Chapter 10
Human health

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10 Human health

This chapter summarises the human health assessment carried out for the upgrade of the Great Western Highway between Blackheath and Little Hartley (the project). The full human health assessment is provided in Appendix F (Technical report – Human health).

10.1 Assessment approach

The methodology for the human health impact assessment is shown in Figure 10-1 and involved:

- review of other technical assessments prepared to support this environmental impact statement (EIS) including Appendix D (Technical report – Transport and traffic), Appendix E (Technical report – Air quality), Appendix G (Technical report – Noise and vibration), Appendix I (Technical report – Groundwater), Appendix J (Technical report – Surface water and flooding), Appendix K (Technical report – Contamination), Appendix O (Technical report – Social), Appendix P (Technical report – Economics and business) and Chapter 22 (Hazards and risk)
- identification of sensitive receivers within potentially impacted communities surrounding the project
- establishment of the baseline community health for the population relevant to the project
- assessment of the potential benefits and impacts to community health during construction and operation of the project
- identification of appropriate mitigation measures to manage potential impacts.

The human health assessment has focused on health-related impacts associated with the potential impacts of other studies shown in Figure 10-1. The assessment has not addressed occupational exposures during construction or operation of the project. Occupational health and safety aspects of the project would be managed separately under current occupational health and safety regulations and guidelines in accordance with the *Work Health and Safety Act 2011* and Work Health and Safety Regulations 2011 as enforced by SafeWork NSW.

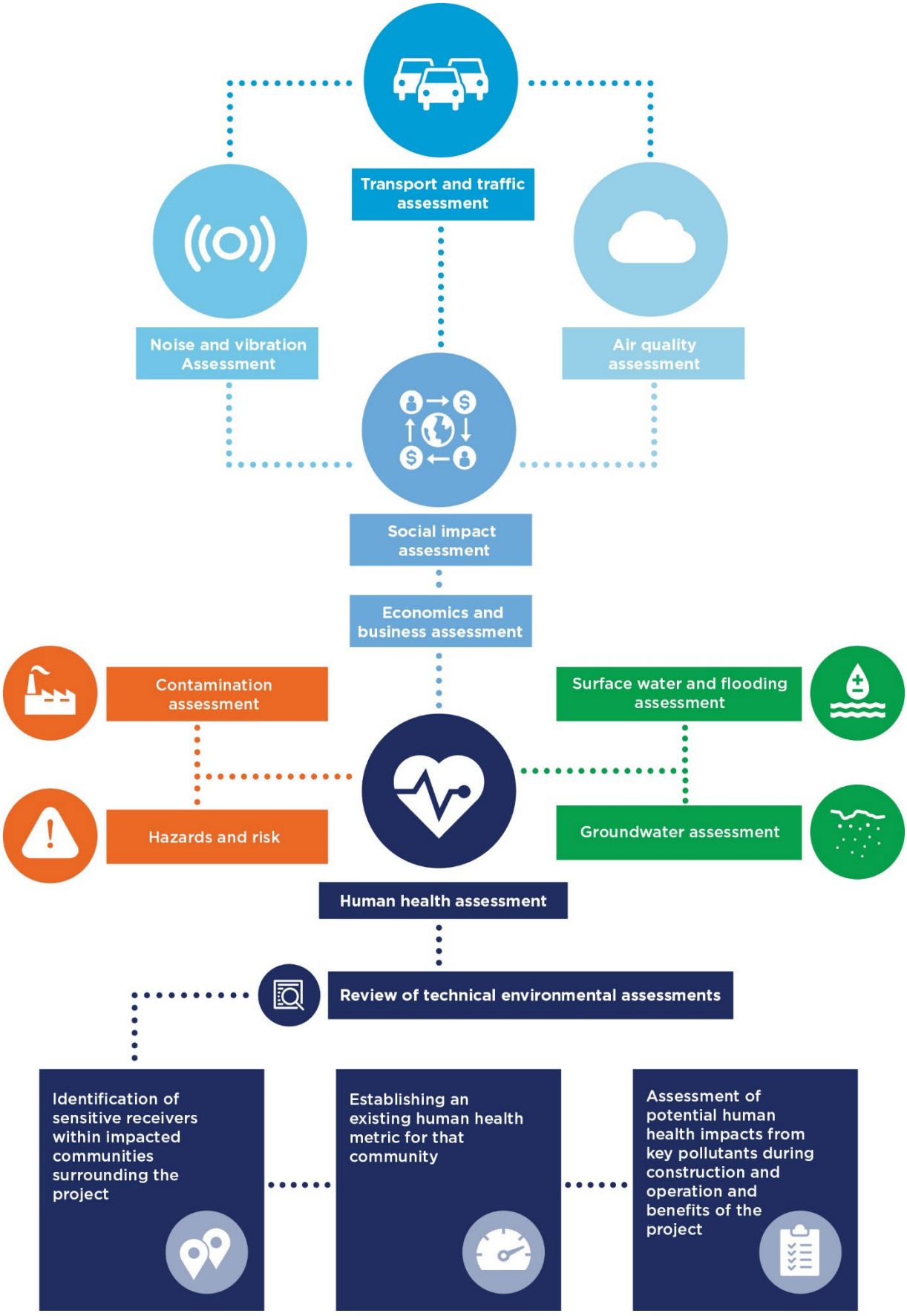


Figure 10-1 Assessment approach for the human health impact assessment

10.1.1 Assessment approach – air quality

Construction

The assessment of construction air quality health impacts was carried out using a qualitative assessment approach for dust, emissions, and odour impacts (refer to Section 9.3.1).

Operation (ambient air quality)

The assessment of operational air quality impacts considered a range of scenarios that includes the operation of the project in 2030 (year of opening) and 2040 (ten years after opening) both with the project and without the project. For further details on the scenarios considered, refer to Chapter 9 (Air quality).

The assessment considered emissions from:

- a typical daily traffic profile reflecting expected annual hourly traffic numbers using the tunnel
- a maximum daily traffic profile reflecting traffic conditions only expected to occur for a small number of days per year
- a regulatory worst case scenario, reflecting the tunnel full of vehicles such that the emissions from the ventilation outlets or portal emissions are at the maximum level. This is not a realistic scenario, however it is used to demonstrate compliance with regulatory assessment requirements.

Potential health-related air quality impacts outside the tunnel have been assessed for nitrogen dioxide (NO_2), particulate matter (PM), carbon monoxide and air toxins (including benzene, toluene, xylenes, 1,3-butadiene, formaldehyde and polycyclic aromatic hydrocarbons). Further information on these compounds including their potential health related impacts and relevant toxicity and health guidelines is provided in Section 5.5 of Appendix F (Technical report – Human health).

The tunnel and ventilation system have been designed to control the concentration of pollutants discharged to the external environment regardless of whether the ventilation outlet or portal emissions option is selected as the preferred design option.

Operation (in-tunnel air quality)

Health related in-tunnel air quality impacts during operation have been assessed for NO_2, carbon monoxide and PM. This includes cumulative exposures to NO_2, carbon monoxide and PM for frequent users of the tunnels.

The tunnel ventilation system, regardless of whether designed for portal emissions or ventilation outlet emissions, has been designed to meet operational in-tunnel air quality standards (refer to Section 9.2.2).

10.1.2 Assessment approach – noise and vibration

Potential noise related health impacts have been assessed against NSW criteria that have been established on the basis of the relationship between noise and health impacts.

Noise guidelines and criteria are generally established based on noise annoyance, which is a more sensitive impact that precedes physiological impacts. As a result, these guidelines are designed to be protective of all adverse health impacts (refer to Section 7.3.1 of Appendix F (Technical report – Human health). Specific health impacts such as sleep disturbance are based on other guidelines for the assessment of night-time noise.

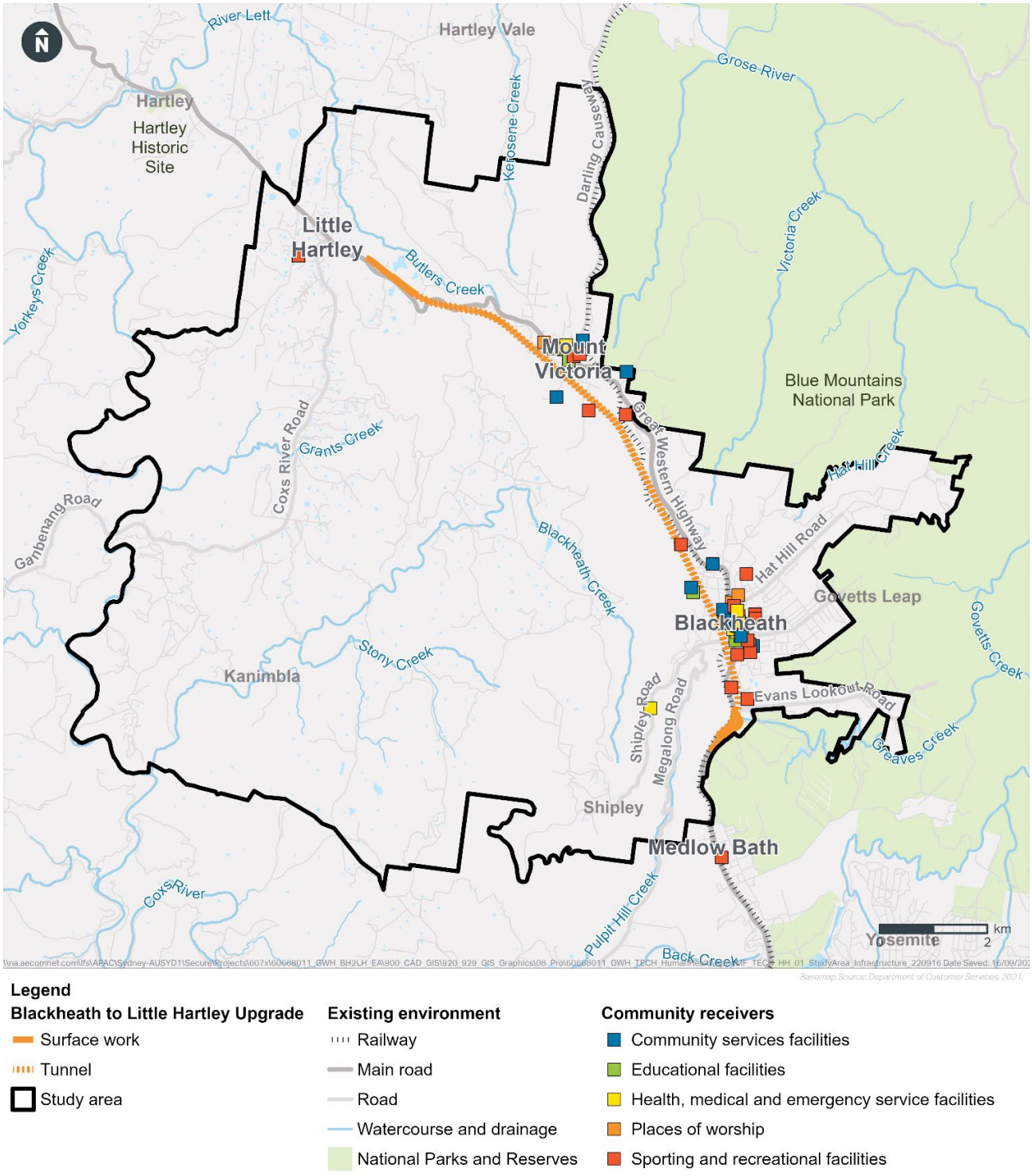
Where the guidelines cannot be met then there is the potential for adverse health impacts to occur in the community adjacent to the project.

10.1.3 Assessment approach – social

The assessment of potential human health impacts associated with social impacts considers changes in traffic, access and connectivity, public safety and contamination, property acquisitions, visual amenity, impacts on green space, equity issues, economic impacts, construction fatigue, and both the long and short-term impacts of stress and anxiety arising from construction and operation of the project. These aspects have been considered qualitatively.

10.2 Study area

The study area is shown in Figure 10-2 and identifies the area over which sensitive receivers have the potential to experience human health impacts.



Legend

Blackheath to Little Hartley Upgrade
- Surface work
- Tunnel
- Study area

Existing environment
- Railway
- Main road
- Road
- Watercourse and drainage
- National Parks and Reserves

Community receivers
- Community services facilities
- Educational facilities
- Health, medical and emergency service facilities
- Places of worship
- Sporting and recreational facilities

Figure 10-2 Human health impact assessment study area and key sensitive receivers

10.3 Incorporation of health issues into the project design

The project has sought to minimise impacts on the community, including health and wellbeing, through:

- an optimised construction methodology which has reduced the construction footprint and number of construction sites, limiting exposure to contaminated land and friable asbestos at the old Blackheath tip site, reducing amenity impacts for residents near Browntown Oval and the old Blackheath tip site reducing noise impacts and construction traffic impacts through Blackheath, and avoiding impacts to social infrastructure at Browntown Oval
- excavating from Little Hartley in an eastbound direction thereby reducing the spoil haulage through Blackheath and Mount Victoria including associated safety and amenity impacts, as spoil would primarily be hauled westbound from the Little Hartley construction footprint
- physical separation of tunnel portals, reducing localised air quality impacts if portal emissions is identified as the preferred option.

Further detail on design refinements for impact minimisation is discussed in Chapter 3 (Project alternatives and options).

10.4 Existing environment

This section outlines the existing environment as it relates to human health including:

- the current health status of the communities surrounding the project
- sensitive and potentially impacted receivers within these communities.

The existing air quality, noise and vibration, and social environment is described in the following chapters:

- Chapter 9 (Air quality)
- Chapter 11 (Noise and vibration)
- Chapter 19 (Social impacts).

10.4.1 Health status of the community

Community health is influenced by a range of factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care.

The community relevant to the project is located within the Nepean Blue Mountains local health district. A summary of the health status of the community is provided in Figure 10-3.

Further information on the health-related behaviours and health indicators for the study area is provided in Section 4.5 of Appendix F (Technical paper – Human health).

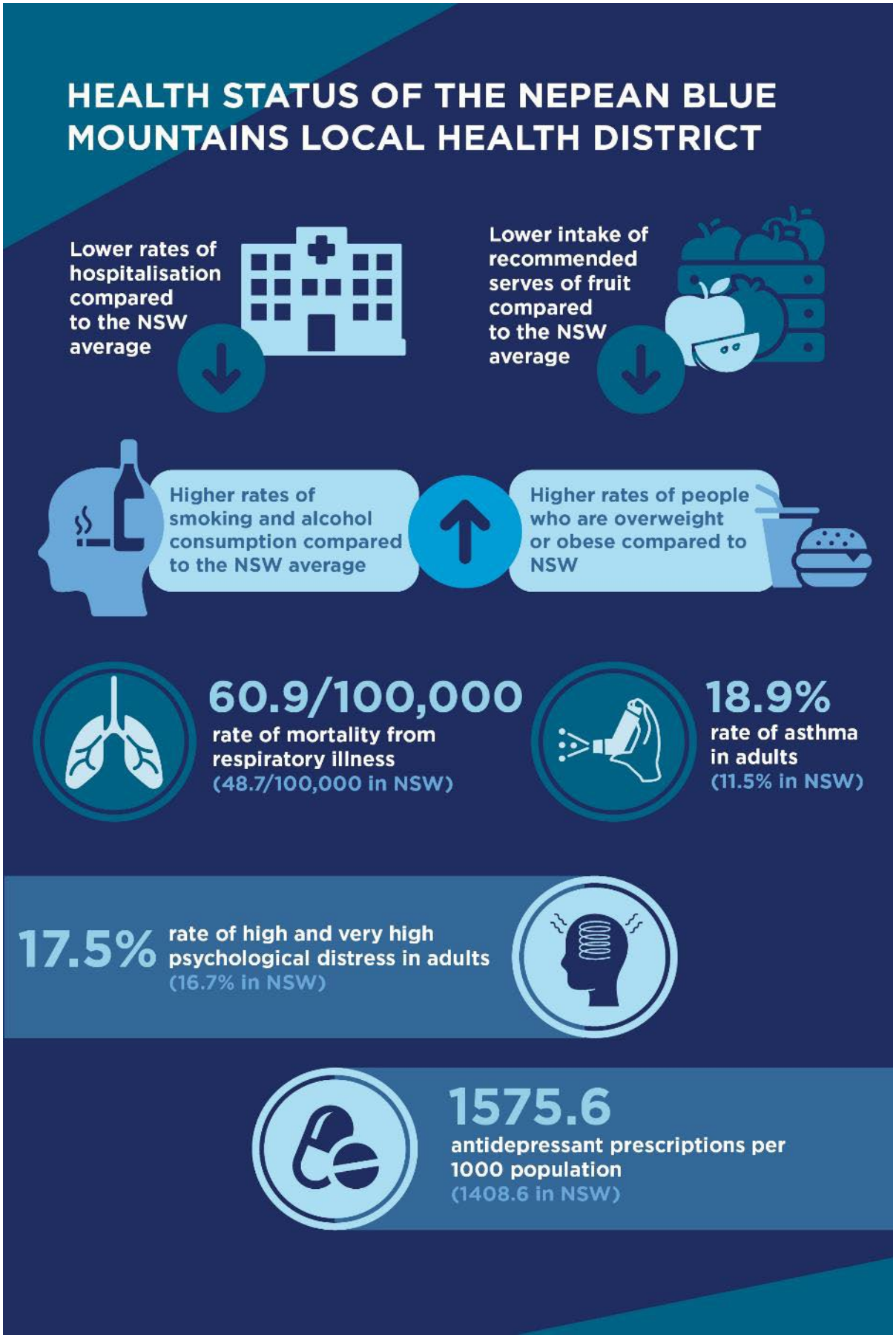


Figure 10-3 Health status of the Nepean Blue Mountains local health district (Australian Bureau of Statistics Census, 2021)

10.4.2 Sensitive receivers and potentially impacted communities

The potentially impacted communities considered in the assessment include those who live or work within the vicinity of the tunnel operations facility, water treatment plant, landscaping, surface road structures, portals, ventilation outlets (if this ventilation design option is selected), and other operational infrastructure associated with the project.

This includes community receivers including hospitals, child-care facilities, schools and aged care facilities, and sensitive receivers such as residential, workplace and recreational receivers. The assessment of noise impacts also identified places of worship and community areas as a sensitive receiver.

Key receivers identified in the study area are listed in Table 4-1 of Appendix F (Technical report – Human health).

10.5 Potential impacts – construction

10.5.1 Health related air quality impacts

Dust can directly affect health including eyes and respiratory systems. The deposition of dust can also increase levels of stress and anxiety as the community perceives the presence of substantial visible amounts of dust as potentially affecting their health. Furthermore, some odours are noxious and can make the community feel unwell.

The assessment of potential air quality impacts during construction presented in Chapter 9 (Air Quality) determined that unmitigated dust impacts pose a low risk to community health. Odours are also not expected to be of significance during construction works. Dust and odour mitigation is proposed during construction. Implementation of these measures would minimise dust related impacts and the potential for associated health impacts such as stress and anxiety. Health related air quality impacts during construction are further discussed in Section 5.4 of Appendix F (Technical report – Human health).

10.5.2 Health related noise and vibration impacts

The distribution of potential construction noise impacts on residential buildings is discussed in Section 7.4.1 of Appendix F (Technical report – Human health).

Movement of construction vehicles

Increases in road traffic noise of greater than two decibels (dBA) (the criterion adopted in accordance with the NSW Road Noise Policy (DECCW, 2011)) have been identified for the Great Western Highway to the west of the Little Hartley construction footprint for the night-time peak construction traffic volume scenario. Daytime construction traffic movements are predicted to increase noise levels by up to 1.7 dBA during peak construction works. The peak construction traffic volumes are a worst-case scenario indicative of peak activities occurring at the same time which is highly unlikely. In the unlikely event that peak construction activities occur at the same time, it is anticipated that it would be for a short duration. Construction footprints have been designed such that heavy vehicles would travel via existing major roadways with use of local roads limited to light vehicles using Evans Lookout Road. The tunnelling methodology for the project whereby spoil is removed westbound from Little Hartley would also minimise the number of heavy vehicles travelling eastbound through Mount Victoria and Blackheath. As these peak noise exceedances are unlikely to occur, the potential for health impacts from individual road noise events, such as sleep disturbance, are low to moderate. Health impacts from construction vehicle noise are further discussed in Section 7.6.2 of Appendix F (Technical report – Human health).

Air-borne construction noise

Chapter 11 (Noise and vibration) identifies residential receivers that are predicted to experience exceedances in noise levels above noise management levels, in the absence of mitigation measures. In some instances, maximum noise levels prior to mitigation are also predicted to exceed the sleep disturbance screening level and awakening reaction levels at a number of receivers.

Where criteria cannot be met with the application of reasonable and feasible mitigation measures, there is the potential for adverse health impacts such as sleep disturbance and annoyance to occur for the receivers in the vicinity of construction footprints, or where noise increases of greater than five dBA occur in the long-term (over a year or more).

Exceedances of the noise management level and the number of impacted residential receivers would vary over the duration of construction. For example, the predicted air-borne noise levels are only likely to occur when works are at the closest point to each receiver building. However, for many work areas, construction activities are mobile and would move around the construction sites, so construction noise impacts may be lower than predicted. Mitigation measures to manage potential noise impacts are identified in Chapter 11 (Noise and vibration) would be implemented to minimise potential health-related impacts related to noise on the surrounding community. This includes noise management approaches for works that would occur outside of standard construction hours.

Mitigation measures would be detailed in a Construction Noise and Vibration Management Plan (CNVMP) which would detail a range of mitigation measures that would result in noise reductions up to 15 decibels (refer to Section 7.6 of Appendix G (Technical paper – Noise and vibration). Monitoring would also be carried out periodically throughout all stages of construction to check that noise and vibration impacts are being appropriately managed, and to review the effectiveness of implemented mitigation and management measures. Where mitigation measures are implemented, the potential for health impacts such as sleep disturbance or annoyance from air-borne construction noise would be low to moderate. Health impacts from air-borne construction noise are further discussed in Section 7.6.2 of Appendix F (Technical report – Human health).

Ground-borne construction noise

Ground-borne noise would occur as a result of tunnel boring machine (TBM) and roadheader tunnelling at a discrete number of locations within the tunnel including at cross passages. A number of receptors are predicted to experience exceedances in ground-borne noise levels. All but one of these receptors (located near the Little Hartley construction footprint) would be located at Blackheath. These exceedances are due to the tunnel becoming shallower closer to the portals.

Tunnelling is proposed to progress at a rate of around 70 to 90 metres per week. It is likely that ground-borne noise would be discernible for up to five days at each affected receiver with the exceedance occurring for up to around two days. Tunnelling advance rates would reduce around the portals, which may increase the duration of exposure for receivers in these areas. As tunnelling moves towards and away from each receiver the noise levels experienced would increase and decrease respectively. All reasonable and feasible mitigation measures would be implemented to manage noise impacts and to minimise potential health impacts where the recommended noise management levels cannot be achieved. The potential for health impacts such as sleep disturbance and annoyance from ground-borne construction noise would be low to moderate. Health impacts from ground-borne construction noise are further discussed in Section 7.6.2 of Appendix F (Technical report – Human health).

Construction vibration

Some items of equipment to be used during construction have the potential to cause vibration that results in human discomfort and/or damage to structures. Managing the potential for such vibration to cause discomfort, annoyance or structural damage at sensitive receiver locations is based on selecting site-specific suitable plant and methods as well as providing suitable separation distances between the equipment and receiver locations.

The management of human comfort related vibration impacts involves monitoring of the predicted impacts, advising the community of impacts and offering respite periods to affected residents where human comfort levels are to be exceeded for an extended period of time during any one day. Health impacts from construction vibration are discussed in Section 7.4.2 of Appendix F (Technical report – Human health).

10.5.3 Health related social impacts

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectively during construction are presented in Chapter 8 (Transport and traffic). During construction, the following changes to the transport network may disrupt people's ability to get around their local area:

- there would be a need for temporary modifications to the existing road network to maintain the functionality of surrounding roads and to protect the safety of all road users, including pedestrians, cyclists, motorists, public transport users and construction personnel. Temporary traffic modifications would be staged so as to not impact traffic movements unnecessarily and to maintain a minimum of one lane in each direction of traffic movement
- additional construction traffic using the Great Western Highway where construction haul routes and construction site access points are proposed. Use of the Great Western Highway would minimise the presence of heavy vehicles on local roads.

Social infrastructure including schools, childcare, health care facilities and recreation areas are mainly located within town centres. Access to these facilities is unlikely to be substantially disrupted as the construction footprint avoids these areas, including Browntown Oval which is adjacent to the Soldiers Pinch construction site and may be impacted by movement of heavy construction vehicles, worker parking and equipment storage. Works would be designed to manage these impacts. Potential health impacts associated with changes in access and connectivity, such as stress and anxiety, are therefore considered negligible.

Construction works have been focused in areas away from the major town centres to minimise interaction between heavy vehicles and pedestrians or cyclists. While there are limited formal pedestrian or cycling paths in the areas further from the town centres where the works would occur, the adjacent projects to upgrade the Great Western Highway would include active transport trails around Blackheath and Little Hartley. Changes to existing road shoulders where people walk or ride would be temporary and their implementation and management would be included in the Construction Transport and Access Management Plan. Potential impacts to the health benefits provided by pedestrian and cycle access, including improved mental health status and maintaining a healthy weight, would therefore be low. Health related impacts from changes in traffic, public transport, access and connectivity are further discussed in Section 9.2 of Appendix F (Technical report – Human health).

Public safety and contamination

Potential hazards during construction are discussed in Chapter 22 (Hazards and risk) and include bushfires, rock falls and the use of dangerous goods. None of the hazards that have been identified during construction have the potential to result in material safety risks to the community.

Known and potentially contaminated sites and potential contamination impacts are discussed in Chapter 15 (Soils and contamination). Contamination risk issues to the community would be associated with the construction phase of the project, when there is a risk of disturbing existing contaminated soil or groundwater during construction activities. In addition, there is a risk of disturbing existing contaminated soil or groundwater sources during construction activities, which could result in exposure of construction workers to contamination. Mitigation measures to manage potential contamination impacts are discussed in Section 15.5.2 and include additional detailed site investigations for areas of potential contamination risk as well as an unexpected finds procedure to be implemented if contamination is identified during construction.

Provided the proposed management measures are adopted, it is expected that there would be negligible impacts to human health in the event that contamination exposures occur during project construction. Health related public safety and contamination impacts are further discussed in Section 8 of Appendix F (Technical report – Human health).

Property acquisitions

Property acquisitions, including substratum acquisition, are presented in Chapter 20 (Business, land use and property).

As primarily a tunnel, the project has been designed to minimise the need for property acquisition by locating the majority of infrastructure below ground. Wherever possible, construction footprints have been designed to minimise property acquisition requirements, as well as impacts on heritage items and ecologically sensitive areas.

The potential for project property acquisition to disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety is considered low.

The project would also require the acquisition of land below the surface of the ground to accommodate the tunnels (substratum acquisition). Residents in areas directly above the tunnel alignment may potentially experience elevated levels of stress and anxiety associated with acquisition below their properties.

Impacts associated with property acquisition would be managed through a range of measures including a counselling service, a community relations support toll-free telephone line, and a property acquisition factsheet. All acquisition would be carried out in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991,* Property Acquisition – A guide for residential owners (NSW Government, 2021a) and Property Acquisition – A guide for residential tenants (NSW Government, 2021b). Health impacts from property acquisition are discussed further in Section 9.3 of Appendix F (Technical report – Human health).

Loss of green space

Green space within urban areas includes green corridors (paths, rivers and canals), grassland, parks and gardens, outdoor sporting facilities, playing fields and children's play areas. Epidemiological studies have been undertaken that show a positive relationship between green space and health and wellbeing (de Vries et al., 2003; Health Scotland, 2008; Kendal et al., 2016; Maas et al., 2006; Mitchell & Popham, 2007).

The health benefits of green space in urban areas include:

- protection of people from environmental exposures associated with flooding, air pollution, noise and extreme temperature
- reduced morbidity and mortality
- improved opportunities for physical activity and exercise.
- improved mental health and feelings of wellbeing, particularly lower stress levels and the perception of restorative effects
- improved opportunities for social interactions.

The project has largely avoided impacts to recreational facilities and parks and the project would not have direct impacts on public open space. Access to the Soldiers Pinch construction footprint would temporarily impact access to Browntown Oval which would need to be managed during construction, however the proposed works would not impact on recreational use of the oval. Given the extensive size of the surrounding Blue Mountains National Park, conservation and nature areas, the changes due to the project are not expected to impact on green space or the passive and active recreational use of green space in the study area. Hence no adverse impacts on health are expected.

Visual amenity

Landscape and visual impacts are presented in Chapter 18 (Landscape and visual).

Visual amenity can be described as the pleasantness of the view or outlook of an identified receptor or group of receptors (e.g. residences, recreational users). Visual amenity is an important part of an area's identity and offers a wide variety of benefits to the community in terms of quality of life, wellbeing and economic activity. Located in the Blue Mountains, the project is within an area known for its natural beauty and high level of visual amenity.

During construction, visual amenity has the potential to be affected by factors such as vegetation removal and the visual appearance of construction footprints.

For some individuals, changes in visual amenity can increase levels of stress and anxiety and may affect the use of outdoor spaces for walking and cycling. These impacts, however, are typically of short duration as most people adapt to changes in the visual landscape. As a result, most changes in visual impacts are not expected to have a material impact on the health of the community. Health impacts from changes to visual amenity are further discussed in Section 9.4 of Appendix F (Technical report – Human health).

Equity issues

The health effects associated with impacts related to transport projects are not typically equally distributed across the community. Groups at higher risk, or more sensitive to impacts, include the elderly, infants and young children, and individuals with pre-existing health conditions, disabilities, or who live in areas of higher levels of air or noise pollution.

The surface works for the project are located in areas where few people live or work – i.e. in areas between the townships along the highway. This means the majority of the impacts during construction are not in the centre of areas of social disadvantage. As such, groups that are at higher risk or more sensitive to health impacts are unlikely to experience an accumulation of health impacts as a result of the project. Health impacts associated with equity issues are discussed in Section 9.6 of Appendix F (Technical report – Human health).

Economic impacts

Business and economic impacts are presented in Chapter 20 (Business, land use and property).

The project would result in a substantial increase in economic activity (including economic stimulus benefits into the local, regional and state economies). Ongoing or improved economic vitality is a key factor that beneficially influences the health of a community. Employment opportunities would grow in the region through the potential increase in business customers and through the increase in demand for construction workers.

Economic impacts during construction as a result of the project, including gross output (market value of goods and services produced) and value added (market value of goods and services produced after deducting the cost of goods and services used) are shown in Figure 10-4.

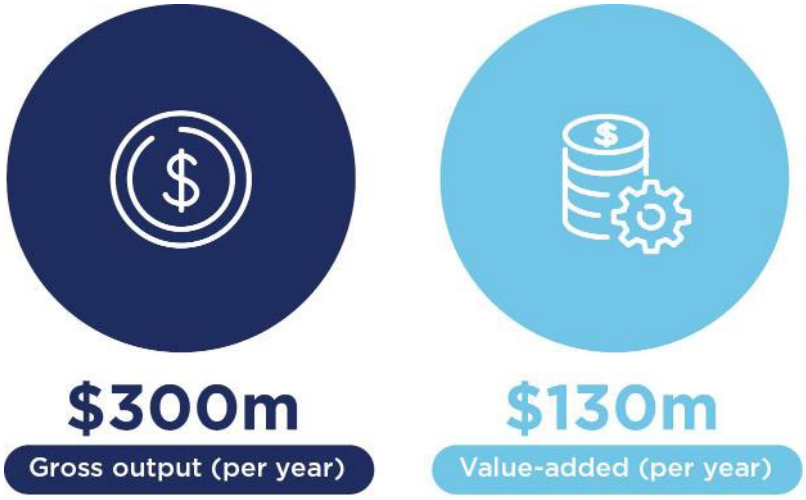


Figure 10-4 Economic impacts during construction (2024 to 2031)

Potential access and connectivity impacts including road closures, impacts on evacuation routes during emergencies and property and business access during construction may negatively affect local business. However, this is expected to be a short-term impact and is not expected to have a substantial impact on the overall activity of local businesses.

Construction expenditure for the project would result in a substantial increase in economic activity, and the project would support a large number of additional jobs a year over the construction period. Increased employment and improved economic vitality are of considerable benefit to human health. For further discussion on health related economic impacts during construction, refer to Section 9.7.1 of Appendix F (Technical report – Human health).

Construction fatigue

Construction fatigue relates to receivers that experience construction impacts from a long construction period, as well as a variety of projects over an extended period of time with few or no breaks between construction periods. Construction fatigue typically relates to traffic and access disruptions, noise and vibration, air quality, visual amenity and social impacts from project that have overlapping construction phases or are back-to-back.

The assessment of construction fatigue includes the following projects that may overlap with the construction phase of the project:

- Great Western Highway Upgrade – Medlow Bath (Medlow Bath Upgrade)
- Great Western Highway East – Katoomba to Blackheath (Katoomba to Blackheath Upgrade)

  Great Western Highway Upgrade Program – Little Hartley to Lithgow (West Section) (Little Hartley to Lithgow Upgrade).

As outlined in Chapter 24 (Cumulative impacts), the areas of greatest potential for cumulative impacts are at Little Hartley and Blackheath construction sites. All projects considered in the cumulative impact assessment would be required to implement mitigation measures to minimise noise and dust impacts. Mitigation measures to address construction fatigue related to the project are outlined in Chapter 24 (Cumulative impacts). Where all projects implement such measures the potential for cumulative impacts to be sufficiently elevated to impact on health is considered low (for air quality) to moderate (for noise).

10.6 Potential impacts – operation

10.6.1 Overview of health related ambient air quality impacts

Nitrogen dioxide

Potential health impacts associated with NO_2 consider both comparison with guidelines for both acute and chronic cumulative exposure (background concentrations plus the project) and an assessment of incremental impacts on health (associated with changes in air quality from the project alone) and are discussed in Table 10-1. Potential health impacts associated with NO_2, are discussed in Section 5.7 of Appendix F (Technical report – Human health).

The redistribution of nitrogen dioxide concentration shows that nitrogen dioxide concentrations adjacent to existing surface roads where traffic volumes are predicted to decrease, with some localised increases adjacent to the ventilation outlet to portals. The locations of maximum increases in nitrogen dioxide are in areas where there are no sensitive receptors (refer to Section 5.7.3 of Appendix F (Technical report – Human health)).

Table 10-1 Potential health impacts from nitrogen dioxide exposure during operation

Exposure type	Potential health impacts
Cumulative exposures	The assessment of acute and chronic health exposures found that under the previous National Environmental Protection Council (NEPC) and NSW Environment Protection Authority (EPA) standards, there are no exceedances predicted for NO_2 in air from the project relevant to the assessment of acute and chronic exposures. Under the current NEPC standards, the assessment of acute inhalation exposures exceeds air quality standards for both the with project and without project scenarios. The with project scenario provides a benefit in reducing peak acute health impacts of NO_2 in the community compared to the without project scenario. The assessment of chronic inhalation exposures exceeds the current NEPC standards for the without project scenario. The with project scenario would reduce NO_2 exposures and result in compliance with the current NEPC standards. While there are some exceedances of the current NEPC standards, no substantial adverse health impacts associated with NO_2, such as potential respiratory illnesses, are expected in the community, noting that the project reduces short and long-term exposures to NO_2 in the community.
Incremental exposures	Population health impacts: • consistent with the predicted reduction in total NO_2 concentrations in the study area, exposures to NO_2 for the population evaluated in the study area would decrease with the project, regardless of whether the design utilises portal emissions or ventilation outlet emissions. These reductions in NO_2 indicate the project would provide some health benefit to the population by reducing the risk of developing respiratory illnesses associated with NO_2 exposure. Localised health impacts • all calculated risks are less than the risk management action level of 1 x 10^{-4}, indicating that maximum changes in NO_2 in the local community as a result of the project are considered to be low and acceptable, and the project would not increase the risk of potential respiratory illnesses associated with NO_2 exposure. This outcome is the same for both ventilation design options.

Particulate matter

Potential health impacts associated with particulate matter are discussed in Table 10-2. Further discussion is provided in Section 5.8 of Appendix F (Technical report – Human health).

The redistribution of $PM_{2.5}$ shows that $PM_{2.5}$ concentrations adjacent to existing surface roads where traffic volumes are predicted to decrease, with some localised increases adjacent to the ventilation outlet to portals (refer to Section 5.8.5 of Appendix F (Technical report – Human health)).

Table 10-2 Potential health impacts from particulate matter exposure during operation

Exposure type	Potential health impacts
Cumulative exposures	The NEPC has proposed standards for air quality including particulate matter concentrations for the year 2025. Maximum 24-hour average concentrations of $PM_{2.5}$ have the potential to just exceed the NEPC goal of 20 for the year 2025 in the without project scenario. In the with project scenario, total concentrations of $PM_{2.5}$ are lower and would comply with the NEPC goal, regardless of ventilation design option. Maximum 24-hour average PM_{10} concentrations meet the NEPC standards for both the with and without project scenarios. Concentrations are lower in the with project scenario, regardless of whether the project is constructed with portal emissions or ventilation outlet emissions. The project would provide potential health benefits by potentially reducing the risk of adverse health outcomes, such as cardiovascular and respiratory illnesses, associated with PM_{10}. Annual average concentrations of $PM_{2.5}$ and PM_{10} meet the NEPC standards and goals, noting that concentrations would be lower with the project, regardless of the portal emissions or ventilation outlet emissions design options. On the basis of the above, the project would result in lower levels of exposure to $PM_{2.5}$ and PM_{10}, which has the potential for some health benefit to the population in the study area reducing the risk of adverse health outcomes associated with particulate matter such as cardiovascular and respiratory illnesses.
Incremental exposures	Population health impacts: • for the population evaluated in the study area, exposures to $PM_{2.5}$ would decrease with the project, regardless of the portal emissions or ventilation outlet emissions design options. This is consistent with the predicted reduction in total $PM_{2.5}$ concentrations in the study area. These reductions in $PM_{2.5}$ indicate the project would provide some health benefit to the population by reducing the risk of adverse health outcomes associated with particulate matter such as cardiovascular and respiratory illnesses. Localised health impacts: • all calculated maximum individual risks are less than the risk management action level of 1×10^{-4}, indicating that maximum changes in $PM_{2.5}$ in the local community as a result of the project are considered to be low and acceptable. This outcome is the same for both ventilation design options. However, it is noted that the calculated maximum individual risks are lower for the ventilation outlet option, compared with portal emissions. The localised health impacts from changes in $PM_{2.5}$ as a result of the project are considered low and acceptable.

Carbon monoxide

The assessment of potential health impacts associated with carbon monoxide indicate that the concentrations of carbon monoxide for both the with and without project scenarios are below the relevant NEPC health-based standards. Carbon monoxide concentrations would be below the NEPC standards regardless of the ventilation design option. As a result, no adverse health impacts such as increases in potential cardiovascular mortality are expected in relation to exposures to carbon monoxide in the local area surrounding the project. For further discussion of carbon monoxide impacts related to human health, refer to Section 5.6 of Appendix F (Technical report – Human health).

Air toxins

Potential health impacts associated with air toxins are discussed in Table 10-3. Further discussion can be found in Section 5.5 of Appendix F (Technical report – Human health). Based on the information in this table, no chronic health risk issues of concern are predicted in the local community associated with air toxics or diesel particulate matter from the project.

Table 10-3 Potential health impacts from air toxins exposure during operation

Exposure type	Potential health impacts
Acute and chronic exposure	The assessment indicates that the total hazard index predicted for acute exposures to volatile organic compounds (VOCs) and chronic exposures to VOCs and polycyclic aromatic hydrocarbons (PAHs) would be less than one for the with project and without project scenarios for 2030 and 2040. Health issues associated with exposure to VOCs and PAHs include respiratory irritation, nausea and headaches, and damage to the kidney and central nervous system. Based on this assessment, there would be no acute or chronic health issues predicted in the local community as a result of the project.
Incremental lifetime carcinogen risk (enHealth, 2012)	The calculated lifetime cancer risks associated with the maximum change in benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are less than $1x10^{-6}$ in relation to all impacts associated with emissions from the project irrespective of the ventilation design option chosen. In addition, the maximum calculated lifetime cancer risk associated with exposure to diesel particulate matter are equal to $1x10^{-5}$ (considered acceptable) for portal emissions and $1x10^{-6}$ for ventilation outlet emissions (considered negligible). Where the more realistic traffic scenario emissions estimates are considered in the assessment of diesel particulate matter, the risk would be lower. On this basis, the calculated carcinogenic risks are considered low and acceptable.

10.6.2 Health related in-tunnel air quality impacts

Further discussion on potential health related in-tunnel air quality impacts can be found in Section 6 of Appendix F (Technical report – Human health).

Nitrogen dioxide

The NO_2 concentrations in-tunnel during normal operations in 2030 and 2040 are forecast to be well below the in-tunnel limit of 0.5 parts per million (ppm). Where operating at capacity the maximum average concentration equals the in-tunnel air limit but does not exceed the limit. As discussed in Section 10.6.1, exposure to NO_2 potentially increases the risk of developing respiratory illnesses. NO_2 concentrations inside vehicles travelling in the tunnels would be lower with windows up and ventilation on recirculation. Therefore, the potential for adverse health impacts for users of the tunnel are considered to be low.

Carbon monoxide

The adopted in-tunnel air quality limit of 50 ppm for a 15-minute rolling average and 150 ppm as a peak value is lower than the available health based guidelines for exposure from the World Health Organisation (2010). As discussed in Section 10.6.1, exposure to carbon monoxide potentially increases the risk of cardiovascular mortality. Forecast in-tunnel concentrations for carbon monoxide for the project are substantially lower than the adopted limits (refer to Section 6 of Appendix F (Technical report – Human health)). Therefore, the in-tunnel air quality limits are considered to be adequately protective of the health of tunnel users in relation to carbon monoxide exposure.

Particulate matter

No guidelines are currently available to evaluate health impacts of very short-duration exposures to particulates. However, keeping vehicle windows closed and switching ventilation to recirculation has been shown to reduce particulate exposures inside the vehicle by up to 80 per cent (NSW Health, 2003). Adopting such measures, as is suggested for other tunnels in NSW, would minimise exposures to motorists within the tunnel, reducing potential adverse health impacts associated with particulate matter exposure.

10.6.3 Health related noise and vibration impacts

Road noise

The operational noise assessment identified that 30 receptors are expected to experience noise in excess of the adopted noise criteria. However, for the majority of these receptor buildings, exceedance of the noise criteria is a result of existing noise levels, rather than due to the project. For the majority of receptor buildings within the noise catchment areas, the change in noise levels is less than two dBA due to the project, which is unlikely to be discernible or impact on human health.

Noise levels are predicted to increase by more than two dBA at one sensitive receiver.

There are two receivers at Little Hartley where noise levels are predicted to equal or exceed the cumulative limit of three dBA. These receivers would be eligible for the consideration of feasible and reasonable noise mitigation measures such as at-property noise mitigation. Noise walls were not considered reasonable given the low number of receivers in this area.

Overall, two properties would experience increases in noise at levels that may be of concern to health as a result of the project. Where noise mitigation measures proposed are implemented, no substantial health impacts are expected for these properties. For the majority of the community road noise impacts would be reduced as a result of the project by reducing traffic on the existing Great Western Highway, resulting in some health benefits by reducing the potential for annoyance and sleep disturbance. For further discussion on health related road noise impacts from operation, refer to Section 7.6.3 of Appendix F (Technical report – Human health).

Fixed facility noise

For both ventilation options, noise impacts during normal and low flow traffic conditions relate to the operation of jet fans near the portal exits. Under the portal emissions option, there is potential for one receptor at Blackheath to experience increased levels of noise that exceed the adopted noise criteria during normal and low flow traffic conditions. During emergency conditions and prior to the application of noise attenuation, 14 receptors at Blackheath may experience increased levels of noise from operation of the fire pump. No exceedances are predicted at Little Hartley.

Under the ventilation outlet option, there is potential for up to four receptors at both Blackheath and Little Hartley to experience increased levels of noise that exceed the adopted noise criteria during normal and low flow traffic conditions. During emergency conditions, 19 receptors at Blackheath may experience increased levels of noise from the operation of the fire pump. No exceedances are predicted at Little Hartley.

Where noise levels are mitigated during normal operations there would be no changes in noise that would result in adverse impacts to community health, such as annoyance or sleep disturbance which can lead to other long-term health impacts. For further discussion on health-related fixed facility noise impacts from operation, refer to Section 7.6.3 of Appendix F (Technical report – Human health).

10.6.4 Health related social impacts

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectively during operation are presented in Chapter 8 (Transport and traffic).

Operation of the project would divert a substantial proportion of through traffic from the existing Great Western Highway into the tunnels. This means the existing Great Western Highway would mostly cater to local users and tourist traffic which would substantially improve local access and movements. By improving traffic access and connectivity during operation, the project could reduce motorist stress and fatigue, reducing adverse health impacts for the community.

Access to social infrastructure is likely to be improved as a result of the project with less traffic congestion on the surface roads. No specific impacts on public transport are expected, other than benefits due to decreased travel times for buses on surface roads and/or within the tunnel for through trips. By maintaining access to social infrastructure and public transport, the project would avoid potential adverse health impacts associated with feelings of isolation, helplessness and dependence. The project may provide potential health benefits by decreasing travel times for buses on surface roads and/or within the project tunnel, and reducing feelings of isolation, helplessness and dependence.

Reduced traffic congestion on surface roads as a result of the project would improve the safety of these roads for use by cyclists. Opportunities to improve at-surface active transport trails between Blackheath and Little Hartley are also being considered as part of ongoing investigation and consultation with relevant councils for potential placemaking initiatives, subject to separate planning approval. By improving pedestrian and cyclist safety during operation, the project would enhance the health benefits associated with providing pedestrian and cyclist access, which include maintaining a healthy weight and improved mental health status.

During operation of the project, the reduction in traffic congestion along the surface roads would improve amenity for residents living in Blackheath and Mount Victoria due to reduced travel times when travelling locally and when using the tunnel, potentially resulting in health benefits associated with decreased levels of stress and anxiety. Health related impacts from changes in traffic, public transport, access and connectivity are further discussed in Section 9.2 of Appendix F (Technical report – Human health).

Public safety

A range of potential hazards have been identified that have the potential to affect public safety during the operation of the project, including traffic accidents and subsidence. The subsidence analysis did not identify any residential properties where estimated settlement was not in compliance with relevant guidelines. With the implementation of recommended mitigation measures, these hazards are unlikely to result in substantial safety risks to the community.

Operation of the project would divert a substantial proportion of through traffic from the existing Great Western Highway into the tunnels, improving public safety on the existing Great Western Highway. By reducing traffic on the existing Great Western Highway, the project would provide potential health benefits by potentially reducing crash rates and improving pedestrian and cyclist safety. Health related public safety impacts are further discussed in Section 8 of Appendix F (Technical report – Human health).

Green space

The project has largely avoided impacts to recreational facilities and parks and the project would not have direct impacts on public open space. The project would not impact on areas of green space during operation, and therefore no adverse impacts to health are expected. The project would provide potential health benefits by improving access and connectivity to areas of green space and social infrastructure. The project would not result in a loss of green space.

Visual amenity

The operation of the project would include changes to the local landscape and visual amenity due to the presence of new project infrastructure (including the tunnel operations facility, water treatment plant, landscaping, surface road structures and ventilation outlets (if this ventilation design option is selected)). The water supply pipeline would be below ground or integrated with other infrastructure (such as bridge) and not visible during operation.

Changes in visual amenity have the potential to increase levels of stress and anxiety, however, most people adapt to changes in the visual landscape. Where long term visual impacts would be adverse, mitigation measures including landscape screening would be utilised where feasible to reduce these impacts. Design development has been influenced by urban design principles that have been established for the project including integrating the project elements and infrastructure into the surrounding environment. A detailed review and finalisation of architectural treatment of the project operational infrastructure would be carried out during further design development including input from the State Design Review Panel.

As a result, most changes in visual impacts would have a negligible impact on the health of the community or increase levels of stress and anxiety. Health impacts from changes to visual amenity are further discussed in Section 9.4 of Appendix F (Technical report – Human health).

Economic impacts

Business and economic impacts are presented in Chapter 20 (Business, land use and property). It is expected that there would be ongoing economic impacts/benefits to the regional economy via the three drivers shown in Figure 10-5.

Figure 10-5 Key economic impact drivers during operation of the project

In the first ten years of operation, it is estimated that the project would result in the economic impacts identified in Figure 10-6. This impact would be largely driven by the productivity uplift associated with business and freight related benefits and increased tourism spend within the regional area. This uplift is expected to be partly offset by a modest decline in passing trade activity, due to a reduction in local through traffic.

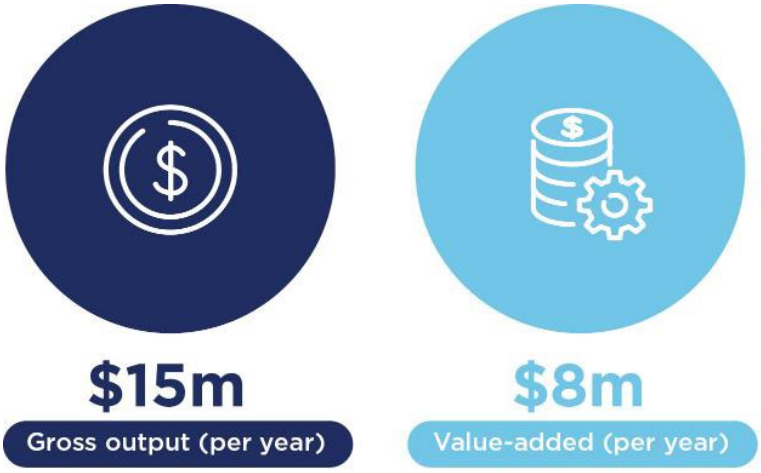


Figure 10-6 Economic impacts during operation (2030 to 2040)

It is also expected that traffic congestion and travel times between Blackheath and Little Hartley would improve for through traffic and local traffic once the project is operational. This would likely improve productivity for local businesses and may also improve access to jobs for local residents due to ease of travel.

Reducing the level of traffic on the existing Great Western Highway by diverting traffic to the tunnels has the potential to improve land value over time due to improved amenity around the project. This may also attract new businesses to move to the areas being bypassed including Blackheath and Mount Victoria.

As stated in Section 10.5.3, increased employment and improved economic vitality are of considerable benefit to human health. The ongoing economic benefits provided by the project, including increase business productivity and increased tourism spend in the area, would provide considerable community health benefits. For further discussion on health-related economic impacts during operation, refer to Section 9.7.2 of Appendix F (Technical report – Human health).

10.7 Environmental mitigation measures

10.7.1 Performance outcomes

Performance outcomes for the project in relation to human health are listed in Table 10-4 and identify measurable performance-based standards for environmental management.

Table 10-4 Human health performance outcomes

SEARs desired performance outcome	Project performance outcome	Timing
The project avoids or minimises adverse health impacts arising from the project.	Design, construct and operate the project to achieve applicable human health based in-tunnel and ambient air quality criteria, and human health based noise and vibration criteria.	Design, construction and operation
The project avoids, to the greatest extent possible, risk to public safety.	Design, construct and operate the project to comply with applicable road design and road safety standards, guidelines and policies.	Design, construction and operation

10.7.2 Mitigation measures

Environmental mitigation measures identified to manage potential human health related impacts as a result of the project are provided in other technical environmental assessment chapters. A full list of environmental mitigation measures for the project is provided in Appendix R (Compilation of environmental mitigation measures).