Operational air quality assessment

The methodology adopted to assess the air quality impacts of emissions from road vehicles and diesel locomotives using an operational Northern Connector included:

- ambient air monitoring
- a representation of the meteorology in this region
- a fleet emissions inventory
- a model of the dispersion of traffic emissions
- determination of the impact of emissions from a diesel locomotive
- assessment of cumulative air quality impact against Ambient Air Quality and Air Toxic NEPM standards.

19.1.2 Policy and legislative requirements

South Australian

Environment Protection Act 1993

The principal piece of legislation addressing pollution in South Australia is the *Environment Protection Act 1993*. In particular, section 25 imposes a general environmental duty on all persons undertaking an activity that pollutes or might pollute the environment, requiring them to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

EPA guideline 386/06 — Air quality impact assessment

EPA guideline 386/06 — Air quality impact assessment using design ground level concentrations, provides advice to proponents of new facilities or developments that may emit pollutants into the atmosphere (EPA 2006).

Environment Protection (Air Quality) Policy 1994

The *Environment Protection (Air Quality) Policy 1994* governs the regulation of air pollution. It specifies maximum pollution levels for stack emission providing for the regulation of industrial pollution and associated source monitoring, where required. It does not deal specifically with sources of diffuse pollution, such as motor vehicles.

Australian

National Environment Protection Council Act 1994

The National Environment Protection Council (NEPC) was established under Part 2 of the *National Environment Protection Council Act 1994* (NEPC Act) and incorporated in the Environmental Protection and Heritage Council in June 2001. The NEPC has two primary functions — to prepare NEPMs and to assess and report on the implementation and effectiveness of NEPMs in participating jurisdictions. NEPMs outline agreed national objectives for protecting and managing aspects of the environment. The NEPMs relating to air are separated into two sections — the Ambient Air Quality NEPM and the Air Toxics NEPM.

National Environment Protection (Ambient Air Quality) Measure 2003

The Ambient Air Quality NEPM, first released by the NEPC in 1998, sets national standards and goals for six common air pollutants (Table 19.1). In 2003, a variation to the NEPM introduced an advisory reporting standard for $PM_{2.5.}$

Table 19.1 Ambient Air Quality NEPM standards

Pollutant	Averaging period	Maximum concentration	
		μg/m^3 at STP	ppm
Nitrogen dioxide (No_2)	1 hour	-	0.12
	Annual	-	0.03
Carbon monoxide (CO)	8 hours	-	9.0
Sulfur dioxide (SO_2)	1 hour	-	0.2
	1 day	-	0.08
	1 year	-	0.02
Particulates (PM_{10})*	1 day	50	-
Particulates ($PM_{2.5}$)**	1 day 1 year	25 8	-

(DEWHA 2003)
* PM_{10}: particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less
**$PM_{2.5}$: particulate matter with an equivalent aerodynamic diameter of 2.5 micrometres or less

The standards and goals in the Ambient Air Quality NEPM are designed to be measured to give an 'average' representation of general air quality for large urban populations. The NEPM monitoring protocol was not designed for assessing the air quality at locations adjacent to major roads and industrial premises.

South Australia has adopted the NEPM guideline levels for air quality, under section 28A of the Environment Protection Act and the NEPC Act. The NEPM limits apply as Environment Protection Policies and are to be taken into account by the EPA in assessing air quality concerns and issues.

Air Toxics NEPM

The Air Toxics NEPM is concerned with collecting data on ambient (outdoor) levels of pollutants at locations where elevated levels are expected to occur and the population is likely to be exposed. Air toxics pollutants are shown in Table 19.2.

Air toxics exist in relatively low concentrations in ambient air. The elevated levels included in the Air Toxics NEPM are associated with locations close to specific sources (e.g. clusters of industrial sites, heavily trafficked or congested roads, and areas affected by wood smoke).

The Air Toxics NEPM specifies monitoring investigation levels for use in assessing any air monitoring data that is and has been collected. They are set as an average level designed to protect air quality and public health for large urban populations.

Table 19.2 Air Toxics NEPM monitoring investigative levels

Pollutant	Averaging period	Monitoring investigative levels
Benzene	Annual	3 ppb
Benzo(a)pyrene (as a marker for PAHs)	Annual	0.3 ng/m^3
Formaldehyde	24 hours	40 ppb
Toluene	24 hours Annual	1000 ppb 100 ppb
Xylene	24 hours Annual	250 ppb 200 ppb

(DEWHA 2004)
ppb: parts per billion; ng/m^3: nanograms per cubic metre

19.2 Existing conditions

19.2.1 Background ambient air quality

Existing air quality conditions adjacent to the Northern Connector corridor were monitored at SA Gun Club on Undo Road, Waterloo Corner (Site A, Figure 19.1). This site was selected as it is removed from all major sources of air emissions, primarily Port Wakefield Road, from all large obstructive objects, including plants and large buildings, and is representative of site specific background conditions. The location of the air monitoring station is consistent with all relevant Australian Standards.

Data monitored over the 36 day monitoring program at this site represented the cumulative air quality impact of the Northern Connector route in terms of cumulative NO_2, SO_2, PM_{10} and $PM_{2.5}$ ground level concentrations. Background concentrations adopted for the purposes of this project are summarised in Section 19.2.3.

Particulates – PM_{10} and $PM_{2.5}$

The time series of the daily averaged particulate ground level concentration over the monitoring period (Table 19.3) demonstrates that both PM_{10} and $PM_{2.5}$ ground level concentrations over the monitoring period predominantly fall below the Ambient Air Quality NEPM guideline levels.

There was an exceedance of the NEPM guideline levels on one day for PM_{10} compounds. It is believed that this can be correlated with a local dust event between 10 am and 5 pm that day and thus this reading was been removed from the analysis of the key PM_{10} statistics.

Table 19.3 Observed PM_{10} and $PM_{2.5}$ dataset

Daily averaged ground level concentration (μg/m^3)	PM_{10}	$PM_{2.5}$
Maximum	44.6	15.6
98th percentile	41.6	14.8
95th percentile	35.7	10.5
90th percentile	33.9	9.8
Average	22.0	8.6
NEPM level	50	25

NO_2

The background NO_2 levels (Table 19.4) monitored in the project area are well within the NEPM level (120 ppb).

Table 19.4 Observed NO_2 dataset for hourly averaged ground level concentrations — Site B

Hourly averaged ground level concentration (ppb)	NO_2
Maximum	18.8
98th percentile	15.2
95th percentile	13.9
90th percentile	12.3
Average	8.9
NEPM level	120

SO_2

The time series profile of SO_2 ground level concentrations in this region is negligible given the lack of any major sources in the region. Emissions from the nearest significant source at Torrens Island Power Station were reflected in the data from this site. The maximum concentration observed over the monitoring period was 1.0 ppb, with the 95th percentile level at 0 ppb. These results are as expected and considered to be typical of the region under consideration.

The contribution of traffic emissions to SO_2 levels is more significant than those from industrial sources. Given the relative positioning of Site A and Site B, the difference in the measured levels of SO_2, which are a direct result of industrial emissions, should not be significant.

Background CO

CO was not monitored as emissions of SO_2 from diesel locomotives were thought to be of greater concern. The high Ambient Air Quality NEPM level for CO (9 ppm) added further confidence to this emission not being of concern. Publicly available data from the Elizabeth monitoring station are used to represent the regional background level of CO in the atmosphere.

The level of CO has steadily been on the decrease at the Elizabeth monitoring site since 2002. Observed levels (maximum 0.64 ppb, average 0.03 ppm) are well within the NEPM guideline level of 9 ppm. The maximum observed background concentration of 0.64 ppb is conservatively used to predict the cumulative impact of this development (EPA 2008a).

19.2.2 Background air toxics

Air toxics were not monitored as part of this air quality monitoring program. Background levels have been adopted from nearby EPA air quality monitoring stations (Table 19.5).

Benzene

Benzene was not part of this monitoring program, given the NEPM investigative guideline is set over an annual averaging period. The relatively short length of the current monitoring program would thus give an unrepresentative dataset. Background concentrations of benzene were obtained from EPA (2007a).

The maximum annual average at the EPA monitoring station at DJ Leane Reserve (less than 20 km from the Northern Connector) was estimated to be 0.0008 ppm, below the NEPM guideline of 0.003 ppm.

Toluene

Toluene was not included in this monitoring program and the EPA monitored level was used to represent the background contribution for toluene.

The level monitored at DJ Leane Reserve, of 0.007 ppm over a daily averaging period, was used to represent the daily averaged concentration background level (EPA 2007a). This is below the NEPM guideline of 1.0 ppm.

19.2.3 Background (existing) air quality levels adopted

The 80th percentile of the monitored dataset through this period is used to represent background conditions in this region, to assess the cumulative air quality impact of the project. The Victorian EPA 'Plume Calculation Procedure' recommends the use of the 70th percentile as background. Therefore, the methodology used is considered to be conservative (Consulting Environmental Engineers 2007). Background levels monitored for this study are summarised in Table 19.5.

Data from a long-term monitoring program, such as that of EPA, were used as long-term average (annual) background levels. The EPA monitoring programs at Northfield and Elizabeth gave annual average background levels for $PM_{2.5}$ and NO_2.

The monitoring program instituted specifically for this project has yielded background levels that are both project specific and conservative for the Northern Expressway air quality assessment.

Table 19.5 Background data representing cumulative concentrations

Compound	Averaging period	Units	Adopted background for Northern Connector air quality assessment	EPA monitored levels	NEPM guideline
Benzene	Annual	ppm	0.0008*	0.0008	0.003
Toluene	24 hr	ppm	0.007*	0.007	1.0
CO	8 hour	ppm	0.64*	0.64^	9.0
NO_2	1 hour	ppm	0.011†	0.003	0.12
	Annual		0.0039*	0.0039	0.03
SO_2	1 hr	ppm	0†	0	0.2
	24 hr		0†	0	0.08
	Annual		0^	0	0.02
$PM_{2.5}$	24 hr	µg/m³	9.4†	8*	25
	Annual		4.9*	4.9*	8
PM_{10}	24 hr		29.8†	30.0#	50

* Background level adopted or included for comparative purposes from long term EPA monitoring program, DJ Leane Reserve (benzene) (EPA 2007a), Elizabeth Downs (CO, NO2, toluene and benzene) (EPA 2008a; 2007b), Northfield (PM2.5) (Consulting Environmental Engineers 2007)

† Background level calculated from project specific air monitoring program at Site A (SA Gun Club)

\# 90th percentile figure from Elizabeth Downs air monitoring station (EPA 2007b)

Background levels of other air toxics compounds assessed as part of this study were considered to be negligible given the absence of any major source of these pollutants through this region.

19.2.4 Meteorological conditions

Meteorology is fundamental to the dispersion of pollutants and, therefore, meteorological data (particularly wind and atmospheric stability conditions) must be carefully assessed and considered when assessing pollutant dispersion.

Roadside pollutant dispersion is primarily influenced by:

- wind speed, direction and profile, and turbulence intensity (affected by terrain)
- temperature gradient, determined from atmospheric stability (which in itself is determined from wind speed, cloud cover and solar radiation)
- mixing height, which is the depth of the atmospheric boundary layer.

Observed wind speed data were obtained from the Bureau of Meteorology (BoM) automatic weather stations at Outer Harbor, RAAF Edinburgh and Parafield Airport, the stations surrounding the Northern Connector.

The data from these stations were assimilated into a prognostic numerical meteorological model (TAPM) to predict more complex meteorological parameters that feed into the air dispersion model. This assimilation process allowed for a more robust assessment of wind speed conditions through this region.

Wind

Local wind conditions that affect the dispersion of pollutants were predicted by comparing observed and predicted wind class frequency distribution and wind rose.

The TAPM wind class frequency distribution graph predicts no calm wind conditions (TAPM v3 typically under-predicts or does not predict calm conditions at all). Low wind speeds inhibit dispersion of pollutants and lead to accumulation near the source. However, this phenomenon is corroborated by observational data from the three BoM stations, which indicate that calms occur less than 5% of the time. Nonetheless, the predicted wind class frequency distribution is seen to be skewed towards lower wind speeds, which is conservative.

The wind roses obtained indicate that the wind direction character of the assimilated TAPM predicted dataset is similar to that observed at the RAAF Edinburgh BoM automatic weather station. Conditions are generally dominated by south-easterly and north-westerly winds, reflecting the diurnal shift in wind conditions from sea breeze to land breeze.

Atmospheric stability

The degree of stability in the atmosphere is determined by the temperature difference between an 'air parcel' and the air surrounding it. This difference can cause the air parcel to move vertically. The Pasquill-Gifford stability category scheme designates stability classes from A to F (and sometimes G), ranging from highly unstable to extremely stable.

The stability class rose and frequency distribution in the region is seen to be dominated by neutral and stable conditions, with stability class D being dominant. The high frequency of relatively stable meteorological conditions is a result of generally low wind speeds in the area. Significant cloud cover in the area, and thus minimal solar radiation, also reduces heating or cooling of the surface, leading to neutral conditions.

Neutral and stable stability classes are observed through the night-time, as expected. Throughout the day, the stability class shifts from neutral–stable to neutral–unstable due to the convective nature of the boundary layer. Convection arises from the solar irradiation of the earth's surface, resulting in enhanced mixing.

Wind speeds are observed to follow the expected outcome, observed from other sites with a similar climate. The processed surface data appears to be reliable based on atmospheric stability class.

Wind speed and stability class conditions are predicted with sufficient accuracy to enable a conservative air quality assessment based on the worst case meteorological conditions.

Mixing height

The mixing height is the depth of the turbulent boundary layer of air near the earth's surface within which ground level emissions are rapidly mixed. A plume emitted above this height will remain isolated from the ground until the mixing height reaches the height of the plume. A plume emitted below this height will be mixed subject to changes in the stability class and wind climate. The height of the mixing layer is controlled by convection (resulting from solar heating of the ground during the day) and by mechanically generated turbulence as the wind blows over rough ground (hence the importance of landuse data).

The estimated mixing height for the project area rises in the morning from just after sunrise until mid-afternoon. After this time, it remains at a relatively stable value until returning to a lower level early in the evening. This diurnal variation of atmospheric structure is consistent with that found in areas with a similar climate to this region. Large values for mixing height occur in the summer months due to the greater convective effects from surface irradiation.

The minimum mixing heights predicted by TAPM are very low due to the coastal location as well as the conservative nature of the predicted meteorological data. The generated meteorological data, therefore, enables a worst case assessment of the dispersion of traffic emissions caused by the project.

19.3 Air dispersion modelling

19.3.1 Air emissions inventory

The following were incorporated into the air dispersion model:

- traffic counts
- traffic composition
- fleet emissions inventory
- atmospheric chemistry
- rail emissions.

Traffic

Factors affecting traffic emissions applicable to the Northern Connector are listed in Table 19.6.

Table 19.6 Factors affecting dispersion of noxious air emissions from roads

Factor	Description
Vehicle fleet composition	Heavy articulated diesel vehicles are the most significant source of PM_{10} and $PM_{2.5}$; accounted for in the vehicle composition profile.
Vehicle technology and fuel standard(s)	Pollutant emission factors are expected to decrease with better fuel standards and improvements in combustion and emission control systems in modern vehicles. A negative growth factor was applied to the emission factors to account for this improvement in analysis of future scenarios.
Speed and queues	Emission rates tend to increase at lower (<30 km/hr) and higher speeds (>70 km/hr). Queuing and variations in speed have not been taken into account in the dispersion model.
Road design	There are no steep gradients and sharp bends along the Northern Connector and this reduces emissions caused by braking and acceleration.

Traffic counts

Projected traffic volumes for 2017 and 2031 for the Northern Connector used in the dispersion model to assess the cumulative air quality impact of this project were higher than those provided in Chapters 3 and 15. These higher volumes provide a sensitivity analysis or more conservative approach to the air quality assessment.

Traffic composition

The percentage of different vehicle classes in the traffic volume is used to develop emission factors that will be representative of the air emissions from the fleet. The typical composition of traffic predicted to use the Northern Connector is listed in Table 19.7.

Table 19.7 Typical vehicle composition

Vehicle class	Northern Connector (%)
Cars (petrol)	82
Cars (diesel)	2.1
Cars (LPG)	2.1
Light commercial vehicles (petrol)	2.4
Light commercial vehicles (diesel)	2.3
Light commercial vehicles (LPG)	0.1
Heavy articulated vehicles (diesel)	6.0
Heavy vehicles (B-doubles, road trains)	3.0

Fleet emissions inventory

Fleet emission factors for the Northern Connector were calculated based on:

- *National Pollutant Inventory Emission Estimation Technique Manual for Combustion Engines version 3.0* (National Pollutant Inventory 2008)

- projected peak traffic volumes
- traffic composition (Table 19.7)
- fuel consumption for diesel vehicles
- the road consisting of a pavement surface.

Emission factors of the traffic using the Northern Connector are given in Table 19.8.

National Pollutant Inventory (2008) does not provide emission factors for any air toxic compound listed under the Air Toxics NEPM apart from benzene. Benzene has the most stringent investigation level of the compounds that are part of this DEWHA study and can thus be used as a gauge to represent compliance with the investigative limits for all other air toxics.

Table 19.8 Emission factors

Criteria pollutants and air toxics	Northern Connector emission factors (g/km-veh)*	
	2016	2031
CO	10.176	7.52
NO2	3.632	2.672
SO2	0.024	0.0176
PM2.5	0.2336	0.1728
PM10	0.24	0.1776
Benzene	0.0256	0.0192
benz(a)pyrene (BaP)†	1.36×10^{-6}	3.04×10^{-7}
Formaldehyde†	0.0096	0.0048
Toluene†	0.0864	0.0352
Xylenes†	0.0544	0.0224

† Emission factors not included in NPI Emissions Estimation Manual (2008); therefore, emissions estimated for Northern Expressway air quality assessment

An annual growth factor of -1.5% was applied to the emission factors to account for improvements in fuel standards as well as combustion and emission control systems in motor vehicles in the future.

Rail

Data from monitoring adjacent to the existing rail line (Site C, Figure 19.1) were used to determine air quality impacts from interstate passenger and freight rail.

- Railway emission contributions for NO_2, SO_2, PM_{10} and $PM_{2.5}$ were determined by calculating the difference between the monitored levels at Site C and Site A. The contribution of the railway to the NO_2 and SO_2 air quality impact was derived by subtracting the maximum observed 5-minute averaged level monitored at Site A (ambient background conditions) from that at Site C (rail line).
- The contribution of the diesel locomotive to the PM_{10} and $PM_{2.5}$ air quality impact was determined in a similar manner. The primary differences were (a) the 90th percentile monitored dataset at each of the two sites was used

to filter the dust events and (b) the 5-minute averaged PM_{10} dataset and the hourly averaged dataset for $PM_{2.5}$, were used to calculate the differences.

- The 5-minute (NO_2, SO_2, PM_{10}) and hourly ($PM_{2.5}$) average ground level concentrations, contributing to emissions from diesel locomotives, were then represented over the required averaging periods to enable a comparison with the legislated NEPM guidelines.
- The cumulative effect of numerous train passes is likely to be negligible given the time period between one pass and another. The train timetable for this region was not obtained but anecdotal indications are of one or two passes through this region every hour.
- A negative growth factor was not applied to the emissions contribution. This is a conservative assumption, as many improvements in fuel standards, combustion and emissions control systems are foreseeable.
- The contribution of the diesel locomotive to benzene emissions was considered to be negligible. Diesel locomotive engines release minimal evaporative emissions of benzene compared to petrol vehicles (NZ MFE 2008). Furthermore, diesel fuel is produced by the hydrocracking of the gas oil fraction of crude and contains insignificant amounts of benzene.
- Emissions of CO from diesel locomotives were considered to be negligible. The maximum predicted ground level concentration from traffic emissions alone was 0.24 ppm over an 8-hour average and railway CO emissions are expected to be significantly lower due to the transitory nature of train pass-bys and the long averaging period over which CO ground level concentrations are assessed.
- Comparison of the relative contribution of CO and benzene emissions contributions of railway and motor vehicles to the Adelaide airshed shows that the former is approximately 0.02% of the latter. The additional air quality impact of diesel locomotives for these two compounds is thus considered negligible.

The contribution of diesel locomotives to the cumulative air quality impact was accounted for in this manner due to the low level of reliability in the emission factors published by the *National Pollutant Inventory Emission Estimation Technique Manual for Aggregated Emissions from Railways* (National Pollutant Inventory 1999). The emission levels in Table 19.9 were added to the modelled traffic emission concentrations and ambient (background) levels to obtain the cumulative ground level concentrations. These will then be assessed against the stipulated Ambient Air Quality NEPM.

The predicted impact for diesel locomotives is determined by monitored air quality at a distance less than 25 m from the edge of the rail tracks. In the case of the Northern Connector, emissions from the rail line would occur up to at least 60 m from the edge of the corridor.

Table 19.9 Rail emissions at less than 25 m from the edge of the tracks

Pollutant	Averaging period	Unit	NEPM guideline	Railway contribution
Benzene	Annual	ppm	0.003	negligible
CO	8 hour		9.0	negligible
NO_2	1hour		0.12	0.0005
	annual		0.03	0.00004
SO_2	1 hour		0.2	0.0003
	24 hour		0.08	0.0001
	Annual		0.02	0.00002
$PM_{2.5}$	24 hour	μg/m^3	25.00	0.21
	Annual		8	0.002
PM_{10}	24 hour		50.00	0.23

19.3.2 Air quality model

The air quality model (Cal3QHCR) is a complex computational line source dispersion model that is used to represent the dispersion of air emissions associated with road traffic. The model is able to estimate ground level concentrations at receiver height (1.8 m) of CO, particulate matter (PM) and NO_2.

Modelling considerations

The key modelling considerations and assumptions are listed in Table 19.10.

Table 19.10 Modelling considerations

Modelling consideration	Description
Meteorology	Meteorology plays an important role in dispersal of pollutants. Meteorological factors (Section 19.2.4) have been incorporated into this model. TAPM predicted meteorological data was used to represent a full year of meteorological wind speed, stability class and mixing height data. The robustness of this dataset was improved by assimilating the simulation with a contemporaneous observed dataset from three BoM automatic weather stations.
Topography	No significant change in terrain was observed in the project area. The road was modelled at an at-grade level.
Traffic volumes	Peak hourly traffic volumes were input into the model to simulate worst-case traffic conditions. These volumes have a direct influence on the maximum predicted ground level concentrations through each section of the carriageway.
Emission factors	Fleet weighted average emission rates, calculated in terms of grams per vehicle per mile
Mixing zone width	The mixing zone width is defined by the model as the width of the road including the median strip and 3 m from the edge of each side of the carriageway. The mixing zone width was set at 69 m (63 m + 3 m + 3 m) in this model.

Modelling consideration	Description
Surface roughness length	A measure of local air turbulence that affects pollutant dispersion: the area surrounding the roads has been assumed to be suburban and a surface roughness factor of 100 cm applied to the intervening land between the road and assessment locations.
Averaging time	Averaging time for emission concentrations was set at 60 minutes to correlate emissions with peak hourly traffic volumes.

Model validation

Air quality monitoring was also undertaken at a site adjacent to Port Wakefield Road to determine emissions from an existing arterial road (Site B, Figure 19.1). The model was validated against monitored data (existing conditions) to assess its veracity.

The results demonstrate that the model over-predicts the maximum cumulative level of NO_2 over the one-hour averaging period. This over-prediction is potentially a result of a combination of meteorological conditions that inhibit the dispersion of pollutants and non-contemporaneous air emissions.

The model represented meteorological conditions throughout the whole year whereas the monitoring program only took place over the summer months.

The level of particulates is shown to be represented accurately over the daily averaging period. The average of the monitored dataset was used as the appropriate comparison level for particulates to account for removal of peak dust events from the analysis.

19.4 Potential impacts

19.4.1 Construction

The key air quality issue associated with construction of a major transport corridor is the management of dust (largely as PM_{10} and total suspended particles).

The main sources of dust from construction would be:

- excavation
- heavy vehicular movement on haul roads
- stockpiles
- removal of vegetation.

The level of dust is highly dependent upon the intensity of the various excavation processes, prevailing winds and time of year.

Dust emissions are a source of both the processes of excavation work and the static sources that form following the activities (i.e. from all exposed surfaces, haul roads and stockpiles). These static sources tend to be the largest contributor to off-site dust impacts. If they are not managed appropriately, general nuisance-related problems would occur that are associated with movement of dust plumes off-site into sensitive areas. A contractor's environmental management plan (CEMP) is necessary to ensure that dust impacts are ameliorated to minimise off-site impact.

19.4.2 Operation

Northern Connector

The cumulative air quality impacts of the Northern Connector have been assessed against NEPM guidelines. The concentrations presented are all cumulative levels inclusive of the ambient concentrations and any impact from noxious locomotive emissions, in the case of the Northern Connector.

The assessment was set at the edge of the Northern Connector corridor/boundary in a location beyond which private residential dwellings could be built. The assessment height was set at 1.8 m.

Due to varying traffic volumes, the Northern Connector was broken down into sections for analysis:

- Northern Expressway to Waterloo Corner interchange
- Waterloo Corner interchange to Bolivar interchange
- Bolivar interchange to Dry Creek salt fields
- in Dry Creek salt fields.

Maximum cumulative ground level concentrations for the project (Table 19.11) demonstrate that the cumulative air quality impact of the project is in compliance with all legislated and investigative air quality limits in the project corridor. The maximum air quality impact occurs through the section in Dry Creek salt fields, which has the maximum daily and peak hourly traffic volumes.

The simulation of the emissions of the air toxic compounds from the Northern Connector (Table 19.12) indicates that the maximum predicted ground level concentrations fall several orders of magnitude below the stipulated NEPM investigative levels. The background level of these compounds in the environment was assumed to be negligible given the absence of any major sources in this region and the lack of publicly available data on these pollutants in this region. This assumption is thought to be valid given that the largest source in the region will be the new source of the Northern Connector. However, the assessment demonstrates that emissions from the roadway would not result in adverse air quality.

Predicted ground level concentrations are seen to decrease from 2016 to 2031. The decrease in specific air emissions from each vehicle (with predicted improvements in fuel quality and combustion technology) will be greater than predicted increases in traffic volumes through the same period.

Maximum cumulative ground level concentrations at all the assessment locations comply with the Ambient Air Quality and Air Toxics NEPM guidelines.

Northern Connector cumulative impacts

The results indicate that Ambient Air Quality NEPM levels would be met at the edge of the corridor and as would any residences beyond this point.

Cumulative ground level concentrations would decrease gradually from the edge of the carriageway. Peak concentrations for PM_{10} and $PM_{2.5}$ are seen to fall towards the current background concentration level at a distance of 130 m from the edge of the carriageway. The final cumulative contribution is in compliance with the Ambient Air Quality NEPM guideline.

The contribution from the railway is negligible with traffic emission contributions dominating. The figures demonstrate that cumulative ground level concentrations are seen to gradually decrease towards background levels.

The cumulative air quality impact assessment has demonstrated that all air quality guidelines have been met. Thus no further design alterations are necessary.

Port Wakefield Road

If the Northern Connector was to be constructed, traffic volumes along Port Wakefield Road from Northern Expressway to Salisbury Highway would be significantly less than current (existing) volumes after the opening of the Northern Connector. In some instances, this decrease in traffic volumes will be in the order of 40–50% from 2017 (with the opening of the Northern Connector) to 2031. A consequent significant decrease in cumulative air quality impacts can be expected.

During operation of the Northern Connector, the level of air quality in the Port Wakefield Road region is expected to fall below current observed levels, in direct proportion to the ratio of future traffic volumes over current traffic volume on the carriageway.

Air quality impacts will also be improved by the current advent of cleaner fuels, combustion and emission control techniques in vehicles as well as a cleaner ambient environment through a reduction in industrial air pollution.

Table 19.11 Summary of maximum cumulative ground level concentrations predicted at the edge of the Northern Connector transport corridor for NEPM guideline pollutants

Criteria pollutants	CO	NO_2		SO_2			$PM_{2.5}$		PM_{10}
Averaging period	8 hour	1 hour	Annual	1 hour	24 hour	Annual	24 hour	Annual	24 hour
Unit	ppm	ppm	ppm	ppm			µg/m^3	µg/m^3	µg/m^3
NEPM guideline	9.0	0.12	0.030	0.200	0.080	0.02	25.0	8.0	50.0
Background	0.64	0.01	3.9×10^{-3}	0	0	0	9.4	4.9	29.8
2016	0.72	0.064	0.0078	0.00094	0.00013	0.000024	14.7	6.5	33.1
2031	0.734	0.0648	0.0085	0.0013	0.00023	0.000045	14.9	7.6	35.6

Table 19.12 Summary of maximum cumulative ground level concentrations predicted at the edge of the Northern Connector transport corridor for NEPM air toxics

Air toxics	Toluene		Xylenes		Formaldehyde	PAHs as BaP	Benzene
Averaging period	24 hour	Annual	24 hour	Annual	Annual	Annual	Annual
Unit	ppm		ppm		ppm	ng/m^3	ppb
NEPM guideline	1	0.1	0.25	0.2	0.04	0.3	0.003
Background	0.007	0	0	0	0	0	0.0008
2016	0.00754	0.0001	0.00029	0.000088	0.00019	0.0061	0.00084
2031	0.0076	0.00011	0.0003	0.000091	0.00021	0.0032	0.00084

19.5 Management and mitigation

19.5.1 Construction

An air quality management plan would form part of the CEMP developed for the project which would include the following dust mitigation measures:

- develop a construction traffic management plan to advise all truck drivers, contractors and vehicular machinery operators of designated vehicle access routes and protocols
- position all haulage routes with heavy traffic away from sensitive receivers as much as practicable (ideally a minimum of 20 m)
- restrict vehicle speeds (e.g. 20–40 km/hr) to minimise wheel-generated dust on unsealed routes
- minimise diesel engine idle times and queuing
- install truck tyre cleaning stations at site boundaries for earth moving vehicles to minimise off-site transport of material, which could cause dust emissions
- where practicable, cover truck loads where there is potential for dust emissions during transport
- maintain all fossil-fuelled plant and equipment for efficient operation
- install appropriate emission control mechanisms (e.g. fabric filter on crushers, concrete batchers) to minimise air emissions
- regularly water exposed surfaces, including exposed stockpiles and unsealed roadways, to suppress dust generation; the contractor should also consider the use of surfactants on various surface types to increase the efficiency of these systems, for example polymer based crusting agents on stockpiles and exposed surfaces which have intermittent to low traffic flow.
- locate stockpiles away from sensitive receivers, as far as practicable
- restrict activities with high dust generating potential (including, heavy excavations and drilling) during periods when strong winds are blowing towards sensitive regions
- engage the affected community through actions including:
  - responding to queries on construction methodologies and to complaints/concerns offered by community members
  - providing regular updates to community members to inform them of upcoming work that could result in any increased levels of emissions
- consider community input when updating the air quality management plan
- undertake air quality monitoring and implement additional management measures, and take additional remedial actions to mitigate off-site impacts.

19.5.2 Operation

The cumulative air quality impact assessment has demonstrated that all air quality guidelines have been met. Thus no further design alterations are necessary.

20 Water quality, drainage and flooding

20.1 Introduction

20.1.1 Assessment approach

The assessment of water quality, drainage and flooding for this project was based on reviewing existing information, identifying issues and assessing risk.

Existing information and data review

For each project section (Northern, Central and Southern; Figure 1.2), existing information and data were reviewed relating to:

- water quality in areas surrounding the project corridor
- catchments and flow characteristics
- drainage system elements
- flooding (including floodplain management)
- stormwater management (including existing natural and engineered stormwater systems).

Issue identification and risk assessment

Based on the review, water quality, flooding and drainage issues were identified for each section of the project.

Following identification of the issues, a qualitative assessment of the likely risks associated with water quality, flooding and drainage was undertaken (in accordance with Department for Transport, Energy and Infrastructure *Protecting Waterways Manual* (DTEI 2002; see Section 5 and Attachment E of the manual).

The risk assessment assessed the impacts of the planning and design, construction and operation phases of the project and identified measures to mitigate potential impacts of the project.

20.1.2 Policy and legislative requirements

Environment Protection Act 1993

General environmental duty

DTEI has a 'general environmental duty' under the requirements of Part 4 (see section 25) of the *Environment Protection Act 1993*. This general duty specifies that a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

Environmental authorisations

Environmental authorisations are required for activities classified as a 'prescribed activity of environmental significance' under Schedule 1 of the Environment Protection Act.

South Australian Environment Protection Authority (EPA) authorisations required for the project would depend on the final design and construction techniques; the following 'prescribed activities of environmental significance' (pursuant to Schedule 1 of the Environment Protection Act) may apply:

- 7(2) Railway operations (construction or operation of rail infrastructure).
- 7(4) Dredging
- 7(6) Earthworks drainage
- 8(7) Discharges to marine or inland

Environment Protection (Water Quality) Policy 2003

In 2003, the EPA introduced the *Environment Protection (Water Quality) Policy* covering South Australia's inland (surface and underground), estuarine and marine waters.

The Water Quality Policy, Part 5(39) Road construction and maintenance — Stormwater, states that 'If an authority constructs or maintains a public road, the code titled the Stormwater Pollution Prevention Code of Practice for Local, South Australian and Australian Government 1997 prepared by the Authority applies'. References to the Code within the Policy means the requirements of the Code are 'statutory' (i.e. enforceable).

Natural Resources Management Act 2004

The *Natural Resources Management Act 2004* (NRM Act), administered by the Department of Environment and Natural Resources, promotes sustainable and integrated management of South Australia's natural resources and provides for their protection.

The NRM Act is relevant to the project in groundwater abstraction, and use and water affecting activities such as diversion of surface watercourses.

Other codes of practice and guidelines

Stormwater Pollution Prevention Code of Practice

This general Code of Practice for the control of stormwater pollution at its source for local, South Australian and Australian Government agencies provides agencies and their contractors with information on the strategies and techniques available to reduce the incidence of stormwater pollution at its source.

Protecting Waterways Manual

The DTEI Protecting Waterways Manual (DTEI 2002) provides guidance on assessing the impacts on water quality and aquatic environments from the construction, operation and maintenance of transport infrastructure.

The manual guided an evaluation of the potential impact of the project on water quality, quantity and aquatic environments, which was part of the review of water quality, flooding and drainage.

20.2 Existing conditions

20.2.1 Surface waterbodies

The major waterways in the project area are:

- Helps Road drain (Northern section; Figure 20.1)
- Little Para River and overflow (Central section; Figure 20.2)
- Dry Creek (Southern section; Figure 20.3)
- Barker Inlet wetlands (Southern section; Figure 20.3)
- Magazine Creek (Southern section; Figure 20.3)
- Range wetland and Magazine wetland (Southern Section; Figure 20.3).

20.2.2 Flooding and drainage

Each of the major surface waterbodies has distinctive flooding and drainage characteristics.

Northern section

Key land use in the Northern section includes open rural land used for agricultural, horticulture, rural living and recreation.

Helps Road drain is the main surface water drain in the Northern section of the project area.

Helps Road drain

Helps Road drain is a 15 km artificially constructed channel that drains a greater catchment area of approximately 74 km^2 covering the Cities of Salisbury and Playford (BC Tonkin 1999). The drain is located at the southern boundary of the Northern section of the project area (Figure 20.1).

Much of the land in the Helps Road drain catchment is highly urbanised, with the existing development being residential in nature, with some areas of industrial land use in the suburb of Elizabeth (south and west).

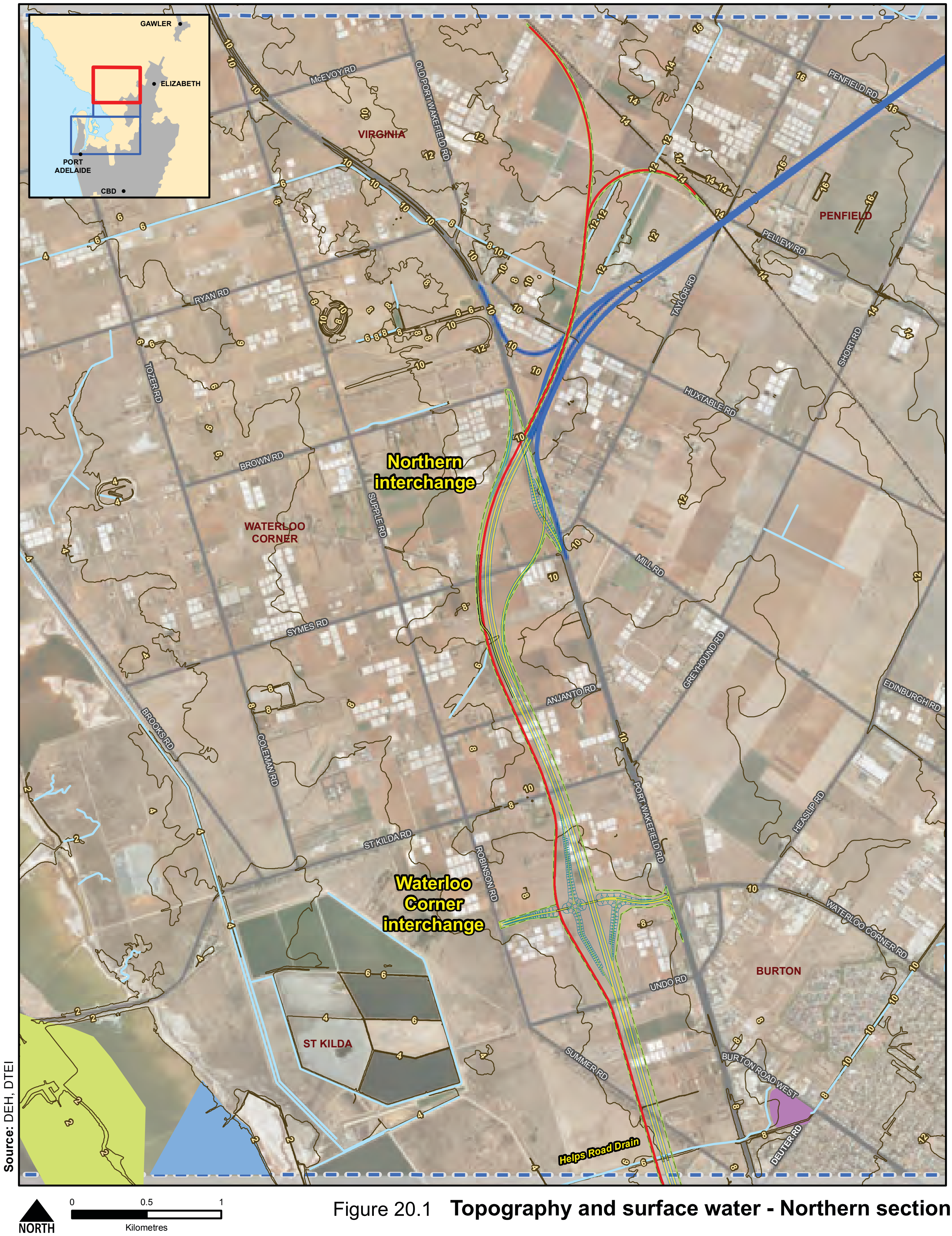


Figure 20.1 **Topography and surface water - Northern section**

- Northern Connector road
- Northern Connector rail
- Northern Connector boundary
- Northern Expressway
- Embankment
- Existing railway
- Existing roads
- 2m contour
- Watercourse
- Intertidal mangroves
- Salt fields
- Wetlands

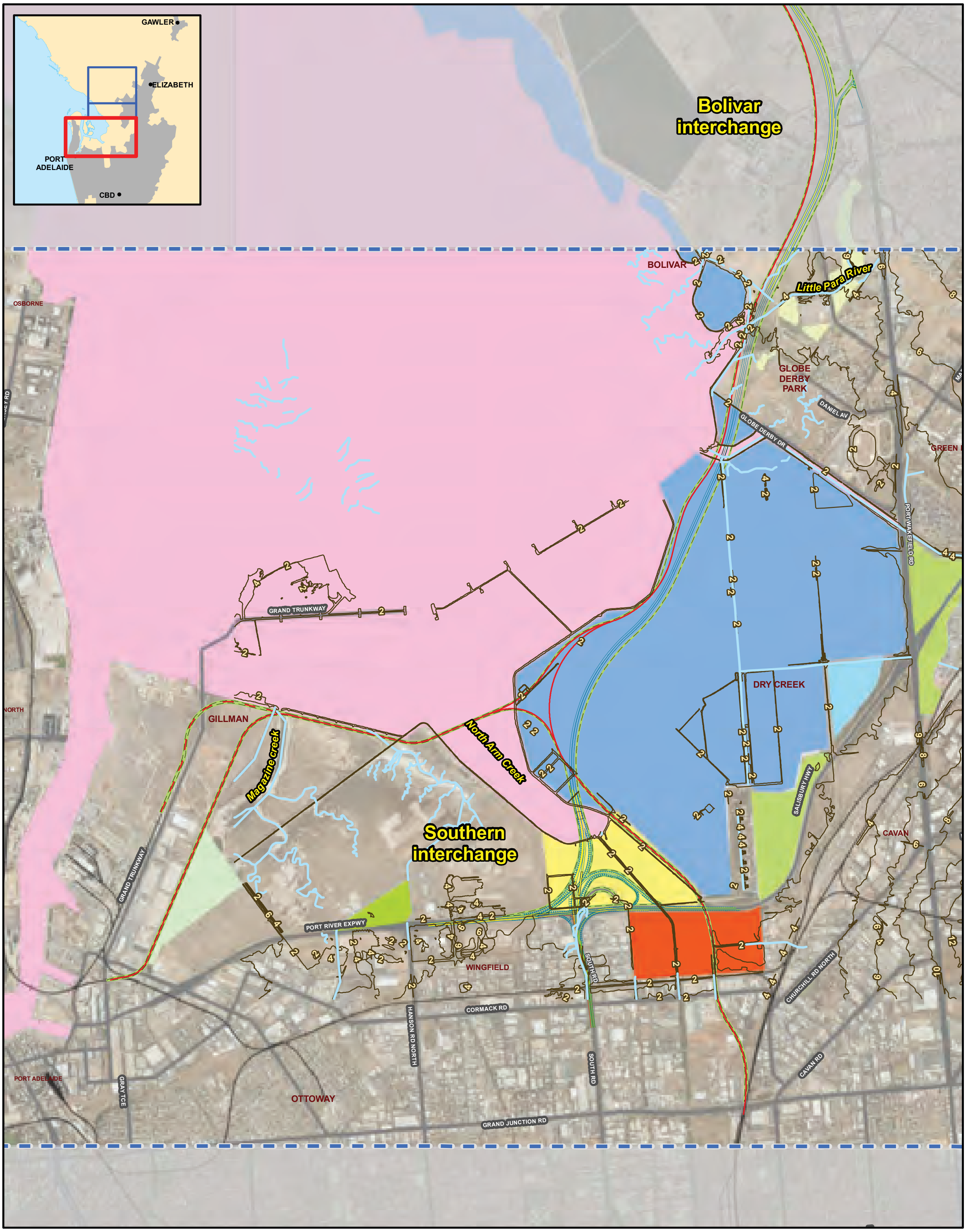
NORTH

0 0.5 1
Kilometres

Figure 20.2 **Topography and surface water - Central section**

- Northern Connector road
- Northern Connector rail
- Northern Connector boundary
- Embankment
- Existing road
- 2m contour
- Watercourse
- Port river Estuary
- Salt fields
- Intertidal samphire
- Little Para outfall wetlands
- Wetlands

Source: DEH, DTEI, DPLG



Source: DEH, DTEI, DPLG

NORTH

0 0.5 1
Kilometres

Figure 20.3 **Topography and surface water - Southern section - preferred road and rail**

- Northern Connector road
- Northern Connector rail
- Spur line to Port Flat siding
- Northern Connector boundary
- South Road Superway
- Embankment
- Existing railway
- Existing road
- 2m contour
- Watercourse
- Salt Fields
- Intertidal samphire
- Barker Wetlands North
- Barker Wetlands South
- Little Para Outfall Wetlands
- Port River Estuary
- Range Wetlands
- Magazine Creek Wetlands
- Greenfield Wetlands Stage 1,2 and 3

The peak 100-year average recurrence interval (ARI) of the drain (box culvert) under Port Wakefield Road is of a Q100 standard with the channel having 26 m^3/s for a 24 hour duration event.

Once across Port Wakefield Road, the drain proceeds west, passing between effluent ponds of the Bolivar Wastewater Treatment Plant (WWTP). It then heads south and eventually discharges into Barker Inlet.

Development, both as new and infill, is expected to continue in the Helps Road drain catchment. While this may theoretically result in increased catchment flows, it is likely that new development would be required to protect downstream properties and infrastructure, in particular the Edinburgh Parks industrial precinct, by installing detention facilities. Minor flows through the Helps Road Drain drainage system could be substantially reduced in the future as more planned stormwater harvesting and reuse schemes are implemented. This is unlikely to affect flows for events in excess of the one-year ARI.

Major flows, at or above the 100-year ARI, are limited by the culvert capacity of the Adelaide–Darwin rail line.

Central section

Key land uses in the Central section include:

- Bolivar WWTP
- expressway-related commercial development fronting Port Wakefield Road.

Little Para River is the main surface water drain in the Central section.

Little Para River

Little Para River has a significant rural catchment of approximately 124 km^2, which is generally steep, with groundcover varying from dense natural vegetation to sparsely grassed areas and pockets of pine forests in the upper reaches. Existing and proposed urban areas above Main North Road are steep and predominantly undeveloped, while the upper and lower plains area downstream of Main North Road are almost fully urbanised, including large industrial and commercial complexes. Cobbler Creek catchment, which feeds into Little Para River, is largely rural above Main North Road, close to the Golden Grove development.

Little Para River passes near Paracombe in the Mount Lofty Ranges, flowing generally in a northerly direction to Little Para Reservoir, north of Golden Grove. The portion of Little Para catchment upstream of the reservoir is 83 km^2, or 67% of the total catchment area. The reservoir, which was constructed in 1978, mitigates rural flows to the extent that critical flows in the lower reaches are in response to urban runoff. The extent of flood mitigation in major events depends on how full the storage is at the time of the event.

The river’s channel is leveed for the entire length between the overflow drain and Port Wakefield Road. West of Port Wakefield Road the river is leveed on the eastern side. The peak 100-year ARI flow in the main channel in the vicinity of Port Wakefield Road (before mitigation works) was approximately 56 m^3/s. Little Para overflow drain, which takes excess flows, was designed to convey 26 m^3/s leaving the main channel capacity at 30 m^3/s.

The capacity of the Port Wakefield Road bridge structure over Little Para River is in the order of 30 m^3/s.

Southern section

Key land uses in the Southern section include:

- Globe Derby Park trotting track
- residential areas adjacent to Globe Derby Park
- Cheetham Salt Ltd salt fields.

The Southern section also includes:

- Barker Inlet north and south wetlands, and Greenfields Stages 2 and 3 wetlands
- Barker Inlet–North Arm Creek mangroves
- Magazine Creek, Magazine wetland and Range wetland.

Dry Creek

The catchment of Dry Creek extends to the top of the Eden escarpment to the east and is bounded generally by the River Torrens catchment to the south and Little Para catchment to the north and east. The catchment is approximately 105 km^2 in area.

Numerous creeks discharge in a westerly direction from the Eden escarpment, traversing the undulating residential areas of the City of Tea Tree Gully and ultimately contributing to Dry Creek.

Dry Creek is contained on the western side by the Para Fault Block until the northern extremity of the City of Port Adelaide Enfield is reached where the creek alignment makes a westerly turn as it makes an abrupt exit to the plains. The creek regime then changes from a moderate to steep gradient with defined floodplains down to Main North Road to a perched channel beyond. Dry Creek flows, from the Main North Road railway line to the tidal outlet, into Barker Inlet.

The creek is an artificially constructed and perched channel. Discharge was formerly controlled by tidal gates; however, these have since been removed. Substantial works have been undertaken at Dry Creek to prevent flooding of adjacent areas.

The peak 100-year ARI flow in Dry Creek at the Port Wakefield Road crossing is 205 m^3/s for the 3 hour critical duration event. The Dry Creek–Port Wakefield Road crossing is a bridge that spans the full width of the channel and has a capacity between Q20 and Q50 according to the latest floodplain mapping. From this crossing, the creek follows the north-eastern edge of Cheetham Salt Ltd salt fields, before discharging into Barker Inlet. The creek in this section has high levees on either side. There is a low-lying area near the corner of Globe Derby Drive and Trotters Drive, north of the levee. Stormwater from the urbanised corner of Globe Derby Park is drained by an existing pump system. Flooding details (City of Salisbury 2008c) indicate a flood of 1 m under Q100 conditions.

Barker Inlet north and south wetlands

Construction of Barker Inlet wetlands started in 1994 with the dual purpose of flood mitigation and treatment of stormwater from the surrounding catchment before it entered the Gulf St Vincent marine environment.

The wetlands, spanning 172 ha, are fed by four stormwater drainage systems, carrying urban and industrial stormwater runoff from a catchment of approximately 45 km^2 (4,500 ha) that extends as far south as Bowden, through suburbs such as Prospect, Gepps Cross, Croydon, Woodville, Regency Park and Wingfield. The land use in the catchment area is both commercial/industrial and residential but predominantly industrial, with major transportation routes (rail) being a feature.

Stormwater from urban and industrial areas enters the wetlands mainly via the following stormwater drains:

- Dunstan Road drain; Hindmarsh Enfield Prospect drain and North Arm East–Henschke St drain on the south side of Salisbury Highway into Barker Inlet south wetlands
- North Arm West drain from the south of Salisbury Highway (adjacent South Road) into Barker Inlet north wetlands
- inflow to the east is discharged from the adjacent Greenfields wetlands into Barker Inlet north wetlands .

Salisbury Highway divides the wetlands into two basins : the southern basin of three freshwater ponds; the northern basin divided by weirs into freshwater and saltwater (inter-tidal) ponds.

The primary function of Barker Inlet wetlands is improving the quality of the water discharging into Barker Inlet. Secondary benefits of the wetlands include:

- flood mitigation capacity
- provision of a diverse habitat for avian species (frequent, seasonal and occasional visitors), including breeding and foraging areas for waterbirds
- removal of litter and debris through gross pollutant traps
- environmental tourism and educational opportunities
- wetland habitat creation for aquatic invertebrates, insects, amphibians, crustaceans, mammals and reptiles
- tidal areas for mangrove accession and samphire regeneration
- potential source of stormwater for reuse.

Greenfields wetlands

Greenfields Stages 2 and 3 wetlands are also found in the Southern section but will not be directly affected by the project. These constructed wetlands were developed in stages with Stage 1 (25 ha) being completed in 1990, Stage 2 (12 ha) in 1993 and Stage 3 (72 ha) in 1995. They were one of the first large, constructed urban wetlands in Australia.

Greenfields wetlands provide flood protection and water retention capacity for stormwater from their catchment.

Range and Magazine wetlands

Range wetlands (17 ha) and Magazine wetlands (36 ha) are located in the project's Southern section in the Gillman area. They receive flows from Torrens Road drainage catchment. Range wetlands receive inflow from Hanson Road and North Arm Road drains, and Magazine wetlands receive inflow from Eastern Parade and Jenkins Street drains (PAE 2007).

Both wetlands drain into the designated flood storage area north of the wetlands. This is an important function of the area, and acts as a temporary storage area for high tides and flood conditions. The wetlands are designed to intercept urban and industrial stormwater runoff and improve the quality before discharge into the mangrove estuary (PAE 2007).

20.2.3 Surface water quality

Surface water quality data (from the EPA) is available for surface waterbodies in the project area, and where there are other tributaries of interest, local government and the community often supplement this information through volunteer-based or locally funded monitoring programs such as Waterwatch. Monitoring frequency varies, from continuous data loggers recording stream flow to quarterly or bi-annual water chemistry assessments.

Surface water (stormwater) quality is a function of the build up of wash-off and of deposited pollutants from surfaces in a catchment. The specific land uses (and associated areas) in the catchment influence the quality of stormwater generated.

The impervious areas in a catchment related to transport (e.g. roads, driveways and car parks) are estimated to be as much as 50–70%, and are thus a prominent source of stormwater contaminants, such as:

- sediment and suspended solids
- heavy metals
- organic material
- oil, grease and hydrocarbons
- nutrients (mainly phosphorus and nitrogen)
- gross pollution and litter (solid matter more than 4 mm diameter).

Surrounding environment

Investigations of surface water quality have focused on the determination of existing conditions through review of water quality data, where available. The information available is limited to EPA monitoring data and the Port Adelaide Enfield State of the Environment Report (2007). Surface water quality is monitored across the Northern Adelaide Plains by community and local South Australian and Australian Government-run programs.

The receiving waters in the project area are Helps Road Drain, Little Para River, Dry Creek, Barker Inlet wetlands, Greenfields wetlands and ultimately Gulf St Vincent. The quality of the surface receiving waters of the project area is typical of urbanised catchments.

Where available, specific water quality data for the receiving waters has been reviewed and is included in the discussion.

Dry Creek

Dry Creek is largely in the City of Salisbury but also runs through the Port Adelaide Enfield suburb of Valley View. It is a fresh to brackish (slightly salty) stream that flows through the northern suburbs before discharging to Barker Inlet. Monitoring results from 2006 show high nitrogen levels (oxidised and total), while phosphorus, turbidity and heavy metal levels are considered to be good (EPA 2008b).

It is considered that the high nitrogen levels are probably derived from fertilisers, animal wastes or leaf litter being washed into urban stormwater drains. These sources are consistent with the observation that total nitrogen in Dry Creek is about 40% soluble oxidised nitrogen and about 60% organic particulate nitrogen.

Barker Inlet

Water quality (water chemistry and algal data) in Barker Inlet estuary (near North Arm Creek) is assessed by EPA as being in good, moderate or poor condition (note: no further definition of ‘good’, ‘moderate’ and ‘poor’ was provided in the EPA data discussion).

Water quality monitoring results for the 2006 period were generally consistent with, or lower than previous seasonal results for this site.

Ammonia, oxidised nitrogen and chlorophyll (a) were all classified as poor at the monitoring site in the estuary. Soluble phosphorus was also elevated. These results are probably due to industrial discharges into the river (such as those from Cheetham Salt Ltd and Bolivar WWTP), historical contamination from the now closed Port Adelaide WWTP and the large number of stormwater drains that discharge into the Port waterways (EPA 2008b).

Heavy metals were classified as poor (copper and zinc), which are most likely due to industry or urban runoff containing heavy metals washing off roads and galvanised iron roofs into the environment during rain events. In July 2006, a new analytical method for heavy metals was introduced, which can detect metals at much lower concentrations than before. It is now possible to confidently compare concentrations to National Water Quality Guidelines (EPA 2008b).

Range and Magazine wetlands

Currently there is no monitoring of the outlet from the wetlands for water quality entering North Arm Creek from the Range and Magazine wetlands (PAE 2007).

20.2.4 Groundwater

General

The project area is underlain by the Adelaide Plains Sub-Basin, consisting of sediments up to 600 m thick (Shepherd 1978), which is part of the larger St Vincent Basin. It contains layers of clay, sand and limestone of Tertiary and Quaternary age, overlying bedrock of Precambrian age.

Groundwater is present in a number of aquifers in the Quaternary and Tertiary sediments of the project area. The deeper aquifers in Tertiary sediments underlie the Quaternary sediments and are separated from the shallow aquifers by up to 35 m of Hindmarsh Clay. The clay provides limited potential for cross contamination between the shallow aquifers and the upper Tertiary aquifers. The deeper, confined Tertiary aquifers are used as a source of good quality water for irrigation and other purposes.

The project area is in the Adelaide and Mount Lofty Ranges Natural Resources Management Board region, predominantly in its Northern group area. The aquifers present in the area are summarised in Table 20.1 (Northern Adelaide and Barossa Catchment Water Management Board 2001).

Table 20.1 Aquifers of the Northern Adelaide Plains

Aquifer*	Description	Thickness (m)	Distribution
Q1, Q2, Q3 Aquifers	Mainly clay and silt with thin layers of sand	1 to 60	Vary from localised to widespread
Q4 Aquifer	Very fine sand	20 to 60	Widespread
T1 Aquifer	Sand, sandstone, sandy limestone	0 to 70	Widespread, thinning towards north
T2 Aquifer	Sand limestone	80 to 120	Widespread, thinning towards north
T3 Aquifer	Sand	5	Most of area
T4 Aquifer	Sand	Up to 60	Widespread, thinning towards north
P Aquifer	Fractured rock	Unknown	Extensive; outcrops to the east of the project area.

* Q aquifers are part of Quaternary aged sediments (only upper four (Q1 to Q4) have any significance)
T aquifers are part of Tertiary aged sediments underlain by Precambrian (P) rocks

Groundwater quality

In the complex mixture of confined and unconfined aquifers in the area, groundwater is sourced mainly from two relatively deep, confined Tertiary aquifers. The EPA monitors water quality in these two aquifers throughout the Northern Adelaide Plains area (i.e. the area surrounding the project area).

Groundwater samples are collected annually from eight bores in the Northern Adelaide Plains area. Indicators that are measured in the aquifer systems include nutrients (nitrogen and phosphorus), heavy metals and salinity. The environmental values that need to be protected are freshwater ecosystems, drinking water, irrigation use and livestock use.

The groundwater is classified as moderate for drinking water quality due to elevated salinity. Some of the elevated salinity is likely to be due to natural variations. However, salinity increases are largely due to leakage of saline water from shallow aquifers and seepage from underlying saline aquifers due to pressure reductions in the aquifer. Salinity was 550–2,000 mg/L; the National Health and Medical Research Council guideline (for taste) has a low value of 500 mg/L and an upper value of 1,000 mg/L (EPA 2008b).

Aquifer storage and recovery

Aquifer storage and recovery (ASR) is a process of injecting water into a suitable underground aquifer for storage and later reuse. ASR activities have been undertaken in various areas adjacent to and surrounding the project area as part of stormwater recycling and wetland development projects of the City of Salisbury, City of Playford and City of Port Adelaide Enfield.

The City of Salisbury has established a network of 30 ASR bores where, during high rainfall periods, excess stormwater is filtered and cleaned by Greenfields wetlands and pumped into the underground storage aquifer for later reuse, including for irrigation.

No ASR bores are located directly in the project area.

20.3 Potential impacts of the project on existing conditions

Construction of transport corridors and the associated vehicle use can affect water quality, aquatic ecosystems, flooding and drainage in three main areas:

- hydrology — volume, timing and direction of surface and subsurface flows
- physical — landforms, altering creek lines, altering ambient water temperature
- pollution — from vehicles, machinery and materials.

For the Northern Connector, potential impacts have been investigated for the project phases of:

- planning and design

- construction
- operation.

A water quality risk assessment (in accordance with the Protecting Waterways Manual (DTEI 2002) Section 5 and Attachment E) was completed to identify impacts associated with water quality, flooding and drainage for each phase of the project. The risk assessment also identified measures to mitigate the potential impacts of the project (Section 20.4).

20.3.1 Planning and design

Specific water quality, flooding and drainage issues to be considered as part of the planning and design phase of the project (Table 20.2) were identified during the water quality risk assessment.

Table 20.2 Summary of water quality, flooding and drainage impacts (planning and design phase)

Issue	Project area	Potential impact	Likely significance
Flooding and drainage	Southern section Barker Inlet wetlands	Increased flooding potential due to bisection of marine intertidal and freshwater zones by road and rail embankments	Critical
Flooding and drainage	Southern section Cheetham Salt Ltd Dry Creek salt fields and southern interchange	Increased flooding (magnitude and frequency) of low-lying land to north of Dry Creek levee due to road embankments Potential for stagnant pools of water to accumulate against road and rail embankments	Low
Flooding/ stormwater detention and storage	Southern section Dry Creek/Globe Derby Park	Increased flooding (magnitude and frequency) of low-lying land to north of Dry Creek levee due to road and rail embankments Reduced stormwater detention storage in and around the area of Dry Creek levee due to road alignment and embankments	High
Flooding/ stormwater detention and storage	Central section Little Para overflow	Increased flooding (magnitude and frequency) adjacent to and surrounding Little Para overflow	Critical
Wetland function	Southern section Little Para River	Impact to volume and function of wetlands (Greenfields Stage 3 wetlands) due to road and rail embankment locations	Critical
Wetland function	Increased footprint due to road over rail (e.g. embankments)	Impact to volume and function of wetlands	Critical

Issue	Project area	Potential impact	Likely significance
Wetland function - Barker Inlet	Southern section Barker Inlet wetlands	Impact to wetland function (Barker Inlet north and south wetlands) due to road embankments	Critical
Potential acid sulfate soils*	Northern, Central and Southern sections	Long-term impacts on infrastructure associated with acid (from disturbance of acid sulfate soils)	Medium

* Chapter 21 has further discussion on acid sulfate soils

20.3.2 Construction

During construction of the Northern Connector, potential impacts on receiving water quality (Table 20.3) could include:

- sedimentation and elevated turbidity levels from poor erosion and sediment control during site disturbance and the movement of construction vehicles
- discharge of water associated with dewatering activities
- litter accumulation from construction packaging and waste material
- hydrocarbon and toxicant contamination from spills and leakages
- altered pH and EC (electrical conductivity) associated with groundwater dewatering activities
- changes in pH levels associated with disturbance of acid sulfate soils.

During construction, sediment would be generated when rain or runoff contacts exposed areas or stockpiles of earth, suspending and transporting sediment to receiving waters located down slope of the construction area. Once in the receiving waters, sediment may affect the aquatic environment in a number of direct and indirect ways. Direct impacts include reduction in light penetration (limiting growth of aquatic plants), smothering of benthos and reduced visibility for predatory species. Indirect impacts of sediment can occur due to the long-term accumulation and desorption of attached pollutants such as nutrients and heavy metals.

Spills of fuels or chemicals may result from poor equipment maintenance or poor housekeeping practices associated with fuel/chemical storage on the construction site. Litter may result when insufficient waste storage devices are provided and from general poor housekeeping activities.

In the southern areas of the project, acid sulfate soils may be exposed during excavation. Leachate produced from these areas or stockpiles of such material has the ability to alter pH and create toxic conditions in receiving waters.

Table 20.3 Summary of water quality, flooding and drainage impacts (construction phase)

Issue	Project area	Potential impact	Likely significance
Acid sulfate soils	Northern section	Impacts on receiving water quality including: ▪ decrea ses in pH ▪ increases in heavy metals ▪ increased toxicity to aquatic flora/fauna ▪ soil contamination along flow lines	Medium
Acid sulfate soils	Southern section Cheetham Salt Ltd salt fields Gillman Barker Inlet wetlands and North Arm Creek	Impacts on receiving water quality including: ▪ decrea ses in pH ▪ increases in heavy metals ▪ increased toxicity to aquatic flora/fauna ▪ soil contamination along flow lines	High
Sedimentation	Southern section Low-lying areas where road and rail embankments would be constructed and 'pre-loaded' before finalisation of project	Impacts on receiving water quality: ▪ increase in turbidity/total suspended solids/total dissolved solids ▪ to aquatic ecosystems by reducing light and smothering organisms ▪ release of associated metals and nutrients	High
Interception of groundwater (<3 m unconfined saline aquifer)	Southern section (Central) – applies to northern area as well	Impacts on receiving water quality (associated with dewatering activities) including: ▪ increase in EC/total dissolved solids ▪ changes in pH ▪ sedim entation	High

20.3.3 Operation

During the operational phase, pollutant export from impervious surfaces has the potential to affect receiving water quality adversely. The DTEI *Protecting Waterways Manual* (DTEI 2002) identifies potential pollutants in runoff from impervious areas:

- gross pollutants and litter (solid matter less than approximately 4 mm diameter)

- sediment and suspended solids
- nutrients (primarily phosphorus and nitrogen)
- oils and surfactant pollutants creating a biochemical oxygen demand
- toxic organic compounds (including herbicides and heavy metals).

Each has different sources and potential impacts.

Gross pollutants and litter

Gross pollutants and litter include human-derived litter, vegetation and coarse sediment. In urban catchments, organic material (leaves from trees and garden waste) is one of the largest contributors to gross pollutant export. From a transport operational perspective, human-derived litter is considered the largest contributor to the gross pollutant load.

Coarse sediment and vegetation may be generated by direct deposition on to the road surface by trucks carrying uncovered loads or by maintenance activities adjacent to the expressway and in the drainage system, or the disposal of waste from cars using the road.

Gross pollutants may affect the receiving environment in a number of ways, as well as reducing the drainage capacity of the stormwater system. Unsightly, gross pollutants reduce both the roadside amenity and visual amenity of waterways. They may physically affect aquatic habitats and organisms, such as entangling birds in plastic and may also contribute to the contamination of receiving waters from other associated pollutants.

Sediment and suspended solids

During dry periods, sediment accumulates on road surfaces from both vehicle movements and atmospheric deposition. During rainfall events the sediment is mobilised to the stormwater system and the receiving environment as suspended solids.

Suspended solids may directly affect the receiving environment by:

- physically coating aquatic plants, reducing light availability and consequently limiting growth
- reducing food availability for aquatic grazers
- reducing visibility due to turbidity, affecting fish and aquatic habitats (DTEI 2002).

Suspended solids are also typically a source of nutrients. Excessive suspended solid pollution may lead to increased nutrient levels in the receiving environment, and thus increases in the numbers of plants that can use high nutrient concentrations, such as emergent macrophytes and algae.

Toxic pollutants, such as heavy metals, may be attached to suspended solids, using the particulate material as a transport medium to the receiving environment.

Nutrients

Nutrients may enter the stormwater system through a number of sources, including sediment, nitrous oxide deposition from vehicle exhausts and organic waste. Excessive nutrient levels may lead to eutrophication and excessive macrophyte and/or algal growth in the receiving environment.

Excessive growth of plants and algae contributes a high organic load to the waterway, which may deprive the water column of oxygen during night-time respiration and through decomposition of decaying material. Some forms of algae may also release toxins into the water column, possibly leading to fish kills.

Oils and surfactants

These substances are generally found in road runoff due to vehicle leaks, poor vehicle maintenance and general vehicular activities. The impacts include toxic effect (toxic organics), reduced visual amenity (oils and surfactants) and increased chemical oxygen demand.

Toxic organic compounds

Heavy metals can be a major source of toxicity in urban runoff, with the key metals being cadmium, copper, chromium, lead, zinc and nickel. They are typically present in both dissolved and particulate form, though most metals are transported in runoff as attached pollutants to suspended solids (DTEI 2002).

Accidental spills

In addition to the pollutant export associated with stormwater runoff, receiving water quality may also be affected by spills caused by accidents during operation of the project. Due to the proximity of the surrounding wetland environments, any spillage of chemicals on the Northern Connector during operation has the potential to enter the receiving waters through the stormwater drainage network.

The sensitive nature and proximity of the receiving environment means that the consequences of any chemical spill may be significant, potentially resulting in the death of plant and animal species coming in contact with the spill.

20.4 Management and mitigation

20.4.1 Planning and design

Flooding and drainage — general

All stormwater design would be undertaken in accordance with recommended principles in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim 1987) and consistent with DTEI standards.

In order to address the flooding and drainage aspects of the project, the project area has been divided into drainage blocks, which relate to the longitudinal drainage characteristics of the existing environment.

The blocks have been developed as follows:

- Northern interchange–St Kilda Road
- Helps Road drain
- Little Para River and Dry Creek
- Cheetham Salt Ltd Dry Creek salt fields
- Southern interchange.

The proposed design specification requirements for works in these blocks are detailed below in Figures 20.4 and 20.5.

Northern interchange–St Kilda Road

The longitudinal terrain of this block is virtually level. The existing stormwater receiving channel is the shallow table drains of St Kilda Road, which have minimal capacity. There is no depth or residual capacity of these drains to take the accumulated and concentrated stormwater flows associated with the road.

The proposed 'basin and weir' approach would form two linear ponds either side of the channel and a weir on the downstream (western) side of the formation.

During an extreme rain event (e.g. 1-in-100 year ARI) the weir would spread surface flows to a thin sheet-flow in a similar situation to the existing and would pose no further flooding hazard.

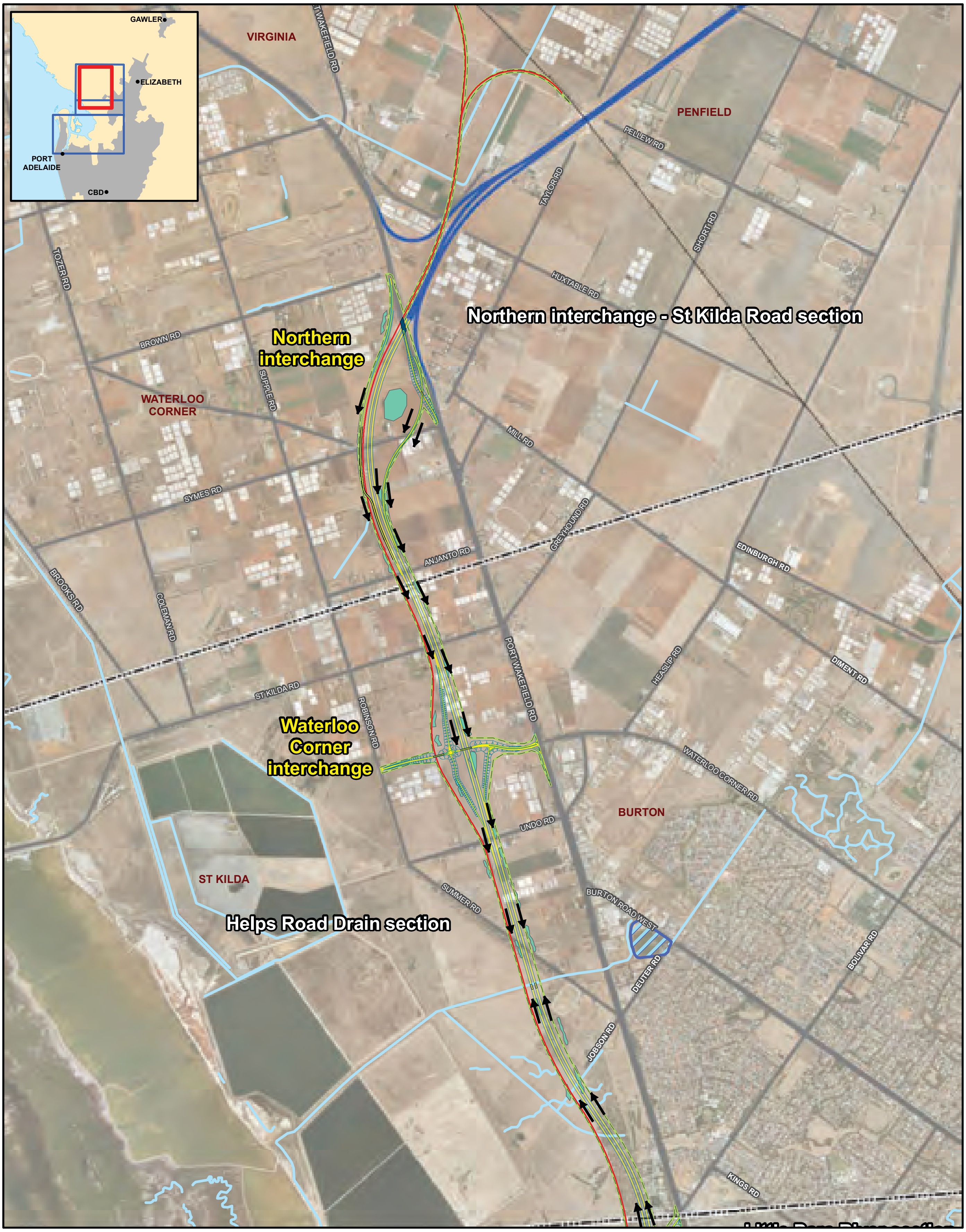
The flow into the St Kilda Road drains would be controlled and varied by the size of the outlet pipe through the levee weir (i.e. the equalising culvert of a Q100 ARI standard) and a localised 'notch' in the levee. As a national freight route, the project has been designed to have Q100 flood immunity.

Helps Road drain

In this block, conventional swales on either side of the corridor are proposed due to the additional longitudinal fall in the terrain that would enable the swales to discharge to Helps Road drain. The longitudinal swales would be designed to a 5-year ARI standard and include 200 mm freeboard.

The Little Para overflow cuts through this block of the project area but would not discharge into the Helps Road system as a mound with a minor pipe (Q5 design specification) would be included in the main swale downstream of the Little Para overflow crossing.

The junction of the longitudinal swale with Little Para overflow would consist of a mound downstream of the junction with a low flow pipe of Q5 capacity (through the mound). A pond formed upstream of the mound would assist the Q5 flow through the pipe. The mound would also serve as a levee to guide Little Para overflow water to remain its current flow path and prevent flow entering Helps Road drain.



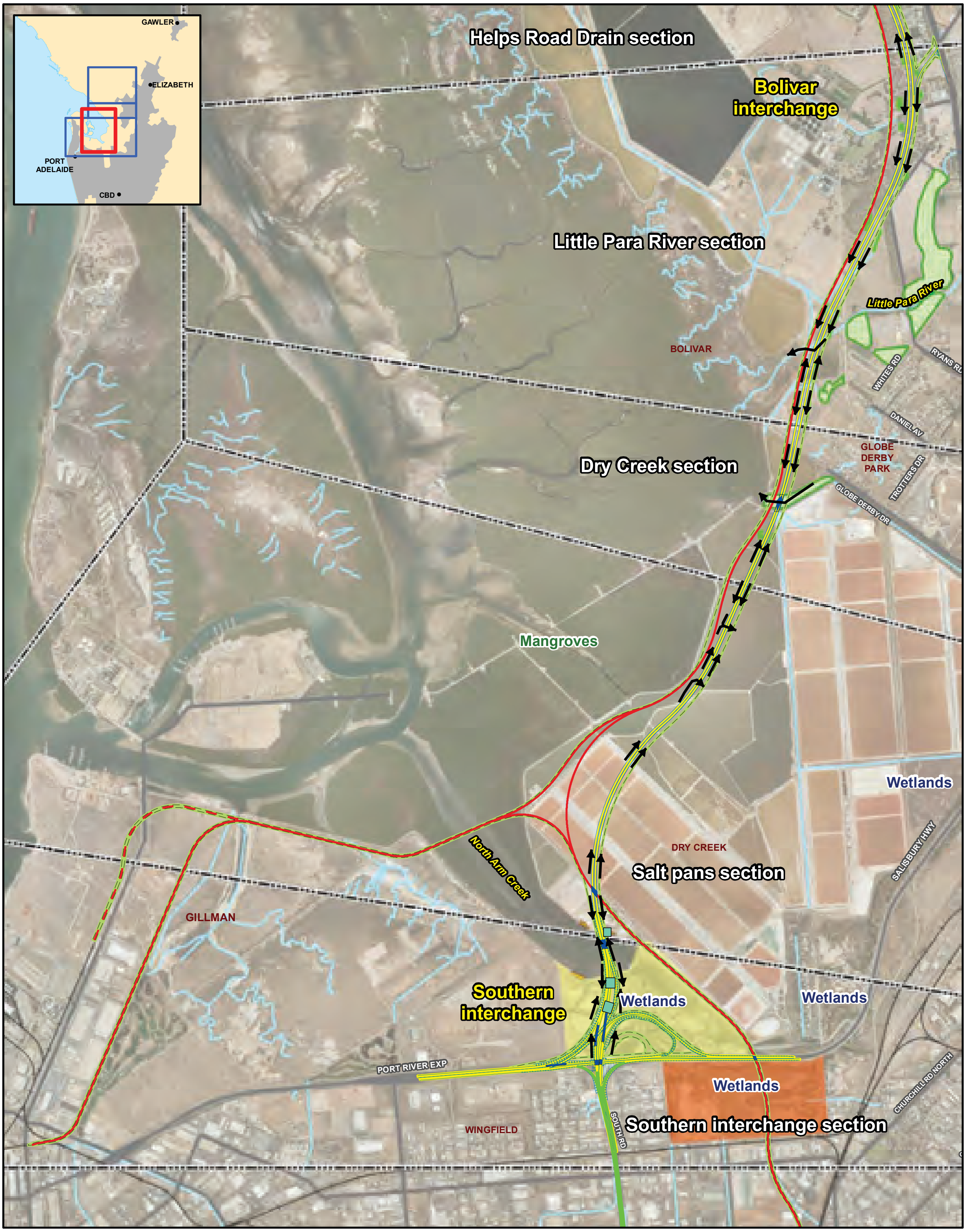
Source: DEH, DTEI

NORTH

0 0.5 1
Kilometres

Figure 20.4 **Stormwater Concept Plan - Northern interchange - St Kilda Road and Helps Road Drain sections**

Northern Connector road	Embankment	Stormwater sections
Northern Connector rail	Watercourse	Wetlands
Northern Connector boundary	Direction of stormwater flow	Detention Basin
Northern Expressway	Existing railway	



Source: DEH, DTEI, DPLG

NORTH

0 0.5 1
Kilometres

Figure 20.5 **Stormwater Concept Plan - Little Para River, Dry Creek Salt pans and Southern Interchange sections**

- Northern Connector road
- Northern Connector rail
- Spur line to Port Flat siding
- Northern Connector boundary
- Existing railway
- Existing road
- Watercourse
- Embankment
- Direction of stormwater flow
- Little Para Outfall Wetlands
- Stormwater section
- Proposed road runoff treatment pond
- Detention basin
- Barker Wetlands North
- Barker Wetlands South

Little Para River and Dry Creek

Little Para River and Dry Creek blocks would have a conventional swale configuration as for Helps Road (i.e. conventional swales on either side of the corridor that would discharge to Little Para River and Dry Creek). The longitudinal swales would be designed to a 5-year ARI standard and include 200 mm freeboard.

A number of existing embankments/levees would require realignment or extension (in the lower lying areas) to accommodate the new swales. Flap valves would be incorporated into the design of the outlets to be located at Little Para River and Dry Creek.

Cheetham Salt Ltd Dry Creek salt fields

Flooding and drainage design elements in the block of the project area running through Cheetham Salt Ltd Dry Creek salt crystallisation fields and concentrator ponds would include elevated road and rail formations.

The final design of the formation would consider the continued operation of Cheetham Salt Ltd operations, and as such, require that no runoff should enter these areas (i.e. complete runoff containment).

Batter swales and a central pond that would capture and hold all road pavement runoff would be incorporated into the stormwater design for this area. Batter swales would discharge (laterally) to the central median. The longitudinal design of the batter swales would address an estimated 20-year ARI standard, subject to further discussion with Cheetham Salt Ltd on the planned duration of operations.

The central pond would form a holding area with water being released through evaporation and soakage. Average annual rainfall for the area is approximately 500 mm (BOM 2009a); average evaporation is approximately 2,500 mm per annum (BOM 2009b).

Southern interchange

The Southern interchange block would consist of elevated viaducts, bridges and embankments located in and over the intertidal mangroves and Barker Inlet wetlands. The design allows for intertidal movement of water into and out of the wetlands as currently occurs.

Stormwater from the interchange would be collected through swales, and the kerbed and piped system, and directed to a holding pond coupled (e.g. turkey nest wetland) with sedimentation properties. In addition to holding the water, the pond would assist in sedimentation and water quality treatment and discharge slowly to the marine intertidal wetlands via a low flow pipe.

Wetland offsets

Wetland offsets and modifications to the existing wetlands would mitigate the direct impacts of the project (see Section 8.13).

Flooding and drainage – watercourse crossings

Proposed design requirements for works associated with major watercourse crossings (Table 20.4) would be refined to specific requirements during the detailed design phase.

Table 20.4 Major watercourse crossing design requirements

Crossing	Proposed design requirement(s)
Dry Creek	Design flow for hydraulic capacity of the crossing would be of Q100 standard; 160 m^3/s according to the City of Salisbury report (Tonkin & Associates 2008) The former higher 200 m^3/s Q100 flow, upstream of Port Wakefield, reduced due to the storage effect caused by Port Wakefield bridge
Little Para River	Design flow for hydraulic capacity of the crossing would be of Q100 standard; 30 m^3/s according to City of Salisbury report (Tonkin & Associates 2006) According to the report the original higher Q100 flow of 56 m^3/s was reduced due to the restricted cross sectional capacity of the lower reaches of the River. The residual 26 m^3/s overflows to the adjacent drainage reserve and to the Little Para Overflow drain.
Little Para overflow	Proposed design flow a Q100 standard of 26 m^3/s (subject to verification by City of Salisbury Council representatives)
Helps Road drain	Proposed design flow a Q100 standard of 30 m^3/s (subject to verification with City of Salisbury Council representatives)
North Arm Creek	Crossing design allows for unimpeded tidal movement Preliminary design: a length of bridge and a number of culverts/pipes

Water quality

A ‘treatment train’ approach has been considered in developing reasonable and practicable measures to address water quality issues associated with the project. A treatment train is a series of treatment measures that cumulatively address water quality issues. The approach fits the nature of the project (and receiving environment) and different treatment measures are required to treat different pollutants (DTEI 2002).

Treatment train measures included in the project design are capable of addressing issues of sedimentation, organic matter, litter and nutrients, and include:

- buffer strips
- diversion drains
- vegetated swales
- sedimentation basins
- retention basins
- constructed wetlands.

Treatment measures to address issues associated with hydrocarbons and accidental spills will also be considered during the detailed design phase.

20.4.2 Construction

Soil erosion and drainage management

Management of potential water quality effects during construction centres on management of suspended sediment transported by stormwater.

A soil erosion and drainage management plan (SEDMP) would be developed and implemented before construction. The SEDMP would be prepared in accordance with EPA guidelines, such as those in *Stormwater Pollution Prevention Code of Practice for Local, State and Federal Government* (EPA 1998).

While soil erosion and the generation of sediment during construction cannot be entirely prevented, sound project planning and appropriate design of control measures would reduce the effect on water quality both on-site and off-site.

Erosion and sediment control would be managed in a variety of ways during construction including:

- diversion banks (created upstream of project work areas) to divert upstream runoff around exposed work areas
- temporary sedimentation basins and minor sediment traps
- check dams (e.g. rock dams)
- hay bales and sandbags
- sediment fences (located along corridors and work areas, e.g. material stockpile areas)
- progressive vegetation of batters
- stabilisation of the road embankment using preloading with cover crop, mulch, soil binding agents or commercial 'crusting' agent
- regular inspections and maintenance of sediment fences, basins and other erosion control measures.

The specific details of the erosion and sediment management measures would be contained in the SEDMP, which would form part of the Contractor's Environmental Management Plan.

Water quality monitoring

Water quality will be monitored during construction but specific details of the monitoring will require review following design finalisation.

A water quality monitoring program for the project will:

- collect baseline data to establish pre-construction conditions

- select locations that would most effectively identify impacts from construction activities
- in some locations monitor on an event basis with a specific rainfall intensity being the trigger for the monitoring event (the trigger would be the amount of rainfall required to generate runoff in the identified area)
- establish photopoints and physical observations associated with water appearance
- collect rainfall and weather details.

20.4.3 Operation

Flooding, drainage and surface water quality

The project would alter and add to existing minor and major drainage and flooding systems in the project area.

Although an increase in the volume of stormwater in the area would result from the project, and alterations and additions to the drainage and flooding systems are required, management of stormwater through collection and discharge would continue in much the same manner as at present.

During operation, management of constructed stormwater-receiving environments, such as wetlands and drainage lines, would be required. No specific treatments are proposed for ongoing operation.

Ongoing maintenance

Drainage features and collection areas would have to be periodically monitored and maintained by cleaning and mowing of swales and buffer strips, de-silting of sedimentation facilities and replacement of damaged erosion protection.

Accidental spill containment

The project is aimed at improving the safety of the road, thereby reducing the potential for accidents. Nevertheless the risk of accidental spillage of hazardous materials would remain.

Any new stormwater drainage swales along the road corridor would be designed to allow the use of temporary bunding and containment of runoff to mitigate potential effects of accidental spills.

A quick response to spills would be facilitated by a spill response plan identifying isolation points, vulnerabilities and an efficient chain of events to enable clean-up.

21 Geology, soils and contamination

21.1 Introduction

21.1.1 Assessment approach

Geology and soils assessment approach

The methodology employed to assess geology and soils for this project was based on:

- desktop review of existing information relating to regional geology and soils (including acid sulfate soils)
- assessment of preliminary geotechnical investigation results.

Site contamination assessment approach

The methodology for assessing site contamination was based on:

- desktop analysis of the route alignment in each section by reviewing land use and development plan zoning, aerial photographs and past projects
- kerbside site inspection
- assessment of potentially contaminating activities across the project area (based on results of the desktop analysis and site inspection).

21.1.2 Policy and legislative requirements

Environment Protection Act 1993

The Department for Transport, Energy and Infrastructure (DTEI) has a 'general environmental duty' under the requirements of Part 4 (section 25) of the *Environment Protection Act 1993.* This general duty specifies that a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm. The South Australian Environment Protection Authority (EPA) guideline and standard applying to the project are:

- *Guideline for Environmental Management of Onsite Remediation* (EPA 2008c)
- *Standard for Production and Use of Waste Derived Fill* (EPA 2010b).

National Environment Protection (Assessment of Site Contamination) Measure

The *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Assessment of Site Contamination NEPM) sets out the basis for assessing the significance of soil contamination. This NEPM has been adopted by the EPA as policy under Part 5, section 28A of the Environment Protection Act.

The NEPM outlines the steps required to undertake an assessment of a site to understand the potential environmental issues associated with the change of land use.

Stormwater Pollution Prevention Code of Practice for Local, State and Australian Government

This general code of practice for the control of stormwater pollution at its source for local, South Australian and Australian Government agencies provides agencies and their contractors with information on the strategies and techniques available to reduce the incidence of stormwater pollution at its source.

The code of practice provides for the preparation of a soil erosion and drainage management plan (SEDMP) where there is a risk of significant pollution to adjoining lands or receiving waters.

21.2 Existing conditions

21.2.1 Physical environment

In terms of geomorphology, geology and soils, the physical environment through which the preferred route of the Northern Connector passes may be divided into two sections: north and south of Bolivar Wastewater Treatment Plant (WWTP).

North of Bolivar WWTP, the project area lies in the Lower Alluvial Plain geomorphic unit, which is characterised by land that is slightly more elevated than the land to the south, and is underlain by alluvial soils representing outwash fan deposits from the major stream lines. Groundwater is expected to be deeper and less saline than in the area to the south, and coastal acid sulfate soils are not generally expected to be present.

The Lower Alluvial Plain, bounded by the Coastal Plain to the west and the Para Fault Zone to the east, includes the residential development east of Port Wakefield Road. The Alluvial Plain is quite flat (typical surface gradients of 0.2–0.4%) and much of this land has been developed for housing, farming, horticulture and industry.

South of Bolivar WWTP, the project corridor lies in the Coastal Plain geomorphic unit, characterised by low-lying land underlain by marine and estuarine soils. The subsurface profile is expected to contain shallow, saline groundwater and include coastal acid sulfate soils.

The coastal plain encompasses the inter-tidal mangrove flats and supra-tidal samphire flats. The western limit of the Coastal Plain is bounded by Gulf St Vincent and the eastern limit is approximately defined by the 6 m Australian height datum (AHD) contour. The near-flat Coastal Plain (typical surface gradients of less than

0.2%) is subject to periodic stream and marine flooding where the land is not protected by levee banks.

The boundary between the geology and soils of the Lower Alluvial Plain and the Coastal Plain is not sharp, but rather transitional, and lies within the grounds of Bolivar WWTP.

21.2.2 Geology and soils

Geology

North of Bolivar WWTP, the near-surface geology comprises the Pleistocene aged Pooraka Formation, which is a deposit of alluvial origin over the Lower Alluvial Plain. It comprises red-brown to light brown sandy clays and clayey sands. Some calcareous silt is present in the unit. The thickness of the Pooraka Formation may also show considerable variation, up to a maximum of approximately 6 m. The clayey strata within the unit are typically stiff.

South of Bolivar WWTP, the near surface geology comprises the Holocene aged St Kilda Formation, which is of marine and estuarine origin and confined to the Coastal Plain.

Soils in the St Kilda Formation show considerable variability with location and depth, due to variations in the depositional environment. The main facies expected to underlie the project area are estuarine and lagoonal. The soil types are black to grey to blue-green in colour, and in composition they range from silts and clays to organic layers including peat and fibrous beds, shelly layers and sands. Shallow saline groundwater is associated with these soils, which also have a fetid odour and acid sulfate potential. The total thickness of St Kilda Formation may vary from under 1 m to nearly 10 m.

Underlying the St Kilda Formation is the Pleistocene aged Glanville Formation. The Glanville Formation is marine sediment, and its distribution is also essentially limited to within the Coastal Plain. It typically comprises grey shelly sand with some calcareous sandy clay and is several metres thick. The groundwater system in the Glanville Formation is only partially confined, and thus has a similar phreatic surface to the groundwater system in the overlying St Kilda Formation.

Soils

An identifiable soil profile is associated with each of the St Kilda Formation and Pooraka Formation surficial geological units.

North of Bolivar WWTP, the soil profile is a red-brown earth type (RB6/RB7). which typically comprises brown loamy topsoil, over red-brown to brown, sandy clay soil with low carbonate content overlying light brown sandy clay, clayey sand and sand below 1–2 m depth.

Along Little Para River and Dry Creek drain, the alluvial-type soil profile is poorly developed and typically comprises variable mixtures of brown clay, silt and sand.

South of Bolivar WWTP, the soil profile is an estuarine muds and sands type, which typically comprises dark coloured clays, silts, sands and organic deposits in variable combinations and sequences.

Acid sulfate soils

Acid sulfate soils are saline soils, which in their natural state, are saturated and contain pyrite (iron sulfide). Upon exposure of the soil to air through soil drainage or excavation, the pyrite becomes oxidised and sulfuric acid is produced. Potential acid sulfate soils are saturated pyritic soils that have not yet oxidised because they have not been disturbed. Actual acid sulfate soils are soils that are naturally pyritic that have been disturbed by dewatering and/or excavation, and generated sulfuric acid. Acid sulfate soils are widespread in coastal areas in South Australia, especially where mangroves are present.

The web-based atlas for South Australia (Figure 21.1) shows that the landward extent of acid sulfate soil mapping appears to be limited to the eastern edge of the Coastal Plain geomorphic unit, which is also the eastern edge of the distribution of the St Kilda Formation soils. This means that only that part of the project area south of Bolivar WWTP lies in the extent of the coastal acid sulfate soil. Actual acid sulfate soils have been identified in the Gillman area and there is potential for these soils to be disturbed during construction, although much of the rail alignment through this area will be on fill embankments.

Limited acid sulfate soil sampling and testing has been undertaken to date as part of the geotechnical investigations for the project. It suggests that potential, but not actual, acid sulfate soils are present.

21.3 Potential impacts of the project

21.3.1 Planning and design

Site contamination

Based on past and present land uses across the project area, a number of potentially contaminating activities have been identified. Typical contaminating activities, potential contaminates and likely significance (based on the development of a transport corridor) are outlined in Table 21.1. From a due diligence perspective, a number of other sites may need to be investigated for potential or actual site contamination before construction. These sites will be identified during the detailed design phase.

Table 21.1 Typical contaminating activities potentially present in project area

Potentially contaminating activity	Potential contaminants	Likely significance
Storage and use of agricultural chemicals during current and historical agricultural and horticultural activities	Various, including metal-based (arsenic, lead, copper, mercury, manganese, zinc) herbicides and fungicides, organochlorine and organo-phosphorus pesticides, phenoxyacid herbicides	Generally low Possibly higher significance in areas of more intense horticultural activities
Use of imported fill materials	Various, including metals and polyaromatic hydrocarbons	Moderate
Use of termiticides beneath existing and historical structures	Organochlorine pesticides, arsenic, chlorpyrifos	Low
Use of asbestos building products	Asbestos minerals	Low
Minor fuel storage and dispensing on agricultural properties (ASTs and drums)	Fuel hydrocarbons	Low-moderate
Stockpiling of wastes	Unknown, possibly including metals	Low
Presence of sheep and/or cattle dips	Arsenic, organochlorine pesticides, organophosphate pesticides, carbamates, synthetic pyrethroids	Low-moderate

21.3.2 Construction

Erosion potential

Exposed soil surfaces may be eroded by:

- wind erosion
- wave action from surface waterbodies
- surface water runoff, either by sheet flow or, especially, line flows.

Soil surfaces and subsurfaces may be dispersed by surface water runoff and/or subsurface seepage for soils that have an inherent lack of coherence in the presence of water.

Excessive erosion from wind and wave actions are considered unlikely to be a significant issue for the project; erosion of soil by surface water runoff is a potentially significant issue, especially during the construction phase.

The main impacts of soil erosion by surface water runoff are loss of material from along the route resulting in potential runoff and siltation of downstream receiving environments, in particular surface waterbodies. Rill and gully formation in earthworks, and local reduction in slope stability, may also develop.

Site contamination

The impacts associated with site contamination during construction are likely to be the exposure of underlying or undetected localised contamination. Any contamination is likely to have been a result of historical activities in the project corridor.

If site contamination is not managed effectively, contaminants may be released to the environment through contact with stormwater or the creation of dust.

Acid sulfate soils

The presence of potential acid sulfate soil does not present a problem if the soil is not disturbed, because potential acid sulfate soil is largely benign in its natural state. However, actual acid sulfate soil, and disturbance of potential acid sulfate soil, is undesirable. Excavations for drainage and bridges structures may disturb actual or potential acid sulfate soils known to exist in the area.

The level of risk associated with potential acid sulfate soil areas is considered to be moderate, due to the likely presence of monosulfidic black ooze at the top of the ground profile underlying the salt fields.

Additional investigations before construction would determine whether acid sulfate soils will be encountered and whether to develop a site specific soil and groundwater management plan.

21.3.3 Operation

Erosion potential

Once the Northern Connector is constructed, the potential for erosion would be greatly reduced due to the reduced surface area of susceptible exposed soils and because a permanent surface water drainage system would have been completed in the construction phase.

However, until a vegetative cover is established over exposed soil slopes, such as embankment batters (or other surface protection is provided), these slopes may still erode, with impacts similar to those described earlier for the construction phase.

Site contamination

As with erosion potential, once constructed, the potential for site contamination would be greatly reduced. Any contamination uncovered during the construction phase would be managed appropriately. Site contamination during the operational phase is likely to be as a result of new leaks and spills.

Appropriate management of the impacts of leaks and spills would need to be considered in more sensitive areas such as the wetlands, adjacent to residential or market garden areas through, for example, the diversion and primary treatment of effluent or stormwater.

NORTH

0 1 2
Kilometres

Figure 21.1 **Acid sulfate soil risk map**

Layer

- Northern Connector road
- Northern Connector rail
- Spur line to Port Flat siding
- South Road Superway
- Northern Expressway
- Existing roads
- Existing railway
- CSIRO 2002 field sample point
- 1 (a) - Actual ASS (disturbed)
- 1 (b) - Potential ASS (disturbed)
- 2 - Potential ASS (mangrove)
- 3 - Potential ASS (tidal stream)
- 4 - Potential ASS (intertidal)
- 5 - Potential ASS (supratidal)
- 6 - Sand
- 7 - Calcerenite
- 8 - Marine soils
- 9 - Other soils

Acid sulfate soils

No new acid sulfate soil impacts would be expected to be associated with the operation of the corridor because the ground profile is unlikely to be disturbed during the service life of the corridor.

21.4 Management and mitigation

21.4.1 Planning and design

Erosion potential

Although the impacts of erosion are mainly associated with the construction phase, a number of measures can be implemented during the planning and design phase to minimise construction phase erosion impacts, for example:

- specifying that dispersive materials are not to be used in earthworks
- designing permanent surface water drainage systems of adequate hydraulic capacity and with suitable scour protection along flow paths
- designing wave erosion protection to earth slopes in contact with surface waterbodies such as North Arm Creek
- minimising flow path gradients and the lengths of any steeply graded flow paths
- designing suitable surface protection measures for earth slopes, such as a quick growing vegetative cover or a geosynthetic erosion protection product.

Site contamination

The impacts of site contamination manifest themselves during the construction phase but activities to quantify the magnitude and extent of any contamination may be assessed during the planning and design phase. This pre-emptive activity, which could minimise problems during the construction phase, may include more targeted intrusive investigations in properties once they have been purchased or as a part of due diligence investigations before purchase.

Acid sulfate soils

The preferred hierarchy of management measures to deal with the risks posed by acid sulfate soils is set out in the Coast Protection Board document no. 33 (Sheard and Bowman 1996). The two most preferred measures are best implemented during the planning and design phase of the project:

- avoidance — leave the coastal acid sulfate soils in an undisturbed state
- minimising disturbance — minimise the opportunity for oxidation of potential acid sulfate soil by minimising excavation and/or dewatering of such soil.

These management measures would be implemented by virtue of the following:

- The greatest acid sulfate soil risk is the mangrove areas (high risk rating). The corridor would pass through a relatively small areas of existing mangroves on each side of the North Arm Creek.
- Design and construction of an embankment that sits above the surrounding Coastal Plain would require very little excavation or dewatering of the existing ground profile during construction.

A thorough acid sulfate soil investigation and risk assessment, in the manner outlined in Sheard and Bowman (1996) will be undertaken during detailed design.

21.4.2 Construction

Erosion potential

Before construction begins, the construction contractor would be required to develop an SEDMP as part of their contractor's environmental management plan (CEMP) in accordance with the *Stormwater Pollution Prevention Code of Practice for Local, South Australian and Australian Government* (EPA 1998).

It would be the responsibility of the contractor to design, construct, operate and maintain drainage and temporary erosion control measures. The contractor must:

- plan and carry out the whole of the construction works to minimise the effects of runoff and erosion on the site and downstream areas (e.g. avoid unnecessary ground disturbance and provide for the proper control of stormwater runoff at every stage)
- ensure that all required runoff, erosion and sediment control measures are in place and comply with the SEDMP before earthworks begin
- establish sediment control structures around all areas prone to erosion, including stockpiles, batters and drainage lines
- locate stockpiles away from drainage lines and in areas least susceptible to wind erosion, or use existing stockpile sites where available.

The erosion control measures to be developed and implemented by the contractor would include:

- staging clearing operations
- installing diversion drains or catch drains to divert concentrated flows to points where they can pass through the works without damage
- establishing temporary cover crops, using sterile plant species
- rehabilitating disturbed areas during the contract period
- stabilising soil to be stockpiled for longer than a period of one month, by grass seeding, covering or other appropriate means

- progressively revegetating the site as work proceeds where this forms part of the contract
- watering the works areas, by use of a water cart available on site full time, and temporarily paving haul roads
- avoiding or minimising dust generating activities during dry and windy conditions
- minimising the extent of exposed, stripped ground surface until covered with appropriate fill material.

These measures are discussed in more detail in Chapter 20.

Site contamination

The CEMP would be required to address site contamination management during construction including:

- systems to be put in place to stockpile and assess any areas of contamination discovered during the construction phase
- provision to be made for protected lay down areas with appropriate sediment and stormwater controls for the stockpiles while they are awaiting sampling and characterisation
- potential locations for on site encapsulation of contaminated soil to be agreed with the EPA (or accredited contamination auditor) and undertaken in line with the EPA (2010) *Standard for Production and Use of Waste Derived Fill*.

Acid sulfate soils

Acid sulfate soils management would only be required if the existing ground profile needs to be excavated below the watertable, with or without dewatering, and if:

- the existing ground profile is found to be unsuitable to act as a foundation stratum to the Northern Connector embankment
- a source of suitable fill material for embankment construction is discovered in the body of potential acid sulfate soils in the Coastal Plain
- point or linear excavations deeper than about 1 m below ground surface are required for service or surface water drainage infrastructure.

Where avoidance is not possible and some acid sulfate soil is disturbed, measures to manage the associated risks would be necessary. These would be set out in the CEMP, prepared before construction begins. The acid sulfate soil component of the CEMP would be developed in line with the EPA Guideline: *Site Contamination – Acid Sulphate Soils* (EPA 2007c) and include proposed management strategies as well as monitoring requirements and verification testing requirements, for the short term and long term. Construction phase measures for managing acid sulfate soil impacts are likely to include:

- stockpiling excavated spoil in a manner that minimises the generation and spread of acidity by: directing surface runoff around stockpile areas, collecting runoff from the stockpiles and not allowing it to discharge, covering the stockpiles with plastic sheeting or similar to minimise contact with the air, and not moving the excavated material further once it has been stockpiled
- neutralising the excavated material by mixing in a sufficient amount of a reducing agent, such as agricultural lime, or by mixing in other excavated soil containing lime or fine shells
- strategically reburying disturbed material below the watertable (may be an option for storage of excavated material that does not have a beneficial use for construction of the Northern Connector)
- maintaining tidal flushing wherever it currently occurs, for example by providing culverts or pipes through the base of the Northern Connector embankment where it would cross over North Arm Creek and other tidal streams.

21.4.3 Operation

Erosion potential

Measures to minimise erosion impacts during operation of the project would include:

- regular inspection and maintenance of formal drainage paths and earth slopes
- replacement of degraded slope protection surfaces such as vegetative covers and geosynthetic products.

Site contamination

Site contamination during operation of the Northern Connector may result from leaks and spills from road traffic accidents. Provision would be made to ensure that drainage from the road is managed to minimise the impact on established sensitive areas, particularly in areas where there is the potential for stormwater or effluent, generated during emergency treatment of the scene, to impact on sensitive locations, such as the wetlands.

Acid sulfate soils

No impacts from acid sulfate soils are expected as a result of the operation of the Northern Connector.

22 Greenhouse gas, sustainability and climate change

22.1 Introduction

Greenhouse gas emissions, sustainability and climate change are inter-related and overlapping subjects governed by a range of policy and legislative requirements.

22.1.1 Policy and legislation

Kyoto protocol

The Kyoto Protocol is an international agreement of 1997 that has been ratified by 178 countries. Australia deposited its ‘instrument of ratification’ in December 2007, which subsequently came into force on 11 March 2008. The protocol aims to reduce global greenhouse gas emissions by requiring developed countries to meet national targets for greenhouse gas emissions over the five year period, 2008–12. It recognises that developed countries have a responsibility to take the lead in international action because they are responsible for most of the world‘s past emissions. Each developed country‘s target was negotiated and agreed internationally.

Australia has committed to meeting its Kyoto Protocol annual target of 108% of its 1990 emissions and is on track to do so (Department of Climate Change 2008). Australia has set a further target to reduce greenhouse gas emissions by 60% of 2000 levels by 2050.

The target is a major priority of *South Australia‘s Strategic Plan* (Government of South Australia 2007a). In 2007, the Government of South Australia enshrined its targets in law, in the *Climate Change and Greenhouse Emissions Reduction Act 2007* and developed its long-term strategic response to climate change, *Tackling Climate Change: South Australia‘s Greenhouse Strategy 2007–2020* (Department of the Premier and Cabinet 2007; see below).

Carbon pollution reduction scheme

The Australian Government has delayed the release of the Carbon Pollution Reduction Scheme until after the end of the current commitment period of the Kyoto Protocol (2012). The scheme was flagged as Australia’s primary policy tool to drive reductions in emissions of greenhouse gases and reduce carbon pollution, by placing a cap on emissions.

The first step in the scheme will be the introduction of a carbon tax in 2012. The tax and scheme may cover emissions from stationary energy, transport, industrial processes, waste and forestry sectors.

The tax may cause carbon-emission intensive goods and services to increase in price, indirectly affect the overall budget to construct the Northern Connector and place greater importance of greenhouse gas estimations.

Effective management and mitigation measures to minimise consumption of resources are discussed in Section 22.5.

South Australia's Strategic Plan

The Government of South Australia has recognised the importance of tackling climate change and attaining sustainability, and one of the major tools to drive change is *South Australia's Strategic Plan* (see Section 3.1.3).

The Plan's sustainability priority most relevant to carbon management associated with the project is to 'achieve the Kyoto target by limiting South Australia's greenhouse gas emissions to 108% of 1990 levels during 2008–12, as a first step towards reducing emissions by 60% (to 40% of 1990 levels) by 2050.

The objective of Attaining Sustainability, focuses on attaining environmental sustainability through:

- a healthier River Murray
- more sustainable management of water resources
- reduced energy consumption and greenhouse gas emissions
- less waste
- soil protection
- protection of plant, animal and marine biodiversity.

The 30-Year Plan for Greater Adelaide

The 30-Year Plan for Greater Adelaide (Department of Planning and Local Government 2010a) has the key priorities of climate change mitigation and adaptation for the built environment. The expansion of Adelaide as a city will also require more efficient infrastructure to promote liveability. In particular, the Northern Connector forms an integral part of the plan's policy for non-stop travel along the strategic South Road and Northern Expressway to reduce stop/start traffic and improve overall greenhouse gas emissions.

Climate Change and Greenhouse Emissions Reduction Act 2007

The Climate Change and Greenhouse Emissions Reduction Act made South Australia the first place in Australia to legislate targets to reduce greenhouse emissions.

The legislation's three targets are to:

- reduce by 31 December 2050 greenhouse gas emissions in the State by at least 60% to an amount that is equal to or less than 40% of 1990 levels as part of a national and international response to climate change
- increase the proportion of renewable electricity generated so it comprises at least 20% of electricity generated in the State by 31 December 2014

- increase the proportion of renewable electricity consumed so that it comprises at least 20% of electricity consumed in the State by 31 December 2014.

The legislation also commits the Government to work with business and the community to develop and put in place strategies for South Australia to take early action to reduce greenhouse emissions and adapt to climate change.

Tackling Climate Change — South Australia's Greenhouse Strategy 2007–2020

South Australia's Greenhouse Strategy, the policy framework for South Australia's greenhouse targets and commitments, takes three key approaches:

- reduce greenhouse gas emissions
- adapt to climate change
- innovate in markets, technologies, institutions and lifestyle.

In order to be able to make and monitor improvements in these areas it is essential to establish a baseline for comparison.

Objective 7.4, To develop sustainable built environments that are responsive to climate change, highlights the need to complement energy efficient urban form with integrated transport strategies, water sensitive urban design and living belts of habitat throughout urban spaces.

The project responds to this objective in its effort to integrate greenhouse mitigation and climate change adaptation strategies into the successful delivery of this significant public infrastructure.

Tackling Climate Change: Government Action Plan to 2012

The action plan is a framework to guide the activities of government agencies in implementing the strategy for South Australia to meets its commitment to achieve the Kyoto emissions reduction target within the first commitment period of 2008–2012.

One of the key integrated land use and transport planning actions identified in this strategy is to plan for and maintain strategic transport corridors, infrastructure and freight intermodal sites.

The Government of South Australia has recognised the importance of tackling climate change, with the Premier of South Australia taking on a new portfolio as Australia's first Minister for Sustainability and Climate Change.

Draft Climate Change Adaptation Framework for South Australia

This Draft Climate Change Adaptation Framework is a first step to developing a coordinated and integrated response to climate change in South Australia. Action to address climate change will allow communities, businesses and individuals to minimise any negative impacts but also to identify and benefit from opportunities presented by climate change. The final framework is intended to facilitate the development of more detailed str ategies at regional, se ctoral and government levels.

Native Vegetation Act 1991

All native vegetation in South Australia is protected under the provisions of the *Native Vegetation Act 1991* (see Section 17.1.2).

Vegetation offsets, such as those required by the Native Vegetation Act, are generally not considered as carbon (or greenhouse gas) offsets because the vegetation in defined set-aside areas is typically already established.

The National Carbon Offset Standard states that the fundamental carbon offset criterion is 'additionality'. Additionality protects the environmental integrity of the offset product by ensuring that:

- real, measurable and permanent emissions abatement has occurred
- the abatement is not achieved through projects that would have been implemented anyway (Department of Climate Change and Energy Efficiency 2008).

Therefore, unless revegetation occurs in an area of greater size than that which is cleared for the Northern Connector, with vegetation of equal or higher sequestration, there will be a net release of carbon emissions.

National Strategy for Ecologically Sustainable Development

The *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments 1992) adopted by all levels of Australian government in 1992, provides broad strategic direction and frameworks for governments to direct policy and decision-making. Its core objectives are to:

- enhance individual and community wellbeing by following a path of economic development that safeguards the welfare of future generations
- provide for equity within and between generations
- protect biological diversity and maintain essential ecological processes and life support systems.

The South Australian Government has taken measures to ensure that ecologically sustainable development (ESD) principles — such as the precautionary principle, intergenerational equity and the conservation of biodiversity — are taken into account in its own decision-making processes. Legislation and government programs increasingly stress compliance with, or demonstration of, ESD objectives and principles.

The ability of the Northern Connector to meet ESD principles is discussed in Section 24.6.

State Natural Resources Management Plan

South Australia's first integrated State Natural Resources Management (NRM) Plan, released in 2006, is a key component of integrated natural resources management arrangements under the *Natural Resources Management Act 2004*.

The policies and strategies set out in the Plan inform the activities of: government agencies; regional NRM boards and groups; local government; community; and industry partners.

It ensures that management actions are better integrated to more effectively and efficiently protect and enhance South Australia's natural systems (catchments, bioregions, landscapes and ecosystems), whether they are managed for production, settlement or conservation.

Coast Protection Board Policy

The *Coast Protection Act 1972* governs the Coast Protection Board, whose duties are to protect the South Australian coast from erosion, damages, deterioration, pollution and misuse. This is done through various instruments, including policies to:

- provide for fair, orderly and ecologically sustainable use and development
- conserve the variety of life forms and ensure that the productivity, stability and resilience of ecosystems is maintained
- promote sharing of responsibility for resource management and planning between the different spheres of government, the community and industry in South Australia
- promote the enhancement of knowledge and expertise for coastal resource management and planning.

The Board has adopted the Intergovernmental Panel on Climate Change (IPCC) median sea level predictions, as part of its hazard policy. It has set guiding principles applying to new development with regard to coastal flooding and erosion and associated protection works.

The Northern Connector has been designed using these guiding principles.

Local government environmental strategies

City of Port Adelaide Enfield

The *Environment Strategy for a Sustainable City 2009–2014* focuses on the key environmental issues and opportunities facing the City of Port Adelaide Enfield (2009).

The main environmental issues, conditions and pressures in the council area have been identified and the strategy contains a range of responses that will define council's new focus for future environment planning.

City of Salisbury

The *City of Salisbury, Sustaining Our Environment — An Environmental and Climate Change Strategy 2007* has been developed to ensure integration across a broad range of independent strategies, policies and projects being developed for the city as well as any new future projects or strategic work.

The purpose of the strategy is to both focus on integrated sustainability initiatives and outcomes in the council, and have clear linkages and provide direction to the wider community and key stakeholders in the local government area (LGA).

City of Playford

The *City of Playford's Environmental Care Goal Plan 2006–2011* sets out the council's approach to ESD in the community over a five-year period.

The plan is a working document prepared in parallel with Playford's Economic Prosperity Plan and its Community Wellbeing Plan to ensure a comprehensive approach to sustainability.

The plan recognises the diversity of landscapes, land uses and built environment present in the LGA and establishes a number of environmental objectives that will guide the environmental management for the medium to long term.

22.2 Existing conditions

22.2.1 Greenhouse gas emissions

Transport sector

The transport sector was accountable for around 79 million tonnes of Australia's total net greenhouse gas emissions in 2006, or 13.7% of Australia's total emissions (Australian Greenhouse Office 2007). Approximately 87.1% of these transport emissions came from road transport, including cars, trucks and buses (Australian Greenhouse Office 2007).

Greenhouse gas emissions from the transport sector are growing substantially. They rose by 22% between 1990 and 2006 (Australian Greenhouse Office 2007) and are expected to continue to rise at least into the near future.

In South Australia, transport sector emissions accounted for approximately 21% of South Australia's 2006 greenhouse gas emission profile (Australian Greenhouse Office 2007).

Vegetation

A total of 49.79 hectares of native vegetation (as defined by the *Native Vegetation Act 1991*) grows in the project corridor. This vegetation includes mangrove forest, samphire shrubland, reed beds, sedgelands, low shrublands and chenopod shrublands with very small areas of riparian Red Gum woodland.

22.2.2 Climate change

The Northern Connector corridor traverses three council areas — Playford, Salisbury (the largest section) and Port Adelaide Enfield.

The City of Port Adelaide Enf eld, and its environs, has been identified as a crucial precinct potentially 'at risk' from a climate change event, such as sea level rise, due to its coastal nature and history as an 'unnaturally' engineered area (SMEC Australia 2007).

Its coastal location and low-lying lands, subject the local region and any infrastructure to risk from the effects of storm surge, sea level rise and stormwater inundation, which in turn present a threat to the local coastal ecosystem.

Sea level rise is already occurring in South Australia at a rate of 1.5 mm per annum and calculated to result in an increase of 0.3 m by 2050 and a further 0.7 m increase by 2100 (Coast Protection Board 2002). This is likely to increase the frequency and extent of seawater flooding, which would have a detrimental impact on habitat distribution, agriculture, coastal buildings and infrastructure.

In response, the City of Port Adelaide Enf eld commissioned the *Port Adelaide Seawater Stormwater Flooding Study* (2005) to evaluate seawater and stormwater flood risks around Port Adelaide. This study takes into account the Southern section of the project.

The f rst stage (collection of coastal hydrology data) was completed in 2005 with scenarios developed for the next 10, 50 and 100 years. The second stage of the project is under way, and will identify a mix of engineering, urban planning and education strategies to ensure adequate adaptive management is in place.

Urban settlement in the project area is largely confined to the area east of Port Wakefield Road, with the exception of the rural living precinct associated with the Globe Derby Park trotting track and the small coastal settlement of St Kilda.

The Northern section of the corridor consists primarily of rural living allotments, most of which are used for horticulture and farming activities.

Several significant existing landscapes along the project corridor risk being affected by enhanced climate change impacts such as sea level rise:

- wetlands
- salt fields — industrial operation
- mangroves
- intertidal flats
- Little Para River
- Dry Creek.

Local climate

Adelaide is described as having a semi-arid climate with long, hot summers and short, wet winters. Average temperatures in summer are approximately 30°C and approximately 14°C in winter.

The Bureau of Meteorology Parafield Airport Weather Station provides annual climatic data for the project area:

- average 9.00 am temperature: 16°C
- average 3.00 pm temperature : 20.6°C
- annual precipitation: 460.50 mm
- annual evaporation: 2,044 mm.

Increasing average temperatures, regardless of any other climate change impact, will increase evaporation rates, and less water will be retained on land and in surface and groundwater systems.

Tidal levels

Outer Harbor sea level data was recently examined by Australian Water Environments (2008) for the Gawler River Floodplain Management Authority, as part of the Gawler River Floodplain Mapping Project. The proximity of the Northern Connector to Outer Harbor makes this tidal analysis relevant to the project area.

The Outer Harbor data has been used to estimate design sea levels by developing an annual frequency plot for combined tide and storm-surge. This takes into account both astronomical tide and meteorologic (surge) effects.

A combined tidal and storm surge level for a 100 year design return period of 2.4 m Australian height datum (AHD) is measured and subsequently recommended for adoption in this project.

Based on a visual assessment of drawings in the *Port Adelaide Seawater Stormwater Flooding Study* (City of Port Adelaide Enfield 2005) study, approximately 70% of existing seawalls are considered to be in good condition, 15% serviceable, 5% excellent and less than 5% in poor condition.

22.3 Project sustainability principles

The sustainability vision of the Northern Connector project is to create an ecologically sensitive road and rail corridor, which builds on existing remnant and significant landscapes, creating urban biodiversity and providing a habitat corridor.

Supporting sustainable design principles could include:

- use water sensitive urban design principles; where possible retain stormwater in the road and rail corridor, and reduce the need for irrigation
- select plants and landscape treatments that would be low in irrigation requirements during establishment

- use endemic and native species to create habitat areas at targeted locations along the route and provide opportunities for increased urban biodiversity
- enhance current areas of biodiversity and habitat value, principally in significant landscape areas of remnant and indigenous vegetation, including Little Para and Dry Creek riparian zones, and Barker Inlet wetlands
- minimise impact to areas of remnant or indigenous vegetation, including the remnant mangrove forests and samphire ecologies of the Port River estuary
- source materials locally to reduce transport requirements.

22.3.1 Achievement of sustainability objectives and principles

The environmental assessment for the Northern Connector must demonstrate its capacity to address social, environmental and economic implications equally in order to meet existing needs without compromising the needs of future generations. As part of approval for the project, a sustainability management plan will be prepared that outlines the extent to which the project addresses 12 ESD principles for:

- flora (Section 8.13 and Chapter 17)
- fauna (Section 8.13 and Chapter 18)
- water quality, drainage and flooding (Chapter 20)
- water conservation and reuse (Chapter 22)
- minimisation of energy consumption, use of renewable energy sources (Chapter 22)
- minimisation contribution to greenhouse gas emissions
- air quality (Chapter 19)
- waste minimisation and use of recycled materials
- geology, soils and contamination (Chapter 21)
- noise and vibration (Chapter 11)
- social impacts (Chapter 13)
- landscape, visual amenity and urban design (Chapter 10).

In an effort to further achieve sustainability objectives the Department for Transport, Energy and Infrastructure (DTEI) has also recently introduced the requirement for lead construction contractors to produce a sustainability implementation plan (SIP). Examples of broad sustainability areas to inform SIP include: carbon management; water conservation management; waste management and resource recovery; soil, erosion and drainage management; air quality management; visual management; biodiversity management; noise management; and culture and heritage management.

Under the carbon management theme for example, the contractor must highlight methods and actions to minimise the carbon footprint of activities and materials used in road construction. To assist contractors, DTEI has developed greenhouse gas and cost saving tables for alternative materials, stationary energy, transport fuel combustion, waste and other greenhouse generation activities. Reductions are expected to be measured in tonnes of equivalent carbon dioxide (t/CO2-e).

22.4 Assessment

22.4.1 Greenhouse gases

A quantitative assessment of the net greenhouse gas (GHG) effect of construction and operation of the project, identified greenhouse gases released to the atmosphere as a result of:

- construction activities assessed using DTEI Greenhouse Gas Assessment Tool (GGAT) v1.0.2
- landscape changes of 32.5 hectares of vegetation removal modelled in relation to stored carbon levels
- replanting and potential sequestration (capture and storage to prevent carbon from being released into the atmosphere) of approximately 35 hectares
- operation activities (road) modelled for 2017 and 2031 using MASTEM traffic modelling (DTEI 2009d) and modal split by traffic vehicle category (ABS 2005)
- operational activities (rail) calculated on length of rail line and savings from the existing rail system configuration between 2011 and 2042
- maintenance (road) estimated based on Park et al. (2005).

Construction

GHG emissions associated with construction, estimated using GGAT, would come from:

- site preparation, including:
  - land use change through vegetation clearing and ecosystem change
  - earthworks
  - vehicle transport at site and mobilisation at pre- and post-construction stages
- fuel use by plant equipment
- construction materials' embodied energy (e.g. concrete, steel, bitumen)
- construction of other infrastructure in this corridor for activities (not included in assessment) including:
  - electricity
  - water (potable)
  - water (recycled)

- sewage
- gas
- waste management.

GHG emissions saved through landscaping sequestration have not been considered as part of this assessment.

Total estimated GHG emissions associated with construction of the project are shown in Table 22.1.

Table 22.1 Greenhouse gas emissions from the project's construction phase

Summary of emissions	Greenhouse gas emissions (t CO_2-e)	Percentage of total
Stationary energy	293	0.16%
Transport fuel combustion	67,591	36.18%
Vegetation clearance	7,379	3.95%
Waste	9,765	5.56%
Materials	101,804	54.49%
Total	**186,832**	**100%**

Stationary energy

An example of stationary energy is power consumption for site offices (sourced from the electricity grid).

Transport fuel combustion

Fuel combustion incorporates equipment fuel use for demolition and earthworks, vegetation clearance, construction of drainage infrastructure, pavement works, rail construction and bridge works.

Vegetation clearance

Basic calculations of greenhouse gas emissions associated with vegetation clearance (decomposition) indicated that 3.95% of overall construction emissions are associated with vegetation clearance. This calculation is based on multiplying the area of grassland and woodland vegetation to be cleared for the project by generic definitions of vegetation type and the decomposition factor for wood and garden waste, taken from Australian National Greenhouse Accounts (Department of Climate Change and Energy Efficiency 2008).

Waste

Construction waste, 5.56% of the total emissions from the project, is primarily generated from earthworks, demolition spoil and construction practices. This assessment has not considered any recycling of construction and demolition waste. Any waste materials that are recycled will reduce the greenhouse emissions associated with the project.

Materials

Materials used for the construction of the Northern Connector project are the largest contributor to emissions at 54.49% of the total (Table 22.2) and include:

- steel: used in concrete reinforcement (including concrete rail sleepers), infrastructure framework and water pipes; the largest contributor of GHG emissions from embodied energy of materials, contributing 35% of construction material related emissions
- concrete: used for drainage, pavement, bridges and rail sleepers
- bitumen: primarily used in road sealing; energy intensive in production.

Table 22.2 Most significant material emission sources

Summary of material emissions (Scope 3)	Greenhouse gas emissions (t CO_2-e)	Percentage
Concrete	31,265	31%
Steel	36,109	35%
Bitumen	14,288	14%
Other	20,141	20%
Total	**101,804**	**100%**

Road and rail operation

Operation of road corridor

Greenhouse gases emitted during operation would largely originate from vehicles travelling on the Northern Connector road carriageways.

Total operational GHG emissions for the road network mostly depend on vehicle modelling including vehicle composition and by extension fuel type and efficiency, vehicle trips and vehicle kilometres travelled (VKT).

Calculation of road operation GHG emissions for two assessment years (2017 and 2031) is based on predictive traffic modelling by vehicle category. Greenhouse analysis is dependent on the extent to which the model can successfully predict future travel behaviour including any potential induced travel demand. The operational GHG model used for this assessment was developed from speed–greenhouse gas emission curves developed by the University of South Australia for the SA Environment Protection Authority (Appendix D).

The speed–greenhouse gas emission curves applied in this context are based on parameter values for all-day average vehicle speeds (Zito 2008). They have been used to develop ‘base case’ (i.e. if the project was not built) and ‘project case’ (i.e. if the project is built) fuel consumption estimates based on the total average speed across the Adelaide metropolitan transport network.

With the operation of the project and resulting road network improvements, total average speeds across the network improve with a commensurate improvement in fuel consumption. This is used to derive CO2-e per kilometre for each vehicle type, per 24-hour period based on the 'fuel combustion emission factors' sourced by the University of South Australia, consistent with the Australian National Greenhouse Accounts (Department of Climate Change and Energy Efficiency 2008).

Other assumptions used in the operational GHG model include the application of Australian Bureau of Statistics data on fuel type breakdown by vehicle type.

Total savings in C02-e per annum (for both 2017 and 2031) are then used to determine annual savings (ramping up between 2017 and 2031) which are aggregated over a 30-year period (to coincide with economic forecast) from the year of operation.

Note that uncertainties in climate projections, future greenhouse emission trends, government policy direction and the impact of subsequent reduction strategies, limit the accuracy of any greenhouse modelling projections.

A breakdown of the Northern Connector project road transport properties and resulting GHG emissions for the assessed years (2017 and 2031) are presented in Tables 22.3 and 22.4. Also shown are the results of traffic modelling for the entire metropolitan Adelaide road network for both the base case and project case scenarios for traffic in the study area.

Table 22.3 Operational traffic greenhouse gas emissions for 2017 and 2031

Vehicle type	**Parameter†**	**2017**		**2031**	
		Base case*	**Project case****	**Base case***	**Project case****
Cars	VEH trips	25,753,453	25,858,187	32,364,718	32,674,992
	Total annual GHG	**2508.8**	**2490.5**	**3344.4**	**3257.8**
	Average speed over network	44.3	45.1	40.3	42.6
Commercial vehicles	VEH trips	1,437,612	1,433,136	2,199,554	2,174,835
LCV	**Total annual GHG**	**66.9**	**66.0**	**108.0**	**104.0**
	Average speed over network	49.4	50.2	43.6	46
Rigid trucks	**Total annual GHG**	**52.6**	**51.9**	**87.1**	**83.8**
	Average speed over network	49.4	50.2	43.6	46
Articulated VEH	**Total annual GHG**	**259.6**	**257.3**	**416.5**	**406.2**
	Average speed over network	49.4	50.2	43.6	46
Buses	VEH trips	192,415	150,688	263,522	263,522
	Total annual GHG	**67.5**	**52.8**	**94.7**	**93.6**
	Average speed over	27.6	27.7	26	26.8

	network				

* Base case: without Northern Connector constructed; ** Project case = with Northern Connector constructed

† VEH trips:(24-hour VKT; Total annual GHG: kt CO2-e; Average speed over network: kmph

Table 22.4 Summary of operational traffic GHG emissions for 2017 and 2031

	2017		2031	
	Base case	**Project case**	**Base case**	**Project case**
Total annual GHG (ktCO2 -e)	2,955	2,918	4,051	3,945
Change In emissions (Base – project case)				
Annual GHG savings (ktCO2 -e) with Northern Connector		**36.9**		**105.5**
Total savings		**2408.94**	**kilotonnes C02-e**	

With traffic volumes across the Adelaide metropolitan network expected to increase, overall anticipated emissions from the road operation of the project are:

- 2,918 kt CO2-e annually through vehicle trips in 2017, or 36.9 kt CO2-e less than without the Northern Connector (i.e. a savings in emissions).
- 3,945 kt CO2-e annually through vehicle trips in 2031, saving 105.5kt CO2-e.

Total savings in kt C02-e per annum (for 2017 plus 2031) are used to determine the annual savings (ramping up between 2017 and 2031) aggregated over a 30-year period from the opening of the project: 2408.94 kt CO2-e (Table 22.3).

Operation of the rail corridor

The emission profile of the rail operation phase and the base case over 30 years are summarised in Table 22.5. The rail routes are shown in Figure 22.1.

Table 22.5 Greenhouse gas emissions from the project's rail operation phase

	Freight GHG emissions over 30 years (kt CO2-e)			
Rail routes	**Port Adelaide destined**	**Interstate Melbourne**	**Interstate destined Adelaide**	**TOTAL**
Using existing rail line via Salisbury	166.94	24.75	53.38	245.07
Using Northern Connector rail line	130.66	37.21	48.87	216.74
GHG savings (kt CO2-e)	36.28	-12.46	4.51	28.33 (savings)

Freight currently travelling to and from Port Adelaide destined locally, along with freight leaving Adelaide destined interstate, travels a notably shorter distance, with fewer carbon emissions (Figure 22.1).

Intermodal freight containers originating from Melbourne and headed towards Perth or Darwin via Adelaide will travel a greater distance. However, freight trains from interstate Melbourne will pass through significantly fewer level crossings, resulting in quicker travel times.

Trains travelling locally to and from Port Adelaide may travel over 6 kilometres less on the proposed system resulting, saving 36.28 kilotonnes of CO2-e.

A further 4.51 kilotonnes of CO2-e will be saved for all freight intermodal containers travelling interstate to and from Adelaide.

Through freight, originating in Melbourne, travels a greater distance on the new system and in turn produces 12.46 kilotonnes more in CO2-e GHG emissions.

Overall, the operation of the Northern Connector rail line will ultimately have a significant saving of 28.33 kilotonnes of CO2-e GHG over the next 30 years alone (compared to ongoing use of the existing system), which will result in a more sustainable rail alignment than that currently in place. This amount is insignificant compared to overall savings in greenhouse gas emissions associated with operation of the road network of the Northern Connector.

Maintenance of the project

Ongoing maintenance activities of the Northern Connector road and rail corridor creating greenhouse gas emissions include fuel use (e.g. from mowing), materials for maintaining the road (e.g. street lights, mine marking) and road pavement repair.

As no estimates were available for maintenance at this stage of the project, a projection was made on the basis of findings by Park et al. (2003), which indicated that emissions associated with maintenance are usually around 3.5% of the construction emissions per annum. From that indication, maintenance emissions are estimated at 7,420 t-CO2-e per annum or 222,600 t-CO2-e over the 30-year operational life of the Northern Connector.

Major road corridors are very rarely decommissioned and would be more likely to be upgraded (beyond the 30 year assessment horizon) therefore emissions associated with decommissioning are not included in the assessment.

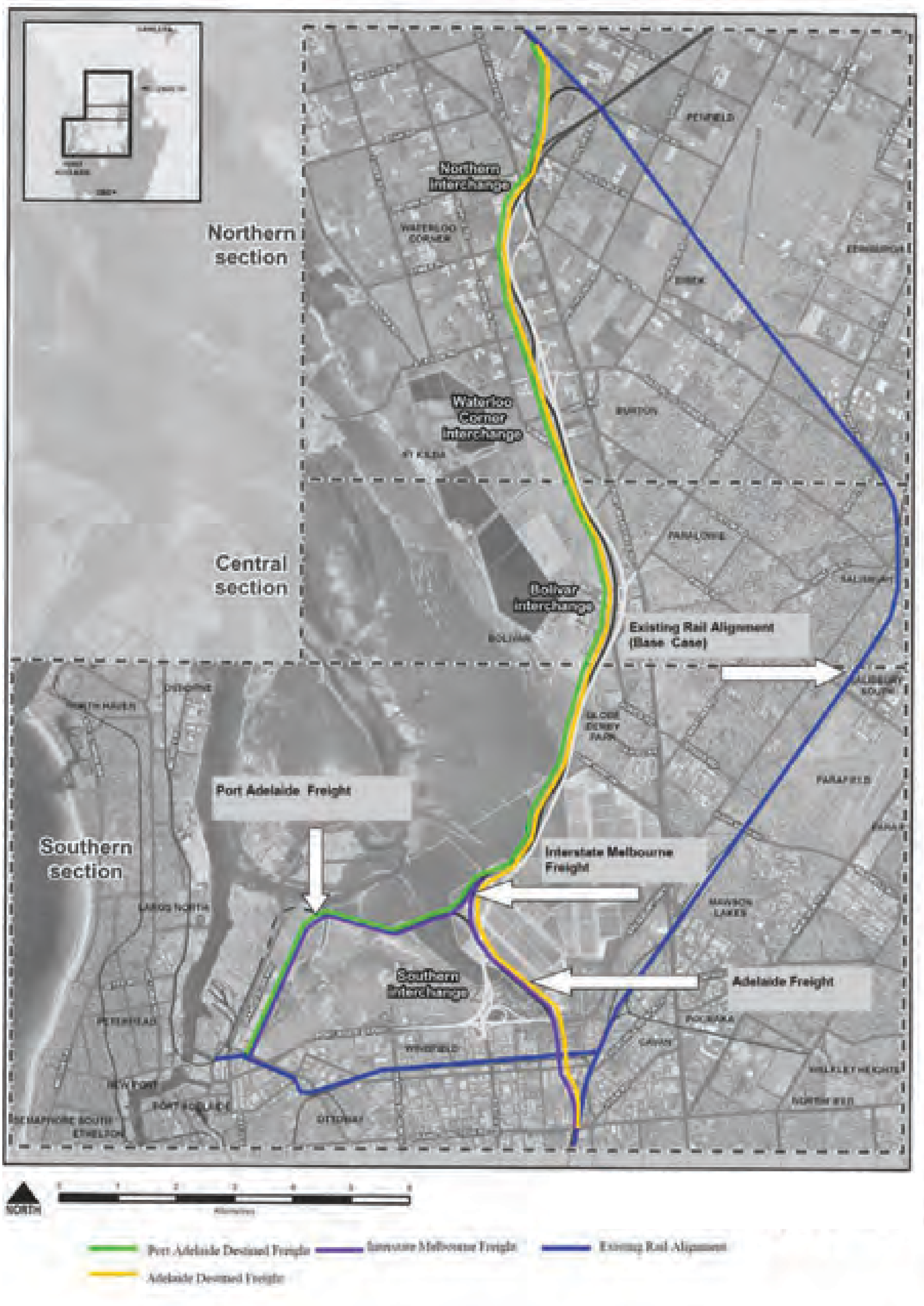


Figure 22.1 Existing and Northern Connector rail routes

Summary of the Northern Connector greenhouse gas emissions from construction, operation and maintenance

Total greenhouse emission savings over the 30-year timeframe of the Northern Connector project are summarised in Table 22.6 for construction, operation and maintenance of the road and rail transport corridor. Overall, with expected increases in road traffic and rail freight, the Northern Connector project will result in a more sustainable road and rail transport system than the existing system.

Table 22.6 Total GHG emission savings over a 30-year timeframe of the project

Project aspect	GHG emissions (kt CO_2-e)
Northern Connector construction related GHG emissions	+187 (increase).
30-year GHG emissions savings for operation of rail	-28.3(saving)
30-year GHG emission savings for operation of the road (year end construction 2015)	-2,409(saving)
Northern Connector maintenance emissions (30-year estimate)	+222. 6 (increase)
Total 30-year emission savings based on construction and operation of the project	**-2027.7 kt (saving)***

* compared to the situation if the Northern Connector project was not built

22.4.2 Sustainability

The environmental assessment for the Northern Connector project must demonstrate its capacity to address social, environmental and economic implications equally to meet existing needs without compromising the needs of future generations.

Environmental impact issues considered under project sustainability include:

- climate change impacts
- emission of greenhouse gases
- waste by-products from construction and operation
- demand on resources and materials.

The potential impacts of these issues, during construction and operation, were assessed, including sources and estimated volume of greenhouse emissions, identification of energy and resource requirements, and forecast traffic volumes and vehicle composition. Where appropriate, mitigation and management measures were identified. Sustainability performance indicators have been developed to report on these mitigation and management measures, and ensure that sustainable development principles are embedded and can be measured during construction.

These sustainability measures will be considered in more detail during the detailed design phase of the Northern Connector project. They will seek to achieve enhanced sustainability outcomes for the project, and may include:

- water efficient and drought tolerant landscape and revegetation, using indigenous species adapted to local soil and natural rainfall conditions
- design of operating conditions for the Northern Connector that will reduce fuel consumption by reducing congestion and improving traffic flow
- reduced greenhouse gas emissions from construction and operation of the Northern Connector
- use of recycled products and materials where practicable and standards allow
- improvement of landscape character and visual amenity through implementation of an urban and landscape design strategy
- enhanced journey experience for road users
- improving the local environment for the community, by integrating the road into the scale and pattern of the surrounding landscape
- contributing to economic growth in the State and nationally through improved efficiencies for transport.

22.4.3 Climate change

A preliminary identification of key climate change issues and impacts for the project was undertaken through:

- consultation with the City of Port Adelaide Enfield, City of Salisbury and the DEH Coastal Protection Branch
- literature review and research of relevant government policies and standards
- review of the existing local environment for sea level rise projections and expectations, and climate change pressures and impacts in the region.

A qualitative risk assessment of climate change issues was undertaken, including developing a strategy for adaptive management of climate change impacts.

A number of features of the Northern Connector are likely to be directly affected by projected climate change.

Climate change impacts potentially affecting the project include:

- temperature
- extreme temperature
- average rainfall
- extreme rainfall
- wind speed
- fire weather
- land subsidence

- coastal inundation
- floodplain inundation
- storm surges and rainfall events
- mangrove and saltmarsh movements
- climate change and Northern Connector infrastructure impacts.

Temperature

The best estimate of average annual temperature under climate change over Australia by 2030 is an increase of approximately 1.0°C, with warming of around 0.7–0.9°C in coastal areas, such as the location of the Northern Connector. Annual temperatures are projected to increase by 2070 by 0.6–4.0°C, depending on the emissions scenario. Spring and summer will experience greater warming than in winter and autumn.

Extreme temperature

Associated with an increase in average annual temperatures, an increase is projected in the frequency of hot days (over 35°C). The Adelaide region currently experiences an average of 17 hot days per year, expected to increase to 23 hot days over 35°C by 2030, and 26–36 hot days by 2070, depending on the emission scenario.

Average rainfall

Projected rainfall changes are less certain than temperature projections. Most global climate models predict a decrease in average annual rainfall in southern Australia. Projected changes in average annual rainfall in the Adelaide region are a decrease of 0–10% by 2030 and 0–40% by 2070. These projected changes vary with the seasons, with winter and spring showing stronger decreases than autumn and summer.

Extreme rainfall

All climate models and scenarios predict increased rainfall intensities (annual rainfall total divided by number of wet days with 1 mm of rain per day or more), as well as more dry days (average days per year with less than 1 mm of rain). This suggests a future rainfall regime with longer dry spells interrupted by heavier rainfall events — in other words, the extremes will become more severe.

Wind speed

Average wind speeds are projected to tend to increase in most coastal areas in 2030 (range of -2% to +7.5% with a best estimate 2–5%). Later in the century, increases in average wind speed are projected to be larger in magnitude.

Fire weather

A recent study (Hennessy et al. 2006) concluded that there would be substantial increases in fire weather risk at most sites in south-eastern Australia. While that study only covered NSW, Victoria and Tasmania, similar increases in fire weather risk can be expected in the Adelaide region. With increased temperatures and wind, and reduced soil moisture, there will be an increased risk of grass and bushfires in and around the project area.

Land subsidence

While not related to climate change, land subsidence has been identified as a factor of particular importance in estimating rates of sea level rise and stormwater flood risk. This influences site level allowances, which are required to ensure the Northern Connector is sufficiently protected from sea level rise in areas where land subsidence is expected to occur — commonly in estuarine areas such as Barker Inlet.

Land subsidence assessments are generally made for a number of scenarios requiring the effects of land subsidence 50 and 100 years into the future. The proposed deck levels for the Northern Connector would need to consider this long-term effect.

Land subsidence rates ranging from 1.8–10 mm/yr have been calculated for a number of areas in the Port Adelaide estuarine areas (Belperio 1993).

The *Port Adelaide Seawater Stormwater Flooding Study* (City of Port Adelaide Enfield 2005) recommends that: 'where the subsidence rate is used to design permanent works that are incapable of being modified or altered to provide protection from flooding due to subsidence, a rate at the higher end of the range (10 mm/yr) should be adopted.' Works of this nature are likely to include development-related landfill operations for the purpose of development.

Conversely, where the rate is used in the design of works that are able to be altered, 'adoption of a lower rate, consistent with that over the remainder of the project area is considered to be appropriate (2.1 mm/yr)'. For the purpose of preliminary impact assessment, this figure has been used for the Northern Connector.

Coastal inundation

Mean sea level could rise significantly from the predicted effect of global warming (enhanced greenhouse effect) on weather systems. Factors including rainfall patterns, wind velocities and sea level rise can all have an impact on the environment in the coastal zone (McInnes et al. 1998; Walsh et al. 1998).

The City of Port Adelaide Enfield has undertaken a study on the effects of sea levels and flooding (2005), with upper-range estimates recommending a net sea level rise of 0.88 m over the 100 years.

The City of Port Adelaide Enfield report acknowledges that these conservative upper range estimates from 2005 are more likely to represent current mid-range estimates, based upon 2007 IPCC global climate change projections.

Allowance for anticipated sea level rise of 0.3 m by 2050 and 1 m sea level rise by 2100, above 2002 levels is the CPB's current policy. These figures are applied in this study.

Floodplain inundation

The Northern Connector would cross five major waterways, and a number of minor drain crossings. All the major watercourses follow the fall of the terrain and generally drain from east to west. They eventually discharge to the sea through Barker Inlet.

Storm surges and rainfall events

An analysis of the correlation between storm surges and rainfall events (City of Port Adelaide Enfield 2005) suggests there is no strong relationship between significant rainfall events and tidal storm surges.

This is supported in the *Gawler River Floodplain Mapping Project*, which concludes: 'the coincidence of extreme sea levels and large peak flood flows is expected to be very rare. Recent studies have identified that floods and peak tailwater conditions are essentially independent' (Australian Water Environments 2008).

Mangrove and saltmarsh movements

The Barker Inlet mangroves have advanced by approximately 1.5 km across the intertidal saltmarsh since the late 1930s. More recent studies (Fotheringham 1994) suggest the advance may be slowing.

Compounded with the effects of sea level rise, it is reasonable to predict that mangroves will continue to advance upon saltmarsh land (unless barriers are in place) and may migrate further inland as a response to increased sea levels.

This movement can be expected to continue with tidal inundation until the mangrove movement meets and is further blocked by an impervious barrier, such as the sea wall surrounding Cheetham Salt Ltd Dry Creek salt fields.

Climate change and Northern Connector infrastructure impacts

The effects of climate change would likely have direct and indirect implications for the project. A context for identification of anticipated direct climate change impacts and adaptation strategies is summarised in Table 22.7.

Table 22.7 Potential direct impacts of climate change on Northern Connector infrastructure

Asset	Possible climate change impacts
Road/ pavement construction and maintenance	▪ changes in rates of deterioration — faster deterioration in wetter areas but potentially slower deterioration in areas where rainfall decreases; deterioration may also result from higher temperatures and increased solar radiation ▪ seawater inundation of surface and/or below ground level roads in coastal areas, potentially resulting in destruction ▪ changes in frequency of interruption of road traffic from extreme weather events and emergency transport routes disrupted
Stormwater/ drainage	▪ exceedance of existing flood defences ▪ exceedance of drainage capacity, more frequent overflows ▪ reduction in drainage capacity due to sea level rise and storm surge ▪ changes in mean and peak stream and river flows ▪ lower levels of rainfall, reducing pressure on stormwater systems
Coastal infrastructure	▪ increased coastal erosion and inundation ▪ increased frequency, or permanent inundation of, coastal infrastructure and utilities (e.g. water, sewerage, gas, telecommunications, electricity, transportation) ▪ increased erosion and/or over-topping of seawalls, jetties and other coastal defences
Biodiversity	▪ shifts in distributions of plant and animal species ▪ increased risk of population and species extinctions ▪ reduced ecosystem resilience to stress ▪ increased ecosystem and species heat stress ▪ increased pressure on sand dune systems ▪ changes to mangrove habitats due to salt water intrusion ▪ increases in ecological disturbances

Risk assessment

A preliminary risk assessment for the project (Appendix E) based on the potential impacts of climate change, identified, assessed and ranked the risks, and then proposed possible mitigation and adaptation measures.

22.5 Management and mitigation

Sustainability

Where appropriate, mitigation and management measures have been identified to address the potential impacts of the proposal and enhance sustainability.

Sustainability performance indicators will be developed to report on these mitigation and management measures, and provide overall guidance to DTEI, contractors, residents and the community, by ensuring that sustainable development principles are embedded and can be measured during construction of the Northern Connector project.

Possible sustainability measures are listed in Section 22.4.2.

Mainstreaming sustainability in design and construction phase

The approach of mainstreaming sustainability in the Northern Connector project incorporates sustainability objectives and principles as part of the 'concept design and planning' phase of the project through the following measures:

- Estimations of water consumption for construction and operation of the Northern Connector will be useful to build water security measures into the overall design (i.e. retention and storage basins to irrigate roadside plantings).
- The switch from a combined road and rail corridor to a separated road and rail corridor where the rail component is raised to a high elevation to act as a sea wall will result in less fuel consumption due to less material required to build up the road corridor.
- The incorporation of open vegetated swale surface water drains will improve water quality and biodiversity.
- Sections of degraded land close to the Northern Connector alignment (such as degraded areas of Barker Inlet north wetland) will be rehabilitated.
- Increased traffic accessibility and improved pedestrian and cyclist access will encouraging more people to ride bikes and thus reduce emissions.
- Endemic vegetation plantings will be incorporated into the landscape design for the corridor.

Other detailed design sustainability aspects will be summarised in the final sustainability management plan after further detailed investigations and studies.

Greenhouse

During planning and design, greenhouse gases would be emitted by office energy requirements, equipment and vehicles. These emissions have not been included in this assessment but could be managed and mitigated through:

- minimising energy use at planning and design office
- purchasing accredited green power for the planning and design office
- downsizing vehicles or shifting to LPG, diesel or high octane unleaded petrol
- taking up sustainable transport technologies and initiatives (hybrid and electric vehicles) for planning and design activities
- implementing car pooling or a green transporter initiative for planning and design office
- video conferencing to avoidance unnecessary travel

- ensuring temporary modulars are appropriately insulated, using more energy efficient appliances, solar hot water and photovoltaic systems for planning and design office.

The design phase of the Northern Connector would consider and/or implement:

- minimising vegetation clearance and replanting using local native species where feasible
- incorporating a wide array of sustainable energy technologies for electricity consuming components of the Northern Connector such as intelligent transport systems, lighting and signage.

Climate change

Strategy for adaptive management of sea level rise and storm impacts

Where the Northern Connector passes through low lying land adjacent to the salt fields, road levels are based on the rail alignment located on the western side of the Northern Connector. It is intended that this rail alignment will act as a sea barrier to protect the road corridor over its design life.

For the protected road corridor in this area the outside lane level has been designed at a height of 3.15 m AHD (similar to the Port River Expressway) and the centre of all traffic lanes at 3.3 m AHD. These heights are based on 2.5 m AHD storm surge and allowance for 0.6 m to 2050 sea level rise (Table 4.5)*.

Designs for the rail line/sea wall have been based on higher levels to account for high sea level rises. The proposed 4.1 m rail height provides for a formation level of 3.6 m consisting of: 2.5 m storm surge, 0.6 m sea level rise, 0.4 m for wave effect, 0.1 m freeboard plus 0.5 m of rock ballast. This level is also proposed through Land Management Corporation land.

Preliminary recommendations to provide protection from a 100-year average recurrence interval for storm surge and extreme rainfall impacts, consistent with Coast Protection Board policy, are:

- a base 2.540 m AHD threshold level to account for potential Outer Harbor tide and storm surge
- an additional 1.0 m amount to account for sea level rise to 2100
- an additional amount to account for land subsidence (2.1 mm/yr)
- an additional 4200 mm to account for effect of wave amplification of the tide from Outer Harbor to inner harbour
- an additional 1300 mm to account for settlement of ground after construction freeboard
- an additional 100 mm to account for freeboard
- an additional 500 mm provided by rock ballast.

Based upon previously outlined climate change impacts, the criteria in Table 22.8 should inform the determination of final AHD deck levels for the final rail alignment located on the western side of the Northern Connector.

Table 22.8 Height and sea level rise required threshold level requirements

Criterion	Data
Design return period (annual equivalent probability)	**100 years**
Outer Harbor tide and storm surge	+ 2.50 m AHD
Local tide amplification to inner habour settlement of the ground	+ 0.10 m
Effect of waves freeboard	+0.40 m
Freeboard** Rock ballast Coast Protection Board recommendations for sea level rise	+0.10 m +0.50 m + 0.60 m to 2050* + 0.70 m to 2100* Total sea level rise = 1.3 m
Estimated land subsidence (2.1 mm/yr)	+ 0.11 m over 50 years + 0.21 m over 100 years

* Current estimated sea level rise subject to change in accordance with Coast Protection Board's current review of its 1991 policy on sea level rise allowances for coastal development; hence design has doubled from + 0.30 m to + 0.60 m to 2050)

** Freeboard usually only applied to buildings but applied to the project for added safety

Based upon a 100-year return, the Northern Connector rail alignment that passes through low lying land adjacent to Cheetham Salt Ltd salt fields corridor is most likely to be influenced by sea level rise over this period. Estimated land subsidence (2100 mm over 100 years) has not been considered as it can be easily overcome by geotechnical and specialised construction techniques such as pre-loading.

The provision of the rail embankment for sea level rise is compatible with the approximate (flexible) pavement life of the new expressway.

The Northern Connector has been designed to be later raised to accommodate higher sea level rise if this is found to be required nearer the time. Land acquisition for the project has been set to accommodate the longer term 2100 requirement for the embankments and road works.

Further land subsidence investigations may allow this to be marginally reduced.

Sea level rise adaptation measures can include:

- earth bank — where sufficient space is available this is considered to be the cheapest option available

- demountable flood defence at road crossings — in some locations, vehicular access will have to be provided through the sea defence systems; proprietary devices are available that provide one way of overcoming this problem
- concrete wall — limited space for bank batters in some locations would dictate using a vertical flood proof wall
- riprap seawall — applies particularly in locations where existing riprap needs to be extended
- facilitate change to more salt water tolerant plants
- protect buffer vegetation in shore zones.

The form of any proposed barrier requires further investigation to identify geotechnical conditions and operational requirements.

Storm adaptation measures can include:

- locate all roads and railways, including bridge decks, above design flood levels that allow for climate change to at least 2050
- size all waterway openings and drainage structures using design peak flows that allow for climate change to at least 2050
- develop and implement the flood risk management plan.

Strategy for adaptive management of change in temperature

Projected shifts in temperature (longer and more severe heat waves and heat effects) may result in damage to Northern Connector infrastructure through footing movements in dry soil as well as accelerated degradation of road pavements and buckling of railway lines. Effects on landscape plantings will also be considerable. To mitigate such impacts the Northern Connector project will:

- consider potential for footing/foundation movement in infrastructure design
- investigate and apply materials and design features to reduce heat impacts of roads and railways
- use drought-tolerant native landscaping.

For more information

For more information, to make an enquiry or join the mailing list contact the Northern Connector project team.
Phone: 1300 793 458 (interpreter service available)
Email: dtei.northernconnector@sa.gov.au
Visit the website: www.infrastructure.sa.gov.au and then follow the prompts.

Για περισσότερες πληροφορίες γι’ αυτό το πρόγραμμα οδοποιίας τηλεφωνήστε στο **1300 793 458**. Διαθέτουμε και διερμηνείς.

Se desiderate altre informazioni su questo progetto stradale telefonate al **1300 793 458**. Ci sono interpreti a disposizione.

Để có thêm thông tin về công trình đường bộ này xin hãy gọi điện thoại số **1300 793 458**. Sẽ có phiên dịch viên.

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