevance factors determines the impact significance and consequence which are summarised in Table 8.2. For example, if a project is assigned a probability of impact score of 2, a duration of impact score of 3, a magnitude/intensity of impact score of 1 and a sensitivity of receiving environment score of 1, the significance of impact would be Medium (2+3+1+1 = 7).

Table 8.1 Assessment matrix

Aspect	Relevance factor		
	Low	Medium	High
Probability of impact	1	2	3
Duration of impact	1	2	3
Magnitude/Intensity of impact	1	2	3
Sensitivity of receiving environment	1	2	3

Table 8.2 Impact significance

Impact significance	Sum of relevant factors	Consequence
Low	1-6	Negative impacts need to be managed by standard environmental management practices. Monitoring to be part of general project monitoring program.
Medium	7-9	Mitigation measures likely to be necessary and specific management practices to be applied. Targeted monitoring program may be required, where appropriate.
High	10-12	Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Targeted monitoring program necessary, where appropriate.

8.2 Cumulative impacts

A total of nine projects have been considered in the cumulative impact risk assessment. These projects are either currently operational, will be constructed and or operational during the life of the Project, or are currently going through an approval process.

It is noted that a number of the projects considered are expected to have limited potential for cumulative impacts. However, these projects have been included due to their location within or near the air quality study area, or their status as a 'State significant' or 'strategic' project and therefore warrants discussion. The Jeebropilly open-cut coal mine has not been considered in the cumulative impact risk assessment as it closed operations in December 2019 (Richter 2019).

The assessed projects which have been considered in the cumulative impact assessment are listed in Table 8.3. The locations of the assessed projects are shown in Figure 8.1.

Table 8.3 Projects considered for the cumulative impact assessment

Project and proponent	Location	Description	Construction dates
K2ARB (ARTC)	Rail corridor from Kagaru to Acacia Ridge and Bromelton	Enhancing and connecting the existing rail corridor (approximately 49 km) from North-east of Kagaru to Acacia Ridge and from south of Kagaru to Bromelton.	2023 to 2025
H2C (ARTC)	Rail alignment from Helidon to Calvert	The H2C project will include 47 km of single-track dual-gauge freight rail line, a tunnel through the Little Liverpool Range and connection to the existing West Moreton Railway Line.	2021 to 2026
Purga Quarry (Boral)	Peak Crossing	The operation of the quarry for extractive activities is approved until 23 December 2023, at which time it will have exhausted all extractable resource. Associated sales and rehabilitation works will continue until 23 June 2025.	Approved for extraction until 23 December 2023, approved for sales until 23 June 2025
Greater Flagstone Priority Development Area (PDA) (QLD Government)	Located within Logan City, west of Jimboomba and the Mount Lindesay Highway, along the Brisbane-Sydney rail line	When fully developed, it is anticipated that the Greater Flagstone PDA will provide approximately 50,000 dwellings to house a population of up to 120,000 people.	2011 to 2041
Bromelton State Development Area (SDA) (QLD Government)	South of Kagaru in Bromelton	Delivery of critical infrastructure within the Bromelton SDA will support future development and economic growth. This includes a trunk water main and the Beaudesert Town Centre Bypass. This infrastructure provides opportunities to build on the momentum of current development activities by major landowners in the SDA.	2016 to 2031

Project and proponent	Location	Description	Construction dates
Ripley Valley PDA (QLD Government)	Approximately 5 km south-west of the Ipswich CBD and south of the Cunningham Highway	The Ripley Valley PDA covers a total area of 4,680 ha and is an opportunity to provide approximately 50,000 dwellings to house a population of approximately 120,000 people. It is located in one of the largest industry growth areas in Australia and offers opportunities for further residential growth to meet the region's affordable housing needs.	2009 to 2031
South West Pipeline: Bulk Water Connection to Beaudesert (Seqwater)	Pipeline alignments sits east of Kagaru, running north from Beaudesert	The proposal is investigating a bulk water pipeline connection from the Southern Regional Water Pipeline to Beaudesert, connecting Beaudesert to the South-east Queensland Water Grid. The pipeline will pass through the site of the future Wyaralong Water Treatment Plant.	2021
RAAF Base Amberley future works (Department of Defence)	RAAF Base Amberley	A white paper has been issued dedicated to future upgrades to RAAF Base Amberley. The total cost of the upgrade work is anticipated to be approximately $1 billion.	2016 to 2022
Remondis Waste to Energy Facility (Remondis)	Swanbank Industrial Estate	Remondis has announced plans to build a $400 million Waste to Energy Facility in Swanbank, south of Ipswich.	Project not yet approved

The results of the assessment of cumulative impacts are presented in Table 8.4. Table 8.4 also presents discussion with respect to the requirements for mitigating potential cumulative impacts.

The projects considered in the cumulative impact assessment have been included due to the potential for cumulative impacts arising from emissions during the construction phase of these projects. With the exception of the H2C and K2ARB projects (which have been included in the operational assessment for the Project) emissions from the operation of the assessed projects are not considered to have the potential to generate significant cumulative impacts. Where relevant, comment on anticipated operational emissions from the assessed projects has been provided in Table 8.4.

The relevance factor for the sensitivity of the receiving environment has been assigned as Low for all projects. This factor has been assigned considering the number of sensitive receptors which may be affected by cumulative impacts with the assessed project, the sensitivity to the emissions which will cause the impact (e.g. dust), and the mostly isolated nature of construction phase emissions from the Project.

Table 8.4 shows that cumulative air quality impacts are expected to be of Low significance for all assessed projects.

Mitigation measures for the construction phase of the Project are recommended in Section 9.3. The recommended mitigation measures for the Project will reduce the potential for cumulative impacts at sensitive receptors.

In addition to the mitigation measures recommended, visual and quantitative dust monitoring will be undertaken at sensitive receptor locations near the Boral Purga Quarry (refer Section 9.4.2) to assist in managing cumulative impacts at these receptors.

Implementation of the recommended mitigation measures in combination with the implementation of a CEMP is expected to be sufficient to minimise the risk of significant cumulative impacts.

Table 8.4 **Cumulative impact assessment of assessable projects**

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
K2ARB (ARTC)	The construction and operation of the Project will occur concurrently with the construction and operation of K2ARB. Cumulative air emissions could impact receptors located near both projects. Air emissions from the operation of K2ARB have been assessed as part of the assessment of the operation of the Project.	Probability of the impact	Medium (2)	6	Low	▪ The significance of cumulative impacts during construction of the Project is considered to be Low. ▪ Recommended mitigation measures for the construction phase of the Project are presented in Section 9.3. Mitigation measures will also be recommended for the K2ARB project in the projects EIS. It is expected that the potential for cumulative impacts will be appropriately managed through the implementation of mitigation measures and a CEMP. ▪ Cumulative impacts as a result of the operation of both projects has been assessed in detail, with the results of the operational phase assessment presented in Section 7.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
H2C (ARTC)	The construction and operation of the Project will occur concurrently with the construction and operation of H2C. Cumulative air emissions could impact receptors located near both projects. Air emissions from the operation of H2C have been assessed as part of the assessment of the operation of the Project.	Probability of the impact	Medium (2)	6	Low	▪ The significance of cumulative impacts during construction of the Project is considered to be Low. ▪ Recommended mitigation measures for the construction phase of the Project are presented in Section 9.3. Mitigation measures will also be recommended for the H2C project in the projects EIS. It is expected that the potential for cumulative impacts will be appropriately managed through the implementation of mitigation measures and a CEMP. ▪ Cumulative impacts as a result of the operation of both projects has been assessed in detail, with the results of the operational phase assessment presented in Section 7.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Boral Purga Quarry	The construction of the Project will occur concurrently with the operation of the quarry. Cumulative air emissions from the operation of the quarry and the construction of the Project could impact receptors located near both projects. The quarry will not be operational concurrently with the operation of the Project, and therefore there is no risk of cumulative impacts for the operational phase of the Project.	Probability of the impact	Medium (2)	6	Low	▪ The significance of cumulative impacts during construction of the Project is considered to be Low. Risk of cumulative impacts is present during the construction phase of the Project only. ▪ The background concentrations adopted for the air quality study area (refer Section 5.2.6) may not be representative of background air quality local to the area near the quarry. However, the presence of the quarry and elevated background dust concentrations as a result of the quarry were considered in the qualitative assessment for the construction phase of the Project (refer Section 6.1). ▪ Recommended mitigation measures for the construction phase of the Project will reduce the potential for cumulative impacts at sensitive receptors near the Boral Purga Quarry. To further manage potential cumulative impacts, visual and quantitative dust monitoring will be undertaken at sensitive receptor locations near the quarry (refer Section 9.4.2).
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
Greater Flagstone Priority Development Area (PDA) (QLD Government)	The construction and operation of the Project may overlap with the construction and operation of the PDA. Significant emissions related to the PDA are anticipated for the construction phase only. No significant emissions are anticipated from the operation of the PDA.	Probability of the impact	Low (1)	5	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ It is considered unlikely that construction for each project will occur in the same localised area simultaneously to the extent that would cause significant impacts to existing receptors. Increased traffic volumes may occur at times in Kagaru during construction of each project, but this is not expected to result in significant impacts. ▪ No additional mitigation measures are required further to those recommended for the Project.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Bromelton State Development Area (SDA) (QLD Government	The construction and operation of the Project may overlap with the construction and operation of the SDA. Significant emissions related to the SDA are anticipated for the construction phase only. No significant emissions are anticipated from the operation of the SDA. The eastern end of the Project at Kagaru is located within the SDA. With the exception of the northern end of the SDA (at Kagaru), the majority of the SDA has significant separation distance to the Project.	Probability of the impact	Low (1)	5	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ It is considered unlikely that intensive construction for each project will occur in the same localised area simultaneously to the extent that would cause significant impacts to existing receptors. Increased traffic volumes may occur at times in Kagaru during construction of each project, but this is not expected to result in significant impacts. ▪ No additional mitigation measures are required further to those recommended for the Project.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Medium (2)			
		Sensitivity of the receiving environment	Low (1)			
Ripley Valley PDA (QLD Government)	The construction and operation of the Project may overlap with the construction and operation of the PDA. Significant emissions related to the PDA are anticipated for the construction phase only. No significant emissions are anticipated from the operation of the PDA. The PDA is located approximately 5.5 km from the Project at its closest point.	Probability of the impact	Low (1)	4	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ Due to separation distance no significant cumulative impacts are anticipated due to simultaneous construction activities. ▪ No additional mitigation measures are required.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
South West Pipeline: Bulk Water Connection to Beaudesert (Seqwater)	The construction of the Project may overlap with the construction of the pipeline. Emissions from the operation of the pipeline are not expected to be significant The pipeline alignment travels to the east of Kagaru.	Probability of the impact	Low (1)	4	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ The only potential for cumulative impacts is when construction for both projects occurs near in Kagaru resulting in increased traffic volumes. Increased traffic volumes are not expected to result in significant impacts. ▪ No additional mitigation measures are required.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1))			

Project	Potential cumulative impact	Impact characteristic	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
RAAF Base Amberley future works (Department of Defence)	Overlap of construction of the Project with construction to upgrade RAAF Base Amberley. RAAF Base Amberley is located approximately 5 km to the north of the Project at its closest point.	Probability of the impact	Low (1)	4	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ Due to separation distance no significant cumulative impacts are anticipated due to simultaneous construction activities. Ongoing development at RAAF Base Amberley may see an increase in localised road traffic but this is not expected to result in significant impacts. ▪ No additional mitigation measures are required.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			
Remondis Waste to Energy Facility (Remondis)	Subject to the approval of the Waste to Energy Facility, there is potential for overlap of construction and operation of the Waste to Energy Facility with the construction and operation of the Project. If approved the construction and operation phases of the Waste to Energy Facility is expected to generate emissions to air. The proposed Waste to Energy Facility is located approximately 12.5 km to the north-east of the Project at the closest point on the alignment.	Probability of the impact	Low (1)	4	Low	▪ The significance of cumulative impacts during construction is considered to be Low. ▪ Existing sensitive receptors (at which compliance with air quality goals will be required for operation) are located within 2.5 km to the south-west of the proposed location of the facility, the same orientation as the Project from the facility. ▪ In addition to the significant separation distance, significant height topography is also present between the two sites. Due to the dispersion of emissions as a result of separation distance and topography, it is expected that emissions from the facility will have negligible impact on air quality at sensitive receptors near the Project. ▪ No additional mitigation measures are required.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of the receiving environment	Low (1)			

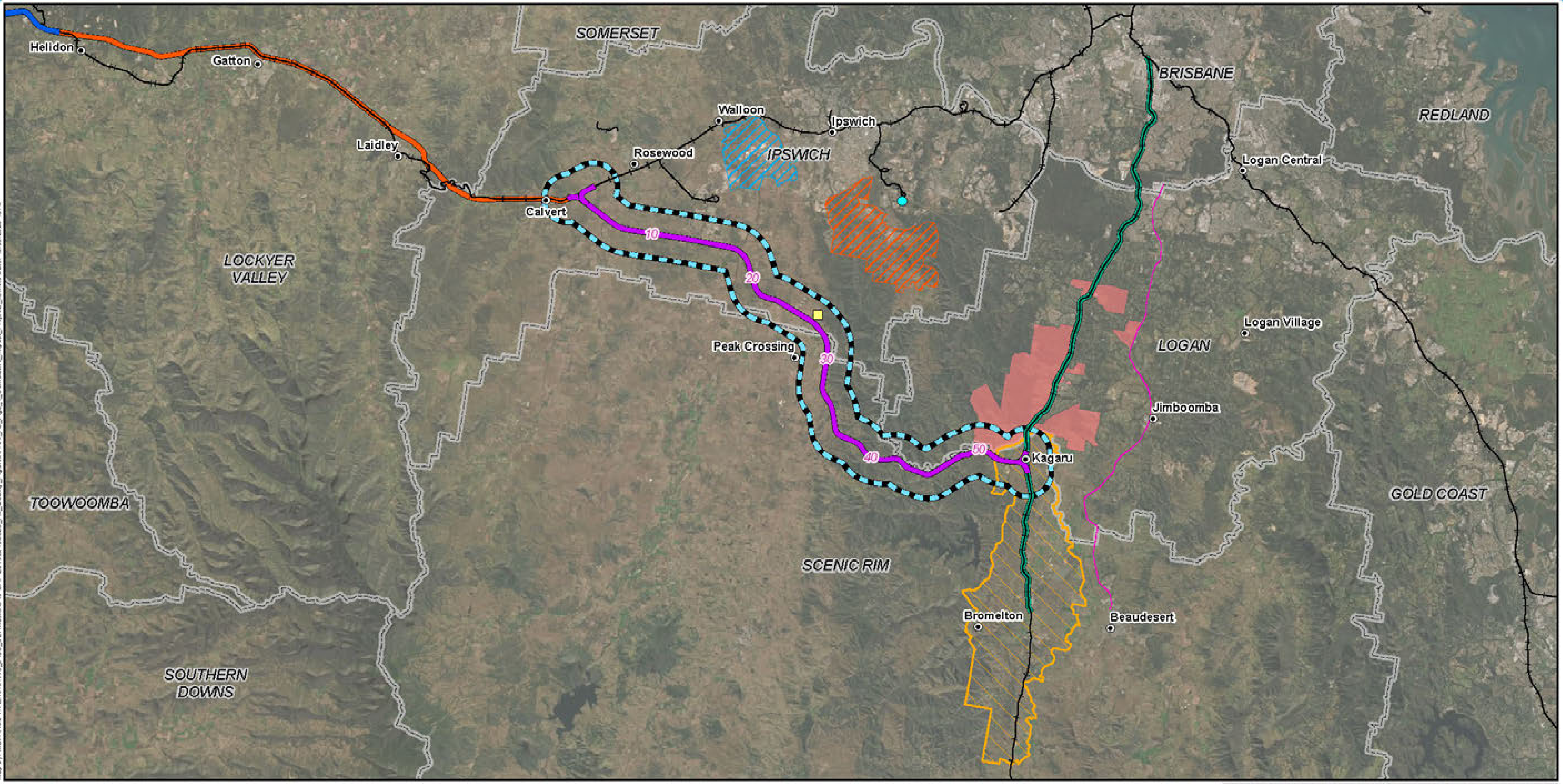
Table notes:

Relevance factors between 1 and 3 were determined using professional judgement to select most appropriate relevance factor for each aspect and summing the relevance factors.

Sum of relevant factors definition:

- Low (1-6): Negative impacts need to be managed by standard environmental management practices. Monitoring to be part of general project monitoring program.
- Medium (7-9): Mitigation measure likely to be necessary and specific management practices to be applied. Targeted monitoring program required, where appropriate.
- High (10-12): Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Targeted monitoring program necessary, where appropriate.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- 5 Chainage (km)
- Localities
- Existing rail
- G2H project alignment
- C2K project alignment
- Local Government Areas

Projects included in assessment

- Boral Purga Quarry
- Remondis Waste to Energy Facility
- South West Pipeline
- Inland Rail H2C
- Inland Rail K2ARB
- Ripley Valley Priority Development Area
- RAAF Base Amberley
- State Development Area Boundary - Bromelton
- Priority Development Area Boundary - Greater Flagstone

A3 scale: 1:350,000

0 4 8 12 16 20km

Future Freight
Integrating Community, Environment and Engineering

Issue date: 15/09/2020 Version: 5
Coordinate System: GDA 1994 MGA Zone 56

Calvert to Kagaru

Figure 8.1:
Location of projects considered in cumulative impact risk assessment

9 Mitigation measures and management strategies

This section outlines the mitigation measures included in the Project design and identifies proposed mitigation measures to manage impacts to air quality in the pre-construction, and construction and operational phases of the Project.

No comprehensive guideline information is currently available for best practice environmental management measures for the emissions of air pollutants from construction related emissions in QLD or Australia. Guidance on management measures are provided within the UK IAQM Guideline for the Assessment of dust from demolition and construction (UK IAQM 2014); however, many of these measures are tailored to the United Kingdom and are not necessarily applicable for Australia. Where similar conditions do exist, the recommended mitigation measures do align with the suggested mitigation measures from the UK IAQM guideline document. Mitigation measures prescribed in the NPI Emissions Estimation Manual for Mining (NPI 2012) are also considered applicable for the construction phase, and select mitigation measures from this document have been recommended.

The mitigation measures that are identified are considered to represent best practice environmental management of air emissions.

9.1 Design considerations

The mitigation measures inherent in the Project design are presented in Table 9.1. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues, including proximity to sensitive receptors. These design measures are relevant to both construction and operational phases of the Project.

Table 9.1 Mitigation measures inherent in the design

Aspect	Initial mitigations
Emissions from refuelling activities during construction	▪ The planning, siting and assessment of potential fuel storage locations has taken into consideration the location of sensitive receptors.
Emissions from construction vehicles	▪ The horizontal and vertical alignment has been established to optimise the earthworks required and achieve as close to a net-balance as is possible. By minimising the material deficit for construction of the Project, the volume of material required to be imported has been reduced. Less imported material equates to fewer construction phase truck movements and less vehicular emissions. ▪ Construction phase haulage routes that provide the shortest journey time between origin and destination have been identified. These routes restrict fuel consumption and vehicular emissions. These routes have been assessed as part of the traffic impact assessment in the EIS.
Fugitive dust emissions (windborne erosion) during construction and operation	▪ Planning of the Project has aimed to minimise clearing extents to that required to safely and efficiently construct and operate the rail corridor. ▪ Laydown areas and other construction-phase facilities have been located to avoid impacts to environmental and social receptors. ▪ Railway batters and other exposed surfaces have been designed to enable stabilisation to reduce fugitive dust emissions.
Emissions from operational locomotives	▪ The Project has been aligned to avoid, where possible, steep terrain and topographical constraints to provide for more efficient operational track geometry and grade. This results in faster train transit time and less locomotive emissions.
Emissions from idling locomotives	▪ The planning and siting of crossing loops at Ebenezer, Purga Creek, Washpool Road and Undullah have been positioned to avoid, where possible, the exposure of sensitive receptors to diesel emissions from idling trains.

9.2 Operational management measures

Dust and air quality management measures will be incorporated into the environmental risk management frameworks that will apply to third party freight train operators as part of network access agreements. The access agreements established will require train operators to prepare suitably detailed environmental management plans for their operations to detail how the operator will manage all risks. These plans will include clear performance requirements and traceable corrective measures and be subject to verification and auditing by the corridor operator.

The assessment of the operational phase has assumed that a number of the operational management measures as required by the South West Supply Chain (QR West Moreton System) Coal Dust Management Plan (2019), such as veneering, are applied to the Project. The mitigation measures in the Coal Dust Management Plan aim to minimise surface lift-off of materials in transit and establishes protocols to minimise spillage onto external areas of wagons to reduce emissions. Additional measures currently implemented through the South West Supply Chain include:

- Coal washing and moisture management
- Load profiling and use of 'garden bed profile'
- Monitoring of performance.

The assessment of the operational phase has determined that veneering is required to achieve compliance with the Project air quality goals for PM_{10} and $PM_{2.5}$ based on the assessed volume of coal trains. The implementation of veneering has been assumed to reduce coal dust emissions from coal laden trains by 75 per cent as discussed in Section 4.4.1.2. With veneering, the assessment of the operational phase of the Project for impacts to air quality and water tank quality has determined that compliance is predicted for all air quality and water quality goals.

Veneering is currently applied to coal trains which use the West Moreton System. Therefore, existing coal trains which currently use the West Moreton System and would use the Project will already implement veneering.

Prior to operation of the Project, engagement will be undertaken with existing stakeholders and members of the South West Supply Chain (including QR, DES, etc) with regards to coal dust management and monitoring requirements necessary to maintain the integrity of the existing South West Supply Chain Coal Dust Management Plan.

Maintenance activities with the potential to generate dust or air quality impacts will be managed under ARTCs Environmental Management System and in accordance with the measures described in EIS Chapter 23: Draft Outline Environmental Management Plan.

9.3 Proposed mitigation measures

In order to manage Project risks during construction and operation a number of mitigation measures have been recommended as presented in Table 9.2. These proposed mitigation measures have been identified to address to Project specific issues and opportunities, address legislative requirements, accepted government plans, policy and practice.

Table 9.2 identifies the relevant Project phase, the aspect to be managed, and the proposed potential mitigation measures. For several of the mitigation measures proposed, the expected control efficiency (emission reduction percentage) has been nominated. The control efficiencies reported have been obtained from the NPI Emissions Estimation Manual for Mining (NPI 2012) and Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains (Connell Hatch 2008).

For a number of emission sources there are multiple available mitigation measures. In the pre-construction and construction phases of the Project, dust sources will be variable and transitory in nature and the potential for impacts will vary with proximity to sensitive receptors. The exact method of mitigation implemented will be determined during construction phase planning and following confirmation of the availability and suitability of water supply sources.

EIS Chapter 23: Draft Outline Environmental Management Plan provides further context and the framework for implementation of these proposed mitigation and management measures.

Table 9.2 Air quality mitigation measures

Delivery phase	Aspect	Proposed mitigation measures
Detailed design	Availability of water for dust suppression and stabilisation during construction	Prior to construction, quantities of water required for dust suppression, construction, landscaping and stabilisation activities will be confirmed. The availability and suitability of water supply sources will be determined and where water supply is deemed insufficient or in high demand for other uses, other dust suppression and stabilisation methods will be implemented.
	Emissions from refuelling activities during construction	Design of fuel storage areas will ensure that fuel tanks will be located at least 50 m from the nearest sensitive receptor, with separation distances maximised as far as practical within site restrictions.
	Fugitive dust emissions (windborne erosion) during construction and operation	Project clearing extents are limited to the disturbance footprint which must be minimised to that required to safely construct, operate and maintain the Project. Laydown areas and other construction-phase facilities will be designed and arranged to minimise emissions and reduce the potential for air quality impacts to sensitive receptors. Design considerations will include the locations of stockpiles, activity areas, travel routes, rumble grids and truck washdown areas, etc. Earthworks and landscape design of railway batters and other exposed surfaces will be designed to incorporate treatments and enable stabilisation to reduce wind erosion.
	Emissions reporting requirements	Emissions reporting requirements for the construction phase will be confirmed during detailed design and respond to National Greenhouse and Energy Report (NGERS) requirements and the Sustainability Management Plan.
Pre-construction and construction	Dust generation from pre-construction activities	Vehicle travel on unsealed roads will be minimised as far as practical. Sealed roads will be used where possible, in accordance with the Construction Traffic Management Plan. Disturbed areas will be rehabilitated and stabilise as soon as practical upon completion of works.
Construction and commissioning	Dust generation from earthworks, clearing and grubbing, mobile plant activity and wind erosion of exposed areas within the construction disturbance footprint	Limit clearing to the disturbance footprint as identified during the detailed design constructability assessment and planning. Limit clearing to that required to safely construct and operate the Project. Where practical, stage clearing and grubbing and construction activities to limit the size of exposed areas. Adequate precautions to effectively minimise the generation of dust, which may affect the safety and general comfort of the travelling public, the contractor's employees and/or occupants of adjacent buildings, during the construction of the work will be undertaken. This will involve regular applications of water or other measures along the sections of the work traversed by the travelling public, as required, to minimise dust. Implement water sprays or other measures to reduce dust emissions from excavation or disturbance of soils or vegetation, or handling ballast. Implement water sprays or other measures to reduce dust emissions from trucks unloading material (anticipated emission reduction of 70 per cent). Implement water sprays or other measures to reduce dust emissions for mobile plant loading to or from material stockpiles (anticipated emission reduction of 50 per cent).

Delivery phase	Aspect	Proposed mitigation measures
		To reduce wind erosion from stockpiles, the following mitigation methods may be used subject to water availability and stockpile activity: ▪ Water sprays (anticipated emission reduction of 50 per cent); ▪ Wind breaks or earthworks profiling (anticipated emission reduction of 30 per cent); ▪ Application of rock armour/covering (anticipated emission reduction of 30 per cent); ▪ Covering of the stockpile with an impermeable covering (i.e. tarpaulin) or binding agent (anticipated emission reduction of 100 per cent). If water sprays are implemented for stockpiles, the application rate of water will be increased for stockpiles which will receive new material regularly, such as tunnel excavation stockpiles. Disturbed areas and exposed surfaces will be stabilised as a soon as practical. The following mitigation methods may be used subject to final purpose of the exposed area: ▪ Initial establishment of vegetation (anticipated emission reduction of 30 per cent); ▪ Maintained revegetation (anticipated emission reduction of 90 per cent); ▪ Establishment of self-sustaining rehabilitation vegetation (anticipated emission reduction of 100 per cent); ▪ Sealing of exposed surface (i.e. concrete, asphalt, etc) (anticipated emission reduction of 100 per cent). Long-term stockpiles will be avoided where possible. However, where necessary (e.g. topsoil), long-term stockpiles will be established in locations with suitable separation from sensitive receptors. During periods of inactivity, stockpiles will be stabilised appropriately. Establish and communicate the protocol for notifying relevant stakeholders when potentially dust generating activities are planned to be carried out, with contact details for queries or complaints.
	Emissions from combustion engines (construction vehicles and generators)	Construction plant, vehicles and machinery will be maintained and operated in accordance with manufacturer's recommendations.
	Use of non-potable water for dust suppression	Water used in dust suppression will be of suitable quality and not result in environmental or human health risks, or impact rehabilitation outcomes. Water additives used to improve dust suppression effectiveness (e.g. the addition of soil binders to water for dust suppression on roads or hard stand areas be risk assessed prior to adoption.
	Dust generated by traffic on access tracks	To reduce emissions from construction vehicle movements on unsealed roads, road watering or other appropriate measures will be applied. Water additives used to improve dust suppression effectiveness will be considered
	Fugitive dust emissions from vehicles transporting materials to and from site	Vehicles transporting potentially dust and/or spillage generating material to and from the construction site will have their loads covered immediately after loading (prior to traversing public roads). Rumble grids and the operation of truck washdown areas will be maintained to reduce trackout of material onto public roads where it may become resuspended. Site based construction traffic is limited to identified haul routes as per the Project Construction Traffic Management Plan.

Delivery phase	Aspect	Proposed mitigation measures
	Cumulative effects of dust emissions from construction and external land uses or activities	Sensitive receptors near the existing Boral Purga Quarry may be impacted by the operation of the quarry and the construction phase of the Project. The cumulative impact of both sources on sensitive receptors and the effectiveness of the proposed mitigation measures for Project construction activity near the quarry will be monitored via visual monitoring and air quality monitoring as discussed in Section 9.4.2. In the event of validated complaints or measured exceedances of the Project air quality objectives, enhanced mitigation will be implemented. Project construction activities to be undertaken near the quarry that have the highest potential to generate air emissions include excavation works and material handling for the construction of the alignment, activity within the laydown area nearest the quarry and vehicle travel on unsealed roads.
	Dust generation and deposition as a result of adverse weather conditions	Avoid ground-disturbing activities including excavation and vegetation clearing during windy conditions where practical. When avoidance of ground-disturbing activities is not practical, implement enhanced management measures, such as water application and/or implementation of temporary stabilisation treatments
Operations	Emissions from the operation of the rail corridor	Prior to commencement of operational activities, engagement will be undertaken with existing stakeholders and members of the South West Supply Chain (including QR, DES, etc) with regards to coal dust management and monitoring requirements necessary to maintain the integrity of the existing South West Supply Chain Coal Dust Management Plan. The assessment of the operational phase has assumed that a number of the operational mitigation measures as required by the South West Supply Chain Coal Dust Management Plan, such as veneering are applied to the Project. Monitor air quality during operation of the Project and report and audit monitoring results as discussed in Section 9.4.3. Monitor, record and audit complaints about dust and emissions in accordance with the relevant complaints management handling procedures.

9.4 Monitoring, reporting and auditing

This section describes how the Project will monitor, report and audit compliance with the Project air quality goals.

9.4.1 Construction phase – weather conditions monitoring

To aid in the avoidance of dust generation during adverse weather conditions, weather forecasts and observations for adverse weather (e.g. winds > 36 km/hr or 20 knots) will be observed during the construction phase of the Project using existing BoM weather stations.

To assist with auditing and the analysis of air quality monitoring and complaints (if received), periods of adverse weather periods will be recorded in monthly environmental reports.

9.4.2 Construction phase – air quality monitoring

Visual and quantitative air quality monitoring will be undertaken for the construction phase of the Project.

Visual monitoring of dust generation (visible plumes) will be undertaken throughout construction. Daily on-site inspections of dust generation will be undertaken by construction staff to monitor dust being generated on-site to inform mitigation measures. In addition, weekly off-site inspection will be undertaken at sensitive receptors located near high intensity construction areas such as heavily trafficked haul roads, excavation areas and laydown areas. Visual monitoring should include checks of dust deposition on horizontal surfaces such as cars and window sills.

Quantitative air quality monitoring will be undertaken via monitoring of dust deposition. Dust deposition monitoring will be undertaken at sensitive receptor locations near the Boral Purga Quarry, which have the potential to be impacted by emissions from the construction phase of the Project and emissions from the operation of the quarry.

Selection of the exact locations for the installation of dust deposition gauges will be undertaken by a suitably qualified air quality professional. The monitoring locations will be demarcated and sign posted.

In the event that dust deposition monitoring determines exceedance of the Projects air quality goal (120 $mg/m^2/day$) at sensitive receptors, additional monitoring, including monitoring of airborne particulate concentrations (e.g. TSP or PM_{10}), may be required. If legitimate air quality complaints are received from locations which are not represented by the location of air monitoring stations, additional monitoring stations may be deployed.

Air quality monitoring data and logs of visual monitoring inspections will be included in the monthly environmental monitoring reports prepared by the construction contractor.

9.4.3 Operational phase – air quality monitoring

Quantitative air quality monitoring will be undertaken during the operation phase at a location along the alignment of the Inland Rail Program. Requirements for the air quality monitoring station will be discussed with the stakeholders of the South West Supply Chain, including DES and DTMR. It is expected that the air quality monitoring station employed will be equivalent in nature to the existing monitoring stations operating as part of the South West Supply Chain Coal Dust Management Plan, and it is expected that the pollutant species monitored will include dust deposition and airborne concentrations of PM_{10} and TSP.

Air quality monitoring data will be reported. The frequency of reporting will be discussed and agreed upon with the stakeholders of the South West Supply Chain, but will be at least annually.

The duration of operation for the air quality monitoring station, the responsibility for the maintenance and ongoing operation of the monitoring station and the responsibility for the reporting of the monitoring station data will be discussed and agreed upon with stakeholders of the South West Supply Chain.

If a complaint related to air quality is received, additional monitoring may occur to investigate the complaint. Further actions and response will be undertaken following monitoring.

Requirements for operational phase monitoring will be included in an Operational Environmental Management Plan which will be developed in future stages of the Inland Rail Program.

9.4.4 Operational phase – emissions reporting

Emissions reporting is to be undertaken where applicable. Emissions reporting requirements will be determined during the detail design phase to be consistent with Infrastructure Sustainability Council of Australia (ISCA) and NGERS requirements.

10 Residual impact assessment

10.1 Construction

Potential air quality impacts to sensitive receptors and the environmental values of human health and the aesthetic environment as a result of the construction phase of the Project have been assessed in accordance with the qualitative impact assessment methodology described in Section 4.1. Assessment of the residual impact of the construction phase of the Project following the implementation of the recommended mitigation measures (refer Section 9.3) is presented in this section.

The assessment of residual impacts to sensitive receptors during the construction of the Project is presented in Table 10.1. The methodology for the residual impact assessment is summarised as follows:

- The receptor sensitivity, initial emission magnitude and initial significance for each construction activity category (demolition, earthworks, construction and trackout) presented in Table 10.1 is the assessed risk of impacts without mitigation as presented Section 6.1 and summarised in Table 6.6
- The residual emission magnitude has been determined qualitatively based on the anticipated reduction to construction dust emissions considering the available mitigation measures and the nominated control efficiencies presented in Table 9.2
- The residual significance (residual impact) has been determined using the IAQM risk matrix for each construction activity (refer Table 6.5) considering the residual emission magnitudes assigned for each activity and receptor sensitivity.

Table 10.1 shows that following the IAQM risk matrix, the residual significance with the proposed mitigation measures is low or negligible.

The IAQM construction dust assessment guidance states:

> *For almost all construction activity, the aim should be to prevent significant effects on sensitive receptors through the use of suitable and effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be "not significant".*

Consistent with the IAQM statement, it is expected that with implementation of the proposed mitigation measures the impacts to air quality with respect to dust deposition and human health will not be significant.

10.2 Operation

A quantitative (compliance) assessment has been undertaken for potential operational impacts, as predicted concentrations at sensitive receptors have been assessed against legislative and other nominated air quality and water quality goals.

The assessment of the operational phase of the Project for residual impacts to air quality and water tank quality (refer Section 7) has determined that compliance is predicted for all air quality goals and water quality goals with the inclusion of veneering based on the volume of coal trains assessed.

Therefore, with the inclusion of veneering the operation of the Project is expected to comply with the adopted air quality goals and is not expected to significantly adversely impact environmental values, including human health and the aesthetic environment.

Table 10.1 Initial and residual significance assessment for potential air quality impacts associated with construction

Activity	Aspect[a]	Potential impact	Receptor sensitivity	Initial significance[b]		Residual significance[c]	
				Emission magnitude	Significance	Emission magnitude	Significance
Demolition	All dust generating sources associated with demolition	Dust deposition	Medium	Small	Low	Small	Low
		Human health	Low	Small	Negligible	Small	Negligible
Earthworks associated with pre-construction and construction phase	All dust generating sources associated with pre-construction and construction phase earthworks	Dust deposition	Medium	Large	Medium	Small	Low
		Human health	Low	Large	Low	Small	Negligible
Construction	All dust generating sources associated with construction phase for the Project	Dust deposition	Medium	Large	Medium	Small	Low
		Human health	Low	Large	Low	Small	Negligible
Trackout associated with pre-construction and construction phase.	All dust generating sources associated with pre-construction and construction phase traffic associated with the Project	Dust deposition	Medium	Large	Medium	Medium	Low
		Human health	Low	Large	Low	Medium	Low

Table notes:

a Refer to Table 9.2 for reference to the proposed additional mitigation measures relevant to each aspect

b Assumes the inclusion of the initial mitigations specified in Table 9.1.

c Assessment of residual risk once the additional mitigation measures identified in Table 9.2 have been applied.

11 Conclusions

An air quality impact assessment has been conducted to determine the potential impacts of the Project on air quality. The air quality impact assessment was undertaken to satisfy the ToR for the EIS.

The air quality impact assessment consisted of the following tasks:

- Identification of peak and typical operational train movements for the year 2040
- Analysis of the expected construction and operational activities which may impact air quality
- Identification of the relevant environmental values for the air environment and establish air quality goals to protect or enhance the identified environmental values
- Discussion of existing air quality and local meteorology
- Identification of potential sources of air emissions due to the Project
- Identification of nearby sensitive receptors
- A qualitative risk assessment of air emissions resulting from the construction phase
- A quantitative dispersion modelling assessment of operational emissions associated with freight rail movements, including prediction of pollutant concentrations in rainwater water tanks
- Identification of mitigation and management measures to minimise potential air quality impacts
- Discussion of the monitoring, reporting and auditing practices which will be implemented for the Project
- Assessment of the residual impact with the implementation of the recommended mitigation measures.

A qualitative construction dust risk assessment was undertaken using the UK IAQM document, Guidance on the assessment of dust from demolition and construction. The risk of dust deposition and human health impacts due to particulate matter (PM_{10}) on surrounding areas were determined based on the scale of activities and proximity to sensitive receptors. The outcome of the assessment showed that that the residual significance with the proposed mitigation measures is expected to be low or negligible. Consistent with the IAQM statement, it is expected that with effective implementation of the proposed mitigation measures the impacts to air quality with respect to dust deposition and human health will not be significant.

A quantitative dispersion modelling assessment was undertaken for the operational phase using the dispersion models CALPUFF and GRAL. Twelve months of meteorological input data representative for the study area was developed for use in CALPUFF. Diesel exhaust emissions from locomotives and fugitive emissions from coal trains were estimated for projected peak and typical train volumes for the Project in 2040. Ground level concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$), NO_2, VOCs, and heavy metals were predicted using CALPUFF and GRAL at nearby sensitive receptors.

The results showed that compliance is predicted for all pollutant species for both the typical and peak traffic volume scenarios with the inclusion of veneering to coal trains.

An investigation into the deposition of dust emissions at sensitive receptor locations showed that predicted pollutant water concentrations would be significantly lower than Australian Drinking Water Guidelines.

The air quality impact assessment undertaken for the Project showed that with appropriate mitigation in place, the construction and operation of the Project can be managed in a way that air quality impacts to nearby sensitive receptors are maintained at an acceptable level where the nominated environmental values of the air environment are protected or enhanced. A CEMP will be required for the construction of the Project to manage potential impacts from dust emissions.

12 References

ABARES (2016). The Australian Land Use and Management Classification Version 8. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

ABMARC (2016). Diesel Locomotive Fuel Efficiency & Emissions Testing.

AECOM (2017). Yelarbon to Gowrie Preliminary Environmental Assessment Report. Brisbane: AECOM.

Allwine, K., & Whiteman, C. (1985). MELSAR: A mesoscale air quality model for complex terrain. Volume 1. Overview, technical description and user's guide. doi:10.2172/5899806

Australian Rail Track Corporation (2017). Inland Rail Sustainability Implementation Framework.

Australian Rail Track Corporation (2018). Inland Rail Environment and Sustainability Policy.

Barclay, J., & Scire, J. (2011). Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessment in New South Wales. Sydney: Office of Environment and Heritage NSW (OEH NSW).

BCC. (2014). Air quality planning scheme policy. Brisbane City Council.

CARB. (2004). Roseville Rail Yard Study. State of California. California Environmental Protection Agency, Air Resources Board.

Casadei, S., & Maggioni, A. (2016). Performance testing of a locomotive engine aftertreatment pre-prototype in a passenger cars chassis dynometer laboratory. Transportation Research Procedia, 605 - 614. doi:10.1016/j.trpro.2016.05.305

Connell Hatch (2008). Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems. report prepared for Queensland Rail Limited. Brisbane: Connell Hatch.

Croft, B., Lohmann, U., Martin, R., Stier, P., Wurzler, S., & Feichter, J. (2009). Aerosol size-dependent below-cloud scavenging by rain and snow in the ECHAM5-HAM. Atmospheric Chemistry and Physics, 9, 4653-4675.

CSIRO (2008). The Air Pollution Model (TAPM) [software]. Version 4.04. Aspendale: CSIRO. Retrieved from http://www.cmar.csiro.au/research/tapm/

Department of Environment and Energy (2000). Fuel Quality Standards Act 2000. Australian Government.

Department of Environment and Energy (2001). Fuel Standard (Automotive Diesel) Determination 2001. Australian Government .

Department of Environment and Science. (2018). Queensland air monitoring 2017. Air Quality Monitoring, Queensland Government.

Department of Environment and Science. (2019a). Air Quality Monitoring Data. Queensland Government. Retrieved from https://data.qld.gov.au/dataset.

Department of Environment and Science. (2019b). Application requirements for activities with impacts to air. Queensland Government.

Department of Environment, Water, Heritage and the Arts. (2008). National Pollution Inventory: Emission estimation technique manual for railway yard operations (Version 2.0). Canberra: Commonwealth of Australia (DEWHA).

Department of Science, Information Technology, Innovation and the Arts (2012). Queensland air monitoring report 2011. Air Quality Sciences, Science Delivery Division, Queensland Government.

Department of Science, Information Technology, Innovation and the Arts (2013). Queensland air monitoring report 2012. Air Quality Monitoring, Science Delivery Division, Queensland Government.

Department of Science, Information Technology, Innovation and the Arts (2016). Queensland air monitoring 2015. Air Quality Monitoring, Science Delivery Division, Queensland Government.

Department of Transport and Main Roads. (2009). Road traffic air quality management manual: a guide to the air quality aspects of the planning, design, operation and maintenance of road infrastructure. Queensland Government.

Douglas, S., & Kessler, R. (1988). User Guide to the Diagnostic Wind Field Model, Version 1.0. San Rafael, CA: System Applications Inc.

enHealth. (2010). Guidance on use of rainwater tanks. Commonwealth of Australia.

Environment Protection Authority. (2007). Publication 1191. EPA Victorian Government.

Environment Protection Authority. (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. News South Wales Government.

European Environment Agency (2016a). EMEP/EEA air pollutant emission inventory guidebook 2016: 1.A.3.c Railways 2016. European Environment Agency. Luxembourg: Publications Office of the European Union.

European Environment Agency (2016b). EMEP/EEA air pollutant emission inventory guidebook 2016: 1.A.3.b.iii Heavy-duty vehicles including buses. European Environment Agency. Luxembourg: Publications Office of the European Union.

Gunawardena, J. M. (2012). Relating vehicle generated pollutants to urban stormwater quality. Doctoral Dissertation, Queensland University of Technology, Science and Engineering Faculty, Brisbane.

Ireson, R., Germer, M., & Schmid, L. (2005). Development of detailed railyard emissions to capture activity, technology, and operational changes. U.S. EPA 14th Annual International Emission Inventory Conference, April 11-14. Las Vegas, NV.

Kim, Y.-K., Lee, J.-Y., Rhee, Y., & Chun, Y.-Y. (2017). Country-specific greenhouse gas emission factors of diesel-electric locomotive in Korea. Transportation Research Part D: Transport and Environment, 57, 74 - 83. doi:10.1016/j.trd.2017.09.009

Lakes Environmental (2017). CALPUFF View User Manual. Lakes Environmental.

Liu, M.-K., & Yocke, M. A. (1980). Siting of wind turbine generators in complex terrain. Journal of Energy, 4(1), 10-16. doi:10.2514/3.62455

Lucas, S. C. (2009). Rainfall harvesting and coal dust: the potential health impacts of trace elements in coal dust rainwater. air Quality and Climate Change, 43(2), 23-30.

Mahrt, L. (1982). Momentum balance of gravity flows. Journal of the Atmospheric Sciences, 39(12), 2701-2711. doi:10.1175/1520-0469

National Pollutant Inventory (2008). Emission estimation technique manual for Railway Yard Operations. Department of the Environment, Water, Heritage and the Arts, Australian Government. National Pollutant Inventory.

National Pollutant Inventory (2012). Emission estimation technique manual for mining. Department of the Environment, Water, Heritage and the Arts, Australian Government. National Pollutant Inventory.

National Resource Management Ministerial Council & National Health and Medical Research Council. (2018). Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. Commonwealth of Australia.

NEPM. (2001). Data Collection and Handling. Technical Paper No. 5, National Environment Protection (Ambient Air Quality) Measure.

O'Brien, J. (1970). Alternative solutions to the classical vertical velocity problem. Journal of Applied Meteorology, 9(2), 197-203.

Oettl, D., Goulart, A., Degrazia, G., & Anfossi, D. (2005). A new hypothesis on meandering atmospheric flows in low wind speed conditions. Atmos. Environ., 39, 1739-1749.

Oettl, D., P.J. Sturm, and R. A. Almbauer (2004): Evaluation of GRAL for the pollutant dispersion from a city street tunnel portal at depressed level. Environmental Modeling & Software, 20, 499 – 504.

Oettl, D., Sturm, P., Bacher, M., Pretterhofer, G., & Almbauer, R. (2002). A simple model for the dispersion of pollutants from a road tunnel portal. Atmos. Environ., 36, 2943-2953.

Oettl, D., Sturm, P., Pretterhofer, G., Bacher, M., Rodler, J., & Almbauer, R. (2003). Langrangian dispersion modelling of vehicular emissions from a highway in complex terrain. J. of the Air and Waste Management Association, 53, 1233-1240.

Office of Environment and Heritage (2015). Air quality statement NSW 2014. New South Wales Government.

Office of Environment and Heritage (2016). Air quality statement NSW 2015. New South Wales Government.

Office of Environment and Heritage (2017). NSW Air Quality Statement 2016. New South Wales Government.

Office of Environment and Heritage. (2018). New South Wales Air Quality Statement 2017. New South Wales Government.

QR National. (2010). Coal Dust Management Plan. Brisbane: QR National.

Richter, J. (2019). Miners hang up their hard hats as Jeebropilly Mine closes. Ipswich First. Retrieved August 25, 2020, from https://www.ipswichfirst.com.au/miners-hang-up-their-hard-hats-as-jeebropilly-mine-closes/#:~:text=The%20official%20closing%20ceremony%20took,fields'%2C%20it%20was%20done

Scire, J. S., Robe, F. R., Fernau, M. E., & Yamartino, R. J. (2000). A User's Guide for CALMET Meteorological Model.

Spiryagin, M., Wolfs, P., Cole, C., Spiryagin, V., Sun, Y. Q., & McSweeny, T. (2016). Locomotive Power Systems Modelling. In Design and Simulation of Heavy Haul Locomotives and Trains (pp. 367 - 395). CRC Press.

Spiryagin, M., Wolfs, P., Szanto, F., & Cole, C. (2015). Simplified and advanced modelling of traction control system of heavy haul locomotives. Vehicle System Dynamics, 53(3), 672 - 691.

StarCrest Consulting Group (2008). Port of Long Beach Air Emissions Inventory - 2006. The Port of Long Beach. Retrieved November 22, 2018, from http://www.polb.com/environment/air/emissions.asp

ThermaDynamics Rail LLC (2014). Diesel-Electric Locomotive Energy Recovery and Conversion - Final Report.

Todd, J. J. (2015). Estimating mortality and morbidity impacts of residential wood smoke in Tasmania. Melbourne: Clean Air Society Australia & New Zealand.

Todd, J. J., Innis, J., & Cunningham, A. (2015). Working towards an estimate of particle pollution exposure in Tasmania with focus on residential wood smoke. Melbourne: Clean Air Society Australia & New Zealand.

Todoroski Air Sciences (2017a). Review of Namoi Ambient Air Quality Data Autumn 2017. NSW EPA.

Todoroski Air Sciences (2017b). Review of Namoi Ambient Air Quality Data Summer 2016/2017. NSW EPA.

Todoroski Air Sciences (2017c). Review of Namoi Ambient Air Quality July 2015 to December 2016. NSW EPA.

Turner, D. B. (1970). Workbook of atmospheric dispersion estimates. US EPA, Office of Air.

UK IAQM. (2014). Guidance on the assessment of dust from demolition and construction. United Kingdom Institute of Air Quality Management.

US Environmental Protection Agency (1992). User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. US Environment Protection Agency.

US Environmental Protection Agency (1998). Compilation of Air Pollutant Emission Factors. Office of Air and Radiation, Office of Air Quality Planning and Standards, United States Environment Protection Agency, Research Triangle Park, North Carolina, 27711.

US Environmental Protection Agency (1998). Compilation of Air Pollutant Emission Factors. Office of Air and Radiation, Office of Air Quality Planning and Standards, United States Environment Protection Agency, Research Triangle Park, North Carolina, 27711.

US Environmental Protection Agency (2009). Technical Highlights: Emission Factors for Locomotives. United States Environment Protection Agency, Office of Transportation and Air Quality. US EPA.

US Environmental Protection Agency (2012). Memorandum: Haul Road Workgroup Final Report Submission to EPA-OAQPS. US EPA.