Government of South Australia

Department of Planning, Transport and Infrastructure

ENVIRONMENTAL IMPACT STATEMENT (EIS)

O-Bahn City Access Project – Stage 1

DISCLAIMER

We, the environmental department at E8 consulting, hereby submit the Environmental Impact Statement for the O-Bahn City Access Project – Stage 1 to the Department of Planning, Transport and Infrastructure. This document is to be read in conjunction with the Feasibility Study submitted by the E8 Consulting management team. We declare that all information contained in this document is true and accurate at the time of submission.

Project Manager

Daniel Caddy

Assistant Project Manager

Liam Wegener

Environmental Team

Manuel Martins – Team Leader

Adrian Matto – Environmental Engineer

Harris Tsimiklis – Graduate Engineer

Argyrios Kikianis – Graduate Engineer

Project Manager

Daniel Caddy

Daniel Caddy

EXECUTIVE SUMMARY

Three design options were proposed to the Department of Planning, Transport and Infrastructure (DPTI) in order to successfully deliver the aims of the O-Bahn City Access Project – Stage 1. These options included:

- Option 1: Additional lane to the Western Bridge
- Option 2: O-Bahn Elevated Superway
- Option 3: O-Bahn Tunnel

This Environmental Impact Statement (EIS) investigated the impacts that these three options have on 7 main environmental considerations in order to determine which option had the lowest overall impact on the environment. These 7 environmental considerations were; flora, fauna, noise pollution, air pollution, soil contamination, water quality and energy. Solutions were also proposed in this EIS in order to offset the impacts of the proposed design options.

The results showed options 1, 2 and 3 receiving relative scores of 3.1, 4.3 and 3.9 respectively. Scores were given on the basis that 0 indicates no environmental impact whilst 10 indicates severe impact. Consequently, since option 1 received the lowest score, it was deemed to have the least environmental impact overall. Nonetheless, given the relatively low scores of each option, all options were considered feasible. In addition to this, results showed that the impacts and offsets associated with options 1, 2 and 3 will cost $2,493,602, $3,175,638 and $3,565,414 respectively. The extra costs associated with options 2 and 3 provided no significant environmental benefit and therefore option 1 was the clear winner.

CONTENTS

LIST OF FIGURES

TABLES

1. INTRODUCTION

1.1. About Us

We, the environmental department at E8 Consulting, encourage best environmental management on all projects through planning, commitment and innovative designs. No matter the project, all reasonably practicable steps are always taken to prevent, minimise or mitigate any adverse effects that our designs have on the environment. We implement sustainable and innovative measures to enhance the environment, whilst maintaining constant collaboration with our clients to ensure their environmental targets are reached. While we are always aiming to challenge the status quo, our strict processes never fail to meet all relevant environmental policies and legislation.

1.2. Project Overview

The Adelaide O-Bahn is the longest and fastest guided bus service in the world, transporting over 8 million passengers per year (Department of Planning, Transport and Infrastructure (DPTI) 2017). The current high speed O-Bahn dedicated bus corridor terminates on Park Terrace at Gilberton. After leaving the dedicated corridor, the O-Bahn buses travel for 1.7km along Hackney Road. Recent times have seen heavy bus congestion during peak hours for this portion of the O-Bahn bus route, reducing the travel time and reliability for users of the O-Bahn service. The O-Bahn City Access Project – Stage 1 aims to improve this current situation along Hackney Road and build on the State Government's significant investment in a stronger public transport network (DPTI 2016). See Figure 10 in Appendix A for a map of the project location.

1.3. Proposed Options

To deliver the aim of the O-Bahn City Access Project – Stage 1, three options have been proposed to the Department of Planning, Transport and Infrastructure (DPTI) in E8 Consulting's Feasibility Study. These are summarised in Table 1 below.

Table 1: Summary of the options proposed to DPTI.

Option	Name	Description of works
1	Additional lane to the Western Bridge	• Widening of the western bridge
2	O–Bahn Elevated Superway	• Tunnel under Park Road • Superway begins to elevate at the end of the tunnel • Realignment of one lane width of Park Road (inbound & outbound) • Overpass spans over the western bridge • Elevated overpass returns to grade just south of Richmond Street
3	O–Bahn Tunnel	• Tunnel under Park Road • Realignment of one lane width of Park Road (inbound) • Pedestrian bridge at the River Torrens will rest above the tunnel • Tunnel returns to grade just south of Richmond Street

***Notes:**

- There will be a shared pedestrian/cyclist bridge adjacent to the Western Bridge in all options.
- All options will require Hackney Road to be widened in the same manner to allow for centrally aligned dedicated bus lanes.
- All options will include bus priority traffic signals at the Bundeys Road intersection.
- A visual representation of options 1, 2 and 3 are provided in Figures 11, 12 and 13 respectively of Appendix A.

1.4. Environmental Impact Statement (EIS) Structure

This Environmental Impact Statement (EIS) has been developed for Stage 1 of the O-Bahn City Access Project. It aims to determine the most optimum and feasible solution from an environmental perspective. Firstly, this EIS presents the environmental policies and legislation E8 Consulting conforms to. The document is then broken down into 7 main environmental considerations. These include:

- Flora
- Fauna
- Noise Pollution
- Air Pollution
- Soil Contamination
- Water Quality
- Energy Consumption

These sections begin by giving an overview of the existing site conditions. A discussion is then provided on the impacts that the three proposed options have on the environmental consideration under investigation. This is followed by solutions to mitigate or offset the impacts and a costing to undertake the proposed works. To conclude, a recommendation will be made to determine which option is best for the specific environmental consideration.

Finally, to achieve the aim of this EIS, the costing to complete all proposed works will be devised, and an overall recommendation will be made by the environmental department to determine which option has the least impact on the environment. To formulate this recommendation, each of the 7 environmental considerations were given weightings and scores based on their significance and environmental impact.

2. ENVIRONMENTAL POLICY

This policy establishes the framework to attain the best-in-class environmental management systems. At E8 Consulting, we pride ourselves knowing that we can continually deliver solutions that minimise the impact on the environment, and we strive to become a leading organisation in environmental protection by delivering innovative and sustainable solutions which provide short term and long term environmental benefits.

To achieve this, we commit to:

- Maintaining Environmental Management System certification to AS/NZS: 14001:2008
- Regularly assessing our designs to ensure they do not impact the environment
- Incorporating unique solutions into our designs in order to achieve green star ratings
- Empowering our team members to think outside the box and be creative
- Utilising sustainable materials throughout a structures entire existence
- Reducing greenhouse gas emissions and pollution from all our operations
- Recognising those who contribute to excellent environmental practices
- Minimising waste from our processes and where possible, recycling and reusing resources
- Comparing our performance against leading environmental management systems
- Communicating this policy to all team members to ensure they are constantly reminded of our commitment to the environment
- Meeting environmental targets whilst still complying with all our other policies

This policy is reviewed on a quarterly basis to continually monitor, evaluate and improve our processes and environmental practices. Compliance by all personnel will guarantee that we achieve our environmental targets and this will set up E8 Consulting for long term success.

Daniel Caddy

Daniel Caddy

Project Manager

12 April 2017

3. ENVIRONMENTAL LEGISLATION

Throughout the duration of this project, E8 Consulting must ensure compliance with a number of legislation. The following legislation have been identified as applicable to the O-Bahn City Access Project – Stage 1:

- Native Vegetation Act, 1991
- Development Act, 1993
- Environment Protection and Biodiversity Conservation Act, 1999
- Environmental Protection Act, 1993
- Highways Act, 1926
- Adelaide Park Lands Act, 2005
- Local Government Act, 1932 & 1999
- City of Adelaide Act, 1998
- Road Traffic Act, 1961
- Crown Land Management Act, 2009
- Natural Resources and Management Act, 2004
- National Environment Protection (Ambient Air Quality) Measure
- Disability Discrimination Act, 1992 (Commonwealth)
- Heritage Places Act, 1993

4. FLORA

Flora is a general term used to describe the plants of a particular region. Flora helps provide excellent amenity that is enjoyed by many communities, and the plants form an integral part of the life style and habitat for many animal species around the world as they provide fauna with the oxygen that is necessary for their survival. This makes flora an essential part of any environment. It is therefore important that the recommended option does not significantly impact on any flora in and around the project area. All efforts will be made to minimise or offset any unavoidable impacts in an effective manner.

4.1. Existing Conditions

In order to identify the existing site conditions, significant research was carried out. To accompany and substantiate this research, the environmental team also conducted a site visit to the project location. This section discusses what was found.

According to the Adelaide City Council State of the Environment Report, most of the vegetation in the project area was cleared during settlement, with vegetation being replanted over time (AECOM 2015). During the site visit, it became clear that the majority of flora in the project area comprises of shrubs, garden beds, street trees, and a variety of large mature trees on the western side of Hackney Road. Some of these large trees are part of a pine plantation (Figure 1) on the Hackney Road flank of Botanic Park (Development of Adelaide Botanic Garden n.d.). A number of the large trees along Hackney Road also meet the regulated and significant size criteria under the *Development Act, 1993* (DPTI 2015b). Information on these significant and regulated trees are provided in Appendix B. Furthermore, DPTI undertook a vegetation survey of the project area in 2014 which concluded that no remnant vegetation is present in the area and no trees or vegetation are considered native under the *Native Vegetation Act, 1991* (DPTI 2015a). Finally, no trees have been heritage listed in the DPTI Project Impact Report.

Figure 1: Hackney Road flank of the Botanic Park indicating the pine plantation (looking south). This picture also indicates the Heritage Gates on Plane Tree Drive (Development of Adelaide Botanic Garden n.d.).

Furthermore, Park 8 of the Park Lands contains not only exotic species, but also some of Adelaide's earliest olive tree plantings. This park is located north of the Bundeys Road intersection, bound by Mann Road and Park Road, as shown in Figure 10 in Appendix A. After planting of the olive trees in 1856, the groves now help supply more than half a million olives and 450L of olive oil each year. Because of their age and use, the groves are considered to be important (City of Adelaide n.d.a). In fact, the Park Land Management Strategy associates the olive groves with major historical developments in the City of Adelaide and the State of South Australia, thereby stating that the groves are of Post-Colonial Cultural Significance, forming not only colonisation to the present, but also a cultural landscape (Strategic and Environmental Planning Department 2001).

Park 9 also forms part of the study area. Although it is less significant that Park 8, the park still contains 10 varieties of trees and offers an oval for recreational purposes. Based on the site visit, this park appears to be more of an amenity space for the community (City of Adelaide n.d.b). Park 9 is also shown in Figure 10, Appendix A.

Moreover, DPTI suggests that the Meidiland Roses in the Hackney Road median, and the single row of vines which separate Hackney Road from the adjacent car parks may have high community value (DPTI 2015b). Additionally, the vegetation listed below is deemed to be of

conservation importance within the Community Land Management Plan - Chapter 14, the Adelaide Park Land and Squares Cultural Assessment Study, and the Botanic Gardens of Adelaide Master Plan Report (DPTI 2015a; DPTI 2015b):

- River Torrens revegetation and biodiversity plantings.
- All White Cedars which date back to the mid-1870s.
- Moreton Bay Fig trees dating from 1880s.
- The Camphor Laurel tree near the Lions Club.

4.2. Impacts & Offsets

All options will require Hackney Road to be widened in the same fashion to allow for the 2 dedicated bus lanes. Therefore, certain impacts to flora will remain consistent across all solutions. Consequently, the succeeding section will discuss these impacts first and then discuss the specific impacts and solutions for all options. All efforts will be made to reduce impacts to flora in an effective manner.

4.2.1 Impacts – General

Due to the widening of Hackney Road, it appears that most significant vegetation impacts would occur along the Hackney Road median and footpaths, as well as the car parking area on the western side of Hackney Road adjacent to the International Rose Garden and the Goodman Building. Therefore, a number of street trees, low shrubs, amenity garden beds and other vegetation including the community value Meidiland Roses and vine trees will be impacted by the solution. Table 2 below provides an approximate summary of the impacts that road widening has on flora in the area. These values are based on observations and the O-Bahn City Access Project Impact Report developed by DPTI in 2015.

Table 2: Summary of impacts to flora due to Hackney Road widening.

Flora impacted	Removal or major impacts cause by pruning
Street trees including the vine trees	140
Area shrubs/ground covers/garden beds including the Meidiland Roses	2528m^2

In addition, according to AECOM (2015), the following regulated trees will require major pruning and there is a possibility that they could be severely impacted:

- Citharexylum quadrangulare (Tree No. 277)
- Quercus ilex (Tree No. 282)

To provide a visual representation of these impacts, Figure 21 has been included in Appendix B. This figure shows the affected flora as well as the regulated tree numbers and their respective locations lying within the possible project footprint for the widening of Hackney Road.

As mentioned in the Transport section of the Feasibility Report, Hackney Road is expected to be widened by approximately 8.3m on either side. These widening works are not expected to cause any damage to the existing pine plantation along the eastern side of Botanic Park.

4.2.2 Offsets – General

Due to the nature of where the widening works must occur, the aforementioned impacts cannot be completely mitigated, however the impacts can be offset. To achieve these offsets, we aim to replant vegetation as close to the removal location as possible. For example, after removing the Meidiland Roses from the median strip, they shall be replaced in between the new bus lanes to improve the Hackney Road streetscape and ensure the amenity of these roses are not lost after project completion. Furthermore, to protect trees 277 and 282, they will be transplanted to the area north of the Bundeys Road intersection (in Park 9) prior to construction as shown in Figure 2. This area currently lacks vegetation and therefore this solution has the opportunity to increase the amenity of the area. If transplanting is not possible, a 2:1 replacement ratio will be utilised as defined in the *Development Act, 1993.*

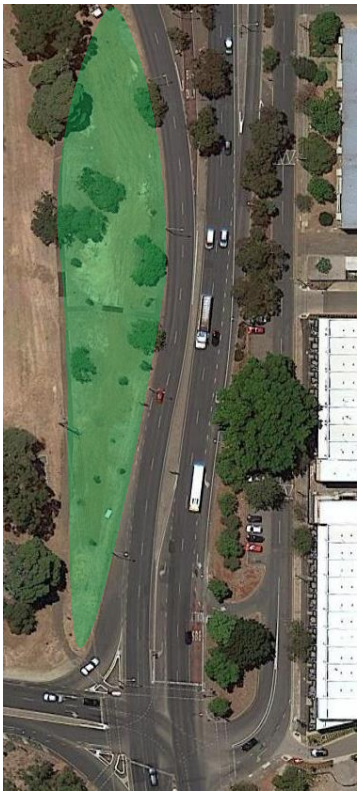


Figure 2: Proposed location for transplanting the regulated trees.

Botanic Gardens prefer to have a tree lined shared pedestrian bike path along Botanic Park to improve the landscape character for users of the park, and to integrate and enhance with the Park Lands. Therefore, the community value vine trees will be transplanted using a 1:1 ratio to achieve this goal. Transplanting these vines has the advantage that less trees will go to waste. If the trees are not suitable (i.e., become damaged during the transplant), Australia Native species such as the Lomandra longifolia and Banksia marginata will be incorporated in the path as they require little maintenance, are suited in all soils, will not die without watering and can withstand cold temperatures (Yee Ko 2012; Britton 2012).

Furthermore, rather than transplanting or replanting all the less significant trees that need removing, it will be more cost effective to recycle the wood from these trees. Therefore, the more significant trees will be transplanted where possible and revegetation will occur to offset the impacts on significant trees, however, the less significant trees will be recycled. This recommendation will remain consistent for options 1, 2 and 3. Recycling trees will prevent the need for further trees to be cut down in the future to produce common materials such as paper. Ultimately, this will decrease the likelihood of disrupting the life-cycle of many plants and animals in other areas of the world as it may prevent more significant trees from being cut down. The recycled wood could even be used as mulch in the Park Lands, Botanic Park or Botanic Gardens to help retain soil moisture, protect roots and provide necessary nutrients to stimulate plant growth (Clain 2011). This mulch can also be used to supplement the trees and vegetation that will be planted outside of Botanic Park.

Large pine trees, like those adjacent to Botanic Park have a strong and complicated root system that will be too difficult and expensive to transplant without permanently damaging the tree (IAC Publishing 2017). Therefore, although it is not expected (as previously mentioned), if some of these pines were damaged during construction, they will also be recycled or replanted using a 1:1 ratio.

4.2.3 Impacts – Option 1

Further to the general impacts, to accommodate the proposed pedestrian/cyclist bridge and widening of the western bridge, several regulated trees and one significant tree will need to be removed. Based on the report written by AECOM (2015), the following is true:

The regulated trees that will need to be removed include the:

- Eucalyptus camaldulensis (Tree No. 513)
- Pinus halepensis (Tree No. 514)
- Pinus halepensis (Tree No. 519)
- Pinus pinea (Tree No. 520)

The significant tree that needs to be removed is the:

- Pinus halepensis (Tree No. 518a)

Note that as shown in Figure 3, additional non-significant trees and vegetation on both banks of the Torrens also need to be cleared or pruned to allow for option 1. However, this area near and around the River Torrens is very degraded already, implying that impacts to flora may not be significant in this region (DPTI 2015a).

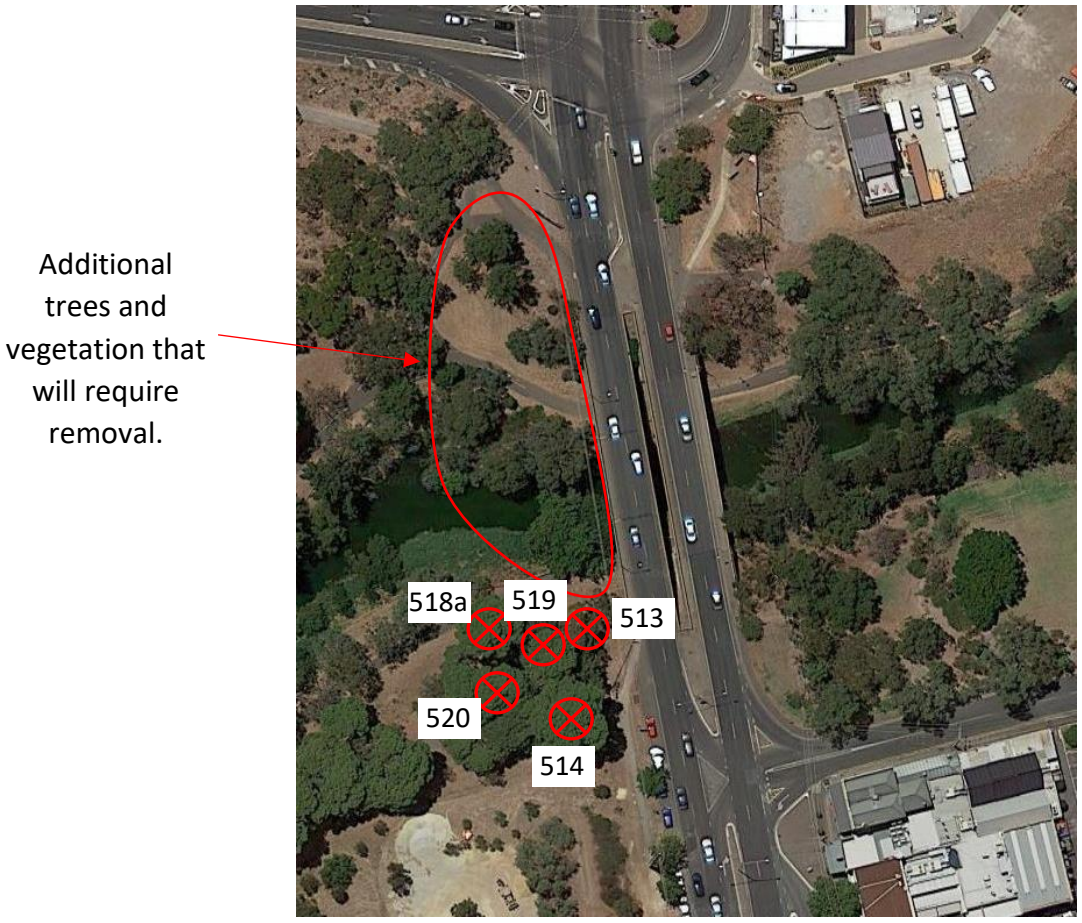


Figure 3: Impact that option 1 has on flora.

4.2.4 Offsets – Option 1

The environmental team proposes to offset the removal of all regulated and significant trees by using a 2:1 and 3:1 replanting ratio respectively. For the same reasons as in Section 4.2.2, the replanting of these trees shall occur in the area north of the Bundeys Road intersection as this area will remain unaffected by the solution. Also as mentioned in Section 4.2.2, all additional non-significant vegetation impacted by this solution will be recycled.

4.2.5 Impacts – Option 2

Option 2 will also impact trees 518a, 513, 514, 519 and 520 as this solution incorporates a pedestrian bridge similar to option 1. However, compared to option 1, more trees (including trees in Park 9) and vegetation will need to be removed around other areas of the site as construction vehicles will need space to construct the overpass. For this same reason, some olive groves in Parngutilla (Park 8) will need to be removed. This will therefore impact the cultural landscape and exotic species within Park 8. Furthermore, the realignment of Park Road will mean that additional amenity shrubs will need to be removed. These shrubs and all other vegetation and trees that will need to be removed due to option 2 are shown in Figure 22 in Appendix B. Table 3 also provides a summary of these impacts. Moreover, not only will the vegetation in Figure 22 need to be removed, the operation of heavy plant required for the construction of the bridge (i.e. cranes) may impact the Structural Root Zone (SRZ) of surrounding trees. This solution therefore has the potential to adversely affect more trees than that shown in Table 3.

Table 3: Summary of impacts to flora due to the overpass.

Flora impacted	Removal or major impacts cause by pruning
Normal trees (including trees in park 9)	110
Olive trees	30
Exotic species	360m^2
Area shrubs/ground covers/garden beds	750m^2

Removing such a large portion of trees and vegetation from this option will result in less CO_2 emissions being incorporated into the plants' respiratory cycle and more emissions being released into the environment. This may cause the existing and target air quality levels discussed in Sections 7.1 and 7.2 respectively to be exceeded.

4.2.6 Offsets – Option 2

Firstly, like option 1, the significant and regulated trees can be replanted to the north of the Bundeys Road intersection after construction. Secondly, the large number of non-significant trees and vegetation will be recycled to offset their removal. Thirdly, other significant vegetation such as the Meidiland Roses and exotic vegetation from Park 8 can be incorporated in a green wall design along the outer side of the existing western bridge. Please see Figure 24 in Appendix H for a concept design of this wall. This solution has the opportunity to save some important vegetation, enhance the amenity of the superway option, maintain the community value of the roses and also improve air quality. See Section 7.3.4 of air quality for a discussion on the benefits that the green wall has on air quality. An example of a green wall design that may be adopted is shown in Figure 4.

Figure 4: Green wall design example (Wang 2014).

The level of maintenance required for the green wall is another factor to consider. This however will depend on the plant selection. Therefore, plants such as the Wave Petunias, Yarrow, Hosta and Impatiens can be used in conjunction with the Meidiland Roses and exotic species, as they require minimal water and fertiliser, thereby reducing maintenance costs (Ward 2013). Nonetheless, most plants must be occasionally pruned, watered and fertilised. One innovative way to maintain the wall would be to set up a remote monitoring system which constantly measures soil temperatures, fertiliser levels and moisture levels in real time through radio telemetry. This will help predict and optimise the maintenance schedule for the wall, saving money (Plant Connection Inc 2017). Tasks such as pruning and fertilising can then be achieved when required, using a custom engineered rolling platform as this will not require

road closure (Wang 2014). An example of this system is shown in Figure 5, while a concept design is shown in Figure 25 of Appendix H. Furthermore, the water captured from the infiltration trenches mentioned in Section 9.2.2 can be recycled to water the wall through an automated drip irrigation system that is embedded into the wall. Should option 2 be the recommended option, this system will be further explored and designed in the detailed design stage.

Figure 5: Custom engineered rolling platform (Wang 2014).

Furthermore, the existing olive groves will need to be replanted after construction is complete to reinforce the existing layout, however, the cultural significance of the groves that are removed will not be preserved by new replacements. Although expensive, it is possible to recycle the wood from the olive trees and incorporate the timber into a landscape feature such as a park bench or bus stop in an attempt to preserve the cultural significance of the groves, as well as serve as a monument for the O-Bahn City Access Project.

4.2.7 Impacts – Option 3

Option 3 poses no additional impacts to flora than option 2 does. This is because the tunnel alignment essentially passes through the same areas which would be needed for machinery to build to overpass. Depending on the construction methodology, trees may also need to be removed to allow space for the tunnel to be built. Therefore options 2 and 3 are considered to have similar impacts to flora. Perhaps the only additional problem that option 3 poses to flora is that excavation, along with heavy machinery, may impact the SRZ of surrounding trees.

4.2.8 Offsets – Option 3

Unlike option 2, option 3 has the opportunity to have 1 green wall on either side of the tunnel for the same reasons outlined in Section 4.2.6. These walls will also be much larger than the walls proposed in option 2. See Figure 26 in Appendix H for a concept design of this wall. In addition, when replanting trees and vegetation for this solution after construction is complete, smaller flora such as the Crape Myrtle, Tibouchina and Berynia should be considered to ensure that when these trees grow, the structural root system is not hindered by the tunnel.

4.3. Costing

After identifying the impacts that the proposed works have on flora and developing solutions to offset these impacts, a costing schedule was devised for the proposed works. The full cost breakdown is provided in Table 19 in Appendix B, while Table 4 below summarises the costs.

Table 4: Costing for flora impacts and offsets - Summary.

Option 1	Option 2	Option 3
$133,230 + $449,280 = $582,510	$301, 140 + $449,280 = $750,420	$451,140 + $449,280 = $900,420

***Notes:**

- $449,280 is the cost associated with the widening of Hackney Road. As previously mentioned, this cost remains consistent across all solutions.
- In the event that no feasible opportunities arise to provide replacement plantings, a payment of $75 per tree or $5,000 per hectare shall be made into a relevant fund such as the Planning and Development Fund, the Councils Urban Trees Fund or the Amenity Planting Fund (*Development Act 1993*).

4.4. Evaluation & Recommendation

The widening of Hackney Road remains consistent across all solutions, therefore, the impacts and offsets associated with this part of the design will not influence the outcome of the recommendation from a flora perspective. Consequently, the decision in this section will be solely based upon what happens North of Richmond Street. Nonetheless, all impacts and offsets associated with the widening of Hackney Road are certainly feasible.

The biggest advantage of option 1 relative to options 2 and 3, is the fact that no vegetation will be impacted to the North of the Bundeys Road intersection. This therefore saves over 100 trees and over 1000m^2 of shrubs and garden beds. Moreover, option 1 will also have no impact on the culturally significant olive groves and exotic vegetation in Park 8. As a result, the amenity of O-Bahn corridor and cultural significance of the park will not be impacted by the solution. In addition, Park 9 will remain undisturbed expect when transplanting trees 277 and 282. Despite options 2 and 3 having the potential to display innovative features with the implementation of a green wall design, the significance of the olive trees, as well as the fact that more than 100 trees can be saved outweighs the benefits of the green wall design. In fact, there is no reason not to implement a green wall along say the new pedestrian bridge for option 1, apart from the fact that it will incur additional costs. Consequently, even the advantages of options 2 and 3 can be incorporated into option 1. To add to this, option 1 costs approximately 22% and 35% less than options 2 and 3 respectively. Therefore, option 1 is the clear winner from a flora perspective.

5. FAUNA

Fauna is a general term used to describe the animals of a particular region, habitat or environment. Therefore, impacting the environment in which animals live in by removing or damaging trees, vegetation and water quality during construction projects can have long-term impacts on fauna. All of the proposed options will impact on fauna to some degree, however offsets will be provided to limit these impacts.

5.1. Existing Conditions

The site visit identified that the project location is not an ideal environment for fauna habitat. This is particularly due to anthropogenic nature of the vegetation, the large portion of paved area, and the high-volume traffic deterring wildlife. The project area is more of a temporary roosting and feeding site for common bird species (DPTI 2015a). Although the project area supports no significant habitat for wildlife, some small mammals and common bird species do live in the River Torrens and Adelaide Park Lands, and rare species have been recorded in the site area. This means there is still a potential for the project to adversely affect some fauna.

5.2. Impacts & Offsets

Due to the limited data available and variable nature of fauna, there were no impacts considered to be specific to a certain option. However, the severity of the impacts to fauna will change slightly based on each option. Therefore, the following sections discuss the impacts to fauna that may occur across all solutions, whilst Section 5.3 and 5.4 will compare and contrast the severity of the impacts as they relate to each option in order to make a justified recommendation.

5.2.1 Impacts – General

An Environment Protection and Biodiversity Conservation (EPBC) Act Protected Matters Report identified that the threatened species, ecological communities and migratory species listed in Table 5 below may potentially habitat within 1km of the project area (DPTI 2015a). As a result, the environmental team suggested that these species may be impacted by the project. The likelihood of these species being impacted is discussed in Section 5.2.2.

Table 5: List of ecological communities, threatened species and migratory species (DPTI 2015a).

	Type	Species	Common name
Listed ecological communities	Threatened Ecological Community	Grey Box (*Eucalyptus microcarpa)* Grassy Woodlands and Derived Native Grasslands of South-eastern Australia	-
Listed threatened species	Threatened Species (Bird)	Botaurus poiciloptilus	Australasian Bittern
		Pedionomus torquatus	Plains-wanderer
		Rostratula australis	Australian Painted Snipe
	Threatened Species (mammal)	Pteropus poliocephalus	Grey-headed Flying-fox
Listed migratory species	Marine	Apus pacificus	Fork-tailed Swift
	Terrestrial	Haliaeetus leucogaster	White-bellied Sea-Eagle
	Terrestrial	Merops ornatus	Rainbow Bee-eater
	Terrestrial	Myiagra cyanoleuca	Satin Flycatcher
	Wetland	Ardea alba	Great Egret, White Egret
	Wetland	Adrea ibis	Cattle Egret
	Wetland	Gallinago hardwickii	Latham's Snipe, Japanese Snipe
	Wetland	Pandion cristatus	Eastern Osprey
	Wetland	Rostratula benhjalensis (sensu lato)	Painted Snipe

Furthermore, all options have the potential to indirectly impact the local fauna community due to the removal of vegetation, however impacts are considered to be minor (AECOM 2015). Vegetation removal may affect the habitat availability, life style and breeding cycle of bird species such as the state rated Grey Currawong, the Rare Crested Shrike Tit and the Australasian Darter. Furthermore, if tree removal results in the depletion of habitat hollows that provide breeding sites, species such as the state rated Vulnerable Yellow-tailed Black-Cockatoo and the Rare Rated Common Brushtailed Possum may be impacted. In addition,

there are a number of threatened freshwater species utilising the Torrens that will be impacted through damage to the riparian system during construction. Having said this, both banks of the River Torrens are significantly degraded already, implying that impacts to fauna may not be significant (DPTI 2015a). Due to the degraded riparian system, the water temperatures will be higher than normal, and the river will have rather low dissolved oxygen levels. This ultimately suggests that the threatened species may already be suffering.

5.2.2 Offsets – General

None of the threatened species, ecological communities and migratory species listed above have been previously recorded in the project area. Therefore, it is unlikely that they will be impacted by the construction activities and vegetation removals required for this project. Furthermore, it is anticipated that the long-term operation of the project will not impact these species either (DPTI 2015a). Table 6 applies the Department of the Sustainability, Environment, Water, Population and Communities' significant impact criteria to each of the threatened species, ecological communities and migratory species that were listed in the EPBC Act Protected Matters Report. These tables further substantiate claims that the aforementioned species will not be impacted. Consequently, no mitigation measures have been put in place.

Table 6: Significant impact criteria applied to the ecological communities, threatened species and migratory species (DPTI 2015a).

	Significant Impact Criteria	Will the solutions impact this criteria? (yes/no)
Threatened Ecological Community	Reduce the ecological community population	No
	Negatively impact habitat that is critical to the survival of an ecological community	No
	Impact on water, nutrients, soils or groundwater levels necessary for an ecological community's survival	No
	Cause a loss of important species by removing flora or fauna	No
Listed threatened species	Lead to a long-term decrease in population size	No
	Reduce the area of occupancy of the species	No
	Negatively impact habitat that is critical to the survival of the threatened species	No
	Disrupt the breeding cycle of the threatened species	No
	Introduce a disease that may cause the species to decline	No
Listed migratory species	Substantially impact important habitat for migratory species	No
	Cause fauna harmful to the migratory species to become established in the habitat region of the migratory species	No
	Impact the breeding, feeding, migrating or resting behaviour of a migratory species	No

Moreover, to limit the breeding impacts on the Grey Currawong, the Rare Crested Shrike Tit and the Australasian Darter, trees and vegetation should not be removed during the birds' breeding season. These times are identified in Table 7.

Table 7: Breeding season of certain bird species.

Bird Species	Breeding Season
Grey Currawong	August to December
Rare Crested Shrike Tit	August to January
Australasian Darter	August to October

Furthermore, to offset the impacts on the state rated Vulnerable Yellow-tailed Black-Cockatoo and the Rare Rated Common Brushtailed Possum, habitat hollows and bird nests discovered during tree removal will be preserved, stored and incorporated into the urban landscape design as fauna habitat. One possible suggestion would be to incorporate these hollows and nests into the green wall design mentioned in Sections 4.2.6 and 4.2.8. If there is a need for animal relocation, Fauna Rescue SA will be contacted to ensure the fauna are relocated under strict guidelines (AECOM 2015).

Although the River Torrens riparian system is significantly degraded already, all efforts shall be made to mitigate the impacts to the threatened species in the River Torrens. Therefore, the environmental team plans to rehabilitate the riparian system by implementing a riparian buffer. A riparian buffer, as seen in Figure 6, is a vegetated area long both sides of a water stream that provides benefits to not only fauna, but also to water quality. See Section 9.2.2 for more details on the effect the riparian buffer has on water quality.

Figure 6: Riparian Buffer (What's Upstream, 2015).

A healthy riparian buffer is key to restoring natural stream functions and aquatic habitats, and it shows evidence of wise land use management. The riparian buffer provides a major source of energy, nutrients and food for communities living in adjacent stream. It also offers valuable habitat, an excellent travel way for a variety of wildlife and keeps streams cool when there is overhanging vegetation. In addition, the riparian buffer shall 'future proof' the area to anticipate the arrival of any migratory species. Such a riparian buffer allows fauna to thrive (North Carolina Wildlife Resource Commission n.d). Furthermore, this buffer allows the amenity of the area to be enhanced as it will allow exotic species and other vegetation to be planted in the area.

Moreover, the riparian buffer will require maintenance every 3 months, costing approximately only 15 cents per meter squared (Maryland Cooperative Extension n.d.). Note that this value was ignored in the final costing as it is very small. The 10% contingency allowed for in the costing of this section (see Table 20 in Appendix C) will account for this maintenance cost.

5.3. Costing

Most impacts related to fauna result from the removal of trees and vegetation. For these costs, please refer to Table 19 in Appendix B. Costs associated with fauna are related to the safe removal of habitat hollows, incorporating habitat hollows into the urban landscape, animal relocation and the rehabilitation of the River Torrens riparian system. For a breakdown of these costs, refer to Table 20 in Appendix C. As discussed in Section 5.4 below, these costs may vary slightly for each option, depending on where hollows are located and how many are found. This means that costing will not be the deciding factor when making a recommendation based on fauna impacts. Therefore, an average cost was developed. As a result, it will cost approximately $26,400 (on average for each option) to carry out the required works that will protect all fauna. Table 8 provides a summary of the costs.

Table 8: Costing for fauna impacts and offsets - Summary.

Option 1	Option 2	Option 3
$26,400	$26,400	$26,400

5.4. Evaluation & Recommendation

Without the presence of data that indicates exactly where birds breed and where bird nests and habitat hollows are located, it is safe to assume that option 1 will have the least impact on fauna as there are less trees and vegetation being affected by the solution. In fact, options 2 and 3 remove the same number of trees as option 1, plus more. This further implies that option 1 is the best solution in regards to limiting impacts to fauna. According to AECOM (2015), impacts to fauna due to the project are considered to be minor nonetheless. Therefore, each solution is considered to be highly feasible regardless. Despite this, based on the aforementioned reasoning, the environmental department recommends option 1. Although quite variable in nature, further investigations should be conducted in the detailed design, to determine, as best as possible, the exact location of bird nests and habitat hollows.

6. NOISE POLLUTION

Hackney road is a vital sub-arterial road which experiences a high volume of vehicular traffic on a daily basis. As a result, these vehicles will inevitably generate a considerable degree of noise. According to DPTI, Noise Pollution is defined as an unwanted sound that can be potentially disruptive to the surrounding environmental and individuals. Therefore, there is a vital need to ensure that the adopted option will not produce any long-term detrimental effects on the environment.

This section of the feasibility report will evaluate and discuss the ramifications of the O-Bahn corridor extension from the perspective of Noise Pollution. It will explore both the current noise levels and noise levels after project completion. If noise mitigation is required, this will also be discussed. In regards to both current and projected noise assessment, our team will be referring to the DPTI Road Traffic and Noise Guidelines (RTNG). Note that this section of the report only discusses Noise Pollution from a design perspective and does not cover noise during the construction phase. As stipulated by the aforementioned guidelines, a noise assessment will be required for Noise Sensitive Receivers.

6.1. Existing Noise Levels

In order to make an informed decision regarding noise mitigation, it is imperative that the existing levels are recorded. The information that will be used in this report will be chiefly derived from a development application report prepared by AECOM (2015). The said report contains results of a noise level assessment which was recorded using RION Noise Loggers. Figure 7 shows four different locations that the noise loggers were placed. Note that as E8 is only concerned with the area from the O-Bahn termination point up to and including the Botanic Road intersection. Hence, only locations 1 and 3 will be considered.

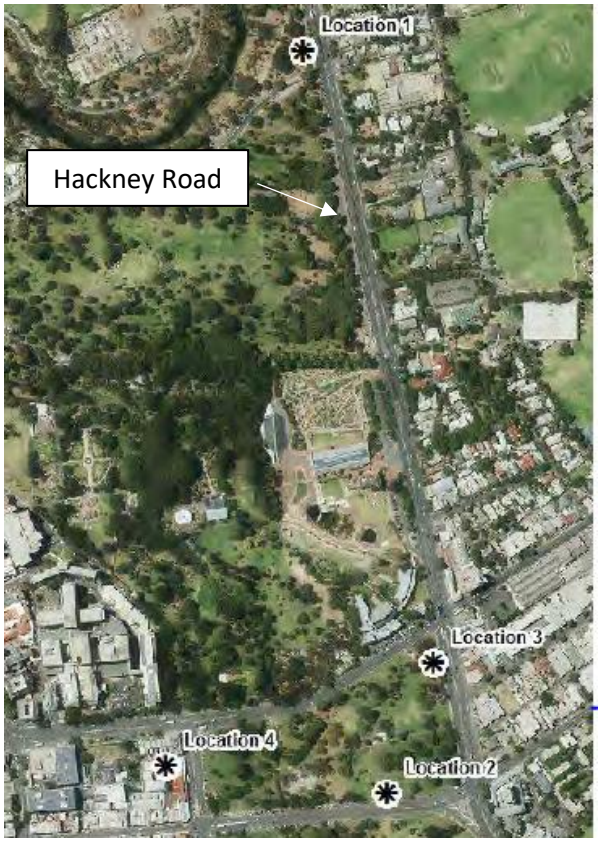


Figure 7: Noise logger locations (AECOM 2015).

The day and night noise levels at locations 1 and 3 are shown in Table 9 below. Note that day-time hours are recorded over a period of 15 hours (7am to 10pm) and night-time hours are recorded over a 9-hour period (10pm to 7am). For the sake of simplicity, the values of the two locations were averaged in order to obtain approximate day and night noise pollution levels.

Table 9: Noise recordings.

Location	Day, dB(A)	Night, dB(A)
Location 1	62.7	57.9
Location 3	63.8	60.1
Average	63.3	59

6.2. Target Noise Levels

Using the flowchart assessment process in Section 3.2.4, the target noise levels after project completion can be predicted. For the convenience of the reader, this flowchart is attached in Appendix D of this report. The existing levels are slightly above 63 dB(A) and 58 dB(A) for day and night respectively. Hence, the outdoor target is:

- 65 dB(A) during the day.
- 60 dB(A) at night.

6.3. Future Noise Levels

Section 4.3 of the RTNG stipulates that if a noise assessment is completed for a specific solution, then the increase in noise levels over a period of 10 years will also be considered. Note that if there is insufficient data available, the highly-experienced environmental team will make a reasonable prediction based on various details pertaining to the solution.

6.4. Impacts & Offsets

6.4.1 Impacts – Option 1

Option 1 will consist of widening the existing western bridge and constructing a shared pedestrian and bicycle path adjacent to the bridge. The main works that will be done in the project area includes implementing a dedicated bus priority lane and widening hackney road to allow for a dual-carriageway (outbound). The RTNG state that a noise assessment will need to be completed only if the works fall under the category of a 'New Road' (essentially a Greenfields site) or 'Redeveloped Road.' Upon consideration, the works on Hackney Road in this option are minor in nature. Although the road will be widened to allow for a dual carriageway, this will only be in the outbound direction. Additionally, the road will not be undergoing any major realignment that would place it in the redeveloped category.

6.4.2 Offsets – Option 1

It is in the opinion of the E8 environmental team that noise mitigation controls will not be required for this option as the proposed works do not meet the criteria for a redeveloped road as defined in Section 3.1.1 of the RTNG. This was also reiterated in the access development report by AECOM. Furthermore, even if this option did qualify as part of a redeveloped road, future noise levels (10 years after completion) will not exceed levels of dB(A) from existing levels (AECOM 2015). One key benefit of this option is that there will be a decrease in overall project cost as mitigation measures will not be needed. Furthermore, there could be greater public approval, as acoustic barriers could be perceived as unsightly. One drawback is the fact that the noise levels may not necessarily decrease.

6.4.3 Impacts – Option 2

Option 2 consists of the implementation of an elevated super way exclusively for buses. The super way will commence on Park Road, pass over the existing western bridge and revert back to grade slightly after Richmond Street. This solution will require a major realignment to Park Road to one-lane width both inbound and outbound. In contrast to the first option, this proposed solution would indeed meet the definition of a re-developed road as specified in Section 3.1.1 of the RTNG as the works are much more significant.

6.4.3.1 Identifying Noise Sensitive Receivers

The next step is to identify potential Noise-Sensitive Receivers within the project area. Based on the criteria provided in Section 3.1.2 of the RTNG, there is evidently some properties that would qualify as being noise-sensitive. On the western side of Hackney Road, there also is a recreational football oval and general parklands for recreational purposes. On the eastern side, some areas that qualify as being noise-sensitive includes:

- Apartment buildings adjacent to Park Road
- Houses on Park Road and Hackney Road
- Adelaide Caravan park
- Vailima Gardens Retirement Facility

6.4.3.2 Assessment Levels After Project Completion

After completion, the elevated super way will experience a constant flow of bus traffic. Buses are generally much noisier in comparison to standard sedans, with noise levels ranging from 77-84 dB(A) at speeds of approximately 50 km/hr (Frost & Ison 2007). The proposed speed limit on the super way will be 60 km/hr, which would result in even higher noise levels. Furthermore, the interaction between the bus and rails will increase these noise levels. Consideration should also be given to the fact that the proposed super way will be elevating the buses and hence have a high impact on the adjacent Noise Sensitive Receivers. It can be reasonably said that this exceeds the target levels prescribed in Section 6.2 of this report and in the RTNG. The interaction between the bus and the rails will be increasing noise levels as well. Hence, the outdoor levels may not be met and mitigation measures will be needed.

In regards to noise from regular traffic, the flowchart in Appendix D can be used to reasonably predict the noise levels 10 years after completion. Although using a noise modelling software is ideal, it is reasonable to say that future noise levels will only be increasing and will not be any less than the levels predicted 1 year after project completion. It has been indicated that a 5% traffic increase in regular vehicles is to be expected. However, an improved traffic flow and an increase in bus commuters will ensure that noise due to regular vehicles would not be an issue. Therefore, the main concern in this case is the noise levels generated by the buses. It should also be noted that the dwellings on Park Road and Hackney Road are within 50m of the new elevated bridge. Consequently, the next logical step prescribed in the RTNG is to consider implementing mitigation methods.

6.4.4 Offsets – Option 2

There are three different modes of mitigation that can be implemented. The first is to mitigate the noise at the source. This is done by implementing mufflers in the vehicular exhaust system and ensuring that it meets all the relevant road regulations. The second mitigation measure is to control the noise at the receiver, which includes making various alterations to the building (i.e. thicker glass on windows). The third solution is to control the noise along the transmission path.

The E8 environmental team has decided that the best approach would be the third method, which is to mitigate the noise along the transmission path. This would entail implementing acoustic barriers above the bridge parapet. These barriers will logically commence and end with respect to the super way in order to contain the noise pollution across that distance. For aesthetic quality, it is preferable to adopt a transparent acrylic barrier both from a commuters perspective and the local community. Figure 8 demonstrates what this solution could possibly look like.

Figure 8: Transparent acoustic barrier (Huanyu Noise Barriers n.d.).

The key benefits of this option is that noise levels will be reduced significantly. However, it will require a higher initial cost to implement the barriers. Further details of increasing the amenity of the barriers will be discussed in the detailed design. For feasibility purposes, some basic dimensions will be given. Regarding the length, the barriers will span for the length of the bridge (between 500 and 600 metres). Using the RTNG as an indicator, it was deemed that an appropriate height for these barriers would be 2.5m.

6.4.5 Impacts – Option 3

Option 3 consists of an underground tunnel which commences at the current O-Bahn termination point. The tunnel will have inbound and outbound lanes and will revert back to grade just past Richmond Street. Park Road will require a major realignment to a one-lane width. Due to the fact that the tunnel is completely new addition to the road and also that the realignment is an extensive undertaking, this option meets the criteria of a redeveloped road and must be assessed.

6.4.5.1 Identifying Noise Sensitive Receivers

With this solution, the same noise sensitive receivers as the previous option will apply. However, the parklands and the bicycle path in this case will require more consideration from a noise-assessment point of view.

6.4.5.2 Assessment Levels After Project Completion

In a similar manner as the previous option, the flowchart from the RTNG will be used and the target levels will remain the same. However, as the buses are travelling at a higher speed (approximately 80 km/hr), it is expected that an increased amount of noise will be generated.

It is reasonable to assume that this will exceed the target levels set in Section 6.2. Therefore, the ways in which the noise can be controlled will be discussed in the following section.

6.4.6 Offsets – Option 3

Although the buses will be generating a large volume of noise due to their increased speeds, this will not matter from a noise pollution perspective. The virtue of using concrete as the main structural element is the fact that by nature it also acts as an acoustic barrier. This means that the noise levels will improve significantly and therefore no extra noise controls will need to be implemented if this solution is adopted. By the same rationale, vibration will not need to be considered on the shared bicycle and pedestrian path which will be directly above the tunnel. However, the tunnel will have an air ventilation system as specified in the Air Pollution section which follows. This needs to be considered. In order to ensure that these extraction fans are not generating an excessive amount of noise, the fan inlet can be lined with sound-absorbing material or the rotational speed of the fan can be reduced.

6.5. Costing

For feasibility purposes, the approximate cost of implementing the acoustic barrier will be calculated. The approximate cost of lightweight acoustic barriers identified by Trevino (2014) is $32 per square foot. The detailed calculations are given in Appendix D. A summary of the calculations are given in Table 10 below.

Table 10: Costing for noise pollution impacts and offsets - Summary.

Option 1	Option 2	Option 3
N/A	$508,064	N/A

***Notes:**

- Options 1 & 3 have no mitigation measures and hence no costing details are required

6.6. Evaluation & Recommendation

In regards to noise pollution, the least preferable solution is considered to be the second option (i.e. the super way). This is due to the fact that it requires largest cost and effort to ensure that it is a viable solution. The first option is the runner-up as it costs the least amount from a design perspective and it also does not need any mitigation measures. However, there

will be little or no change in the current noise levels. Therefore, the third option will be most viable from a noise-pollution perspective as the design itself will prevent any noise reaching the outside of the tunnel. Furthermore, the noise generated by the air ventilation system can be easily contained. Thus, E8 environmental team recommends the third option as the most viable solution from a feasibility perspective.

7. AIR POLLUTION

Air pollution occurs when foreign and potentially harmful substances are emitted into the environment and change the composition of the air. This can usually result from sources such as: Industrial factories, motor vehicles, paints and numerous other causes. In relation to this project, the E8 environmental team is specifically concerned with motor vehicle exhaust emissions which result from the internal combustion process. It is imperative that the environmental team ensure that there are no long-term effects to the air quality in the project area as this could be detrimental to the health of the populace.

This section of the report will commence by assessing the current air quality levels in the project vicinity pre-construction. The target criteria will then be set in accordance with the South Australian Environmental Protection Authority's (EPA SA) criteria for air pollution. All three project solutions will be assessed to determine if the target criteria will be exceeded and mitigation measures will be proposed if required. Consequently, the most feasible option from an air quality perspective will be recommended.

7.1. Existing Air Levels

The development application report by AECOM (2015) explored the existing air quality levels of various Adelaide suburbs, namely: Kensington, Northfield, Netley and Adelaide CBD. For analysis purposes, the authors took a conservative approach and used the slightly higher Netley values as the existing conditions. These values were taken from EPA SA in 2013 and are shown in Table 11 below.

Table 11: Existing air quality conditions.

Pollutant	EPA Air Quality Results (µg/m^3)
PM_{10} (24-hour period)	16.5
$PM_{2.5}$ (24-hour period)	7.3
NO_2 (1-hour period)	13.4

Please note that PM_{10} and $PM_{2.5}$ denotes Particulate Matter measured as 10 micrometers or less and 2.5 micrometers or less respectively. It should also be noted that VOC's and CO is not

measured by EPA SA, however, the authors have determined that the values would be quite low for Adelaide regardless.

7.2. Target Air Levels

The target levels for this project are also given by EPA SA. These are defined as 'criteria' air pollutants and will be the compounds that E8 is concerned with. These compounds include:

- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO_2)
- Particulate Matter (both PM_{10} and $PM_{2.5}$)
- Volatile Organic Compounds (VOC)

The E8 environmental team will endeavour to approach each option in relation to these target levels and determine if it is reasonably possible that the solution in question will exceed these levels. The development application report by AECOM (2015) identifies target levels as determined by EPA SA and NSW Environmental Protection Authority. These are shown in Table 12 below.

Table 12: Target levels.

Pollutant	Concentrations (µg/m^3)
PM_{10} (24-hour period)	50
$PM_{2.5}$ (24-hour period)	25
NO_2 (1-hour period)	113
CO (1-hour period)	29,000
VOC (3-minute period)	53

It is evident that the existing air quality levels do not exceed the target levels. The next logical step is to assess each option in relation to these levels.

7.3. Impacts & Offsets

7.3.1 Impacts – Option 1

As stated previously, the first option consists of widening Hackney road and the existing western bridge. It is to be expected that post-construction the project area will experience a higher number of vehicles on the road due to factors such as population growth. The subsequent increase in vehicular traffic may cause an issue by increasing the volume of exhaust emissions. However, some factors need to be considered.

Firstly, it is evident that traffic congestion is one of the largest causes of an air pollution increase in the project area. This means that there will be large idling times and vehicles will be forced to deaccelerate and accelerate numerous times. Consequently, this results in increased air pollution from vehicles exhausts in comparison to vehicles travelling at a constant velocity (Zhang & Batterman 2013). This solution proposes the implementation of individual bus signals and dedicated bus lanes, which would result in a significant decrease in traffic congestion. As a result, it can be expected that the emissions will be better dispersed as vehicles will be able to travel at the speed limit more often and will not be idling for an unnecessary length of time. Therefore, it can be reasonably said that air quality levels will be closer to existing levels rather than target levels.

It should also be noted that the widening of Hackney Road will require the removal of some significant trees as stated in the flora section. Trees assist in reducing air pollution via Photosynthesis and their removal could potentially impact the air quality of the area.

7.3.2 Offsets – Option 1

In order to mitigate the removal of trees, the trees can be replanted to a section just north of the Bundeys Road intersection. Furthermore, recycling trees can also play a large role in reducing the carbon footprint overtime. In fact, recycling trees can save the need for other trees to be cut down to make common materials such as paper. If 30 trees were saved from recycling, up to 430kg of CO2 may be absorbed from the atmosphere each year. Moreover, recycling trees will also mean that there is less waste material sent to a landfill. This is also beneficial as wood can react with other waste materials to release Greenhouse Gasses (GHGs) that pollute the environment when sent to a landfill.

It can be concluded that this option will not negatively impact the environment after project completion as traffic congestion will be reduced and any trees that are removed will be replanted or recycled.

7.3.3 Impacts – Option 2

The second option will now be considered from an air quality perspective. In regards to traffic congestion, the same rationale as the first option can be used. Although regular traffic will be steadily increasing after project completion, the reduction in traffic congestion will indeed alleviate this. In fact, the elevated super way will completely separate the buses from regular traffic for some distance. This will result in a further reduction in congestion in comparison to option 1. However, there are also some other considerations regarding this solution. It was established that the acceleration of vehicles results in an increase in the amount of air pollution being emitted from the exhaust system (Zhang & Batterman 2013). When the buses enter the overpass, they will be accelerating a considerable degree. This could have a potential impact to the air quality within that specific area, although it is not likely to exceed the specified target criteria. In the case that it does affect the air quality, there are some measures that will be taken to reduce this.

7.3.4 Offsets – Option 2

It was stated in the previous section that some trees will need to be removed as a result of the Hackney Road widening. As stated in the flora section, some trees can be replanted slightly North of the Bundeys Road intersection. However, compared to option 1, the said section also explains that it will not be feasible from an economic standpoint to replant all the trees affected from option 2. Therefore, a solution to this is to implement a Green Wall on one side of the existing western bridge. This wall can provide a variety of advantages from an air quality perspective. The vegetation in the green walls, similar to trees, will produce oxygen as a result of photosynthesis. It will also mitigate urban heat island effects by lowering the temperature in the vicinity. Furthermore, it has been found that green walls that are implemented in street canyons are able to remove 40% of NO_2 and 60% of PM from the surrounding environment (Pugh et al. 2012). Although future levels cannot be exactly predicted in regards to this solution, it can be reasonably assumed that the target levels will not be exceeded through the means of a green wall and decreased traffic congestion.

Moreover, it is possible that these measure will in fact improve air quality when compared to existing conditions.

7.3.5 Impacts – Option 3

In regards to the tunnel, much of the same logic can be applied as the previous two options. From a traffic perspective, the tunnel will function in a much similar way to the elevated super way, namely that it completely separates regular vehicular traffic from bus traffic. Again, this will result in a significant decrease in traffic congestion despite a gradual increase in the number of vehicles utilising this corridor.

Furthermore, the air quality inside the tunnel must also be considered. A multitude of buses will be travelling through this tunnel on a daily basis and will subsequently be emitting pollution in the tunnel.

7.3.6 Offsets – Option 3

Additionally, green walls can also be implemented in this solution as stated in Section 4.2.8. In fact, the green wall implemented in the tunnel will cover a larger area than the wall for option 2. This will ensure that the external air quality will not only be meeting the target requirements, but will likely improve the air in comparison to the existing conditions.

To mitigate the pollution that will be emitted in the tunnel, proper air ventilation in the tunnel needs to be considered. To guide the team, the AustRoads Guide to Road Tunnels (2010) will be used. The guide encourages designers to use realistic scenarios of atmospheric conditions. As the buses are relatively free-flowing through the tunnel and are not subjected to intermittent stopping, it is realistic that the air pollution will be free-flowing as well. Given the length of the tunnel and the speed limit within the tunnel, E8 recommends providing air ventilation in the form of roof-mounted exhaust ventilators. Based on similar tunnels, it was deemed appropriate to provide 8 fans each way (16 total). This will ultimately ensure that the internal air quality is not exceeding the target limits. Please note that the approximate costing of this solution will be covered by the E8 services team.

7.4. Costing

As stated previously, replanting of trees and green walls are some mitigation methods that have been prescribed. All the necessary costing for these measures have already been calculated in the Flora section of this report. Therefore, please refer to Appendix B for a detailed breakdown of these calculations. The summary is shown in Table 3 below.

Table 13: Costing for air pollution impacts and offsets - Summary.

Option 1	Option 2	Option 3
$133,230 + $449,280 = $582,510	$301, 140 + $449,280 = $750,420	$451,140 + $449,280 = $900,420

***Notes:**

- $449,280 is the cost associated with the widening of Hackney Road. As previously mentioned, this cost remains consistent across all solutions.

7.5. Evaluation & Recommendation

E8 will now make a recommendation of which option is the most viable from an air quality perspective. From a costing point-of-view, option 1 will be the most viable option as it only requires the replanting of trees. However, air quality levels are likely to increase or remain at existing conditions, rather than improving the conditions. Therefore, the most suitable option will be either the second or third option. Of these two options, both have the potential to implement green walls. However, the green wall area covered by the tunnel will be significantly larger in comparison to the super way (i.e. providing greater potential to clean the surrounding air). In regards to traffic congestion, the tunnel may provide a higher benefit as the buses will be travelling at higher speeds. Furthermore, the elevated super way may reasonably contribute more to air pollution due to the acceleration of the buses when surmounting the incline. Although the tunnel requires buses to accelerate to higher speeds as well, the air ventilation systems in the tunnel will be sufficient to alleviate this. Therefore, it is the opinion of the E8 environmental team that the most viable solution from an air quality perspective will be Option 3 – Tunnel.

8. SOIL CONTAMINATION

Soil Contamination (or Soil Pollution) is defined as the degradation of the natural soil environment due to the presence of unwanted compounds. These compounds are usually man-made and can result from a variety of activities, namely: Industrial activities, agricultural activities and improper waste disposal. It is the duty of the E8 environmental division to ensure that contaminated soil is properly remediated or disposed of in order to reduce long-term detrimental impacts to the project environment.

This section of the report will assess the existing conditions. The respective impacts of each option will then be assessed in turn and general remediation measures will be proposed. This section will then conclude with an approximate costing and a subsequent recommendation. To deal with soil contamination, the team will follow the necessary criteria according to the ASC NEPM 1999 standards, The Environment Protection Act (SA) 1993 and the EPA Waste Derived Fill Standard throughout all areas of the design stage. These standards will be used to follow and meet the measures needed for soil dumping, remediation's and contamination levels.

8.1. Existing Conditions

The surface soil is predominately red/brown earth that underlays most of the Adelaide CBD and Park Lands, while the soil beneath the project area consists of mainly silty sandy clay that has been previously discovered in recent nearby developments along Hackney Road. Furthermore, from conducting research on the project area, we discovered that contaminated soil has been previously found in several projects throughout Adelaide's CBD. Over the years, works in the Park Lands and on the Adelaide Oval, Adelaide Oval Footbridge and Britannia Roundabout for example all showed a presence of contaminated soil. AECOM (2015) suggests that the presence of contaminated soil in these projects was likely due to the Park Lands being historically used as dumping grounds for contaminated soil, and also due to naturally occurring hydrocarbons forming from the extended presence of vegetation. Perhaps this contamination may have also been present due to the soil not being recycled properly throughout early stages of construction (DPTI 2015b).

Since the projects previously mentioned are located around the project area, it is likely that contaminated soil will be encountered along Hackney Road during construction. Infact, the fill and natural soil layers in the project location have been classified against SA EPA's Waste Derived Fill Standard in the aim of disposing or re-using contaminated soil. The fill material is also classified as exceeding low level contaminated waste based on Benzopayrene and total PAH concentrations (AECOM 2015). Therefore, the team will take careful consideration before and after soil excavation has commenced. Moreover, research also indicates that there will be a higher level of contamination in the upper soil layers of Hackney Road and that contamination will decrease with depth (DPTI 2015b).

8.2. Impacts & Offsets

In regards to the impacts of each option, it is difficult to precisely determine the amount of contaminated soil that will be excavated on-site. However, as stated previously, contaminated soil was recently found on the nearby Britannia Roundabout Upgrade project. Specifically, it was found that the top **600mm** of soil was contaminated. For feasibility purposes, the environmental team will assume the same amount of contamination for the O-Bahn corridor extension. Please note that this is solely an approximate value and the amount of soil contamination may change as the project progresses. Therefore, it is imperative that one sample per 250 m^3 of soil is taken and analysed as stipulated in the Waste Derived Fill (WDF) Standard. Furthermore, the relevant obligations and requirements in Table 3 of the WDF standard will need to be completed if contaminated soil is found.

8.2.1 Impacts – Option 1

Option 1 will be completed in 2 phases. Phase 1 will comprise of constructing a shared pedestrian and cyclist bridge over the Rover Torrens and continue as a path along the western side of Hackney Road. The dual lane path will have an approximate width of 3m, require an excavation depth of approximately 540mm along Hackney Road and have a total length of 1.5km. Phase 2 will comprise of adding 2 additional lanes to Hackney Road, extending the western bridge for a dedicated central bus lane and widening the road by approximately 8.3m on either side. This will require an excavation depth of 540mm and will have a total length of approximately 1.2km.

The total weight (in tonnes) for this option was calculated in Appendix E. It was determined that all of this soil will be contaminated as excavation will be less than 600 mm deep. Therefore, the total value of the contaminated soil was calculated as **15,617 tonnes.**

8.2.2 Impacts – Option 2

Option 2 will involve constructing an underground O-Bahn tunnel, which passes under Park Road, and eventually ramping up to a dual lane elevated superway. The underground O-Bahn tunnel will approximately remove 500 tonnes of excavated soil. Moreover, the 40 round concrete columns supporting the superway have a diameter of roughly 1m and these columns will be installed approximately 20m below ground level. It should be noted the widening of Hackney Road remains consistent throughout all 3 options, and has subsequently been added onto the calculations. The values for the waste fill (clean soil) and contaminated soil were found to be **15,665 tonnes** and **1,208 tonnes** respectively. Again, calculations are found in Appendix E.

8.2.3 Impacts – Option 3

Option 3 will comprise of constructing an underground tunnel to pass under Park Road and return to Grade South of Richmond Street. The tunnel will be constructed roughly 10m below ground level which will allow the tunnel to eventually span over the River Torrens from the North bank to the South bank. The tunnel will have an estimated width of 8.7m, height of 7m and will have an approximate length of 600m. Constructing an underground tunnel will require an estimated soil area of **50,589 tonnes** to be removed for sheet piling and **33,600 tonnes** for the stable slope construction as specified by out Geotechnical Team. Since this soil removes the most amount of earth, we expect to see the highest levels of contamination from this option. Infact, calculations show that approximately **21,881 tonnes** of soil is expected to be contaminated, including the soil excavated in the widening of Hackney Road.

8.2.4 Offsets – General (Remediation Measures)

Historically, contaminated soil has generally been disposed of by deposition at a local landfill, albeit at a higher cost. From an environmental perspective, this may not be an ideal scenario as it does not incorporate any ‘green’ elements, such as recycling of the soil. Therefore, the environmental team will consider remediating the soil onsite as it will prevent the need for

waste being deposited to landfill, and it will also allow us to recycle the soil. A common method is known as soil flushing. Soil flushing involves the use of flooding a contaminated soil sample with water or a liquid solution based on the chemical contaminants present. The liquid will slowly pass through the soil, removing any chemical contaminants from the soil and leaving large contaminants such as rocks behind. The contaminated fluid will be collected and transferred to the surface, which will then be ready for disposal to a local water management site. Soil flushing will require the ability to safely control the flow and recover the flushing fluid (Park 2009).

Once this method has removed the soil contaminates, the soil can be recycled. Clay soil is excellent for bulk earth works and since the site is predominately clay, the remediated soil could be transported to other projects that require a significant amount of soil, i.e., the Northern Connector Project. The recycled soil could also be used to cover the existing track in option 3 or for cosmetic purposes in the O-Bahn City Access upgrade such as for garden beds and landscaping. Although it would be ideal to remediate the soil rather than landfill deposition, the cost of the measure must be taken into consideration as well. This will be discussed accordingly in the *Evaluation & Recommendation* section.

It should also be noted that there is a significant amount of uncontaminated Waste Fill (clean) soil that will be excavated as well. This soil will definitely be recycled and can be used as backfill in any area of the O-Bahn extension project. Furthermore, it can be sent to the Northern Connector Project for Backfill purposes.

8.3. Costing

In regards to costing, an approximate price of completing the previously mentioned control measures has been determined for each option. The breakdown of the relevant calculations has been added in to Appendix E of this document. A summary of this is given in Table 14 below. Some assumptions were made for the purposes of simplicity. For example, the cost for low-level soil contamination was assumed for cost calculations in relation to landfill deposition. Hence a value of $160 per tonne was taken from Sinclair Knight Merz (SKM 2013). Furthermore, the cost for soil flushing depends on a variety of factors such as site-characteristics. Therefore, an average value of $180 USD (approx. $240 AUD) was taken from

(Roote 1997). It should be noted that these values are relatively dated and price will need to be confirmed in the detailed design. For feasibility purposes these values will suffice.

Table 14: Costing for soil contamination – summary.

Costs		
Option	Deposition	Soil flushing
1	$2,498,720	$1,874,160
2	$2,506,400	$1,878,672
3	$3,500,960	$2,625,840

8.4. Evaluation & Recommendation

In regards to the remediation measures, soil flushing appears to be the cheaper option in comparison to landfill deposition. This measure is also beneficial as it maximises the recycling potential for the soil. The treated soil can then be reused as backfill in other parts of the project area and also for the purposes of cosmetic design as mentioned earlier. Therefore, it is the opinion of the E8 environmental team that soil flushing should be implemented in the final design. Moreover, careful excavation will be required in order to prevent any further soil contamination along or near Hackney Road.

In regards to soil contamination, the best option will inherently be the solution that focuses on the least amount of soil excavation as larger amounts of excavation and remediation will equal a higher cost, time and effort. In light of this, it is evident that option 2 and 3 will not be as viable from a soil contamination perspective as the same amount of excavating required in option 1 will be completed in addition to extra excavations due to the superway columns or for the tunnel piles. Hence, it is the opinion of the E8 environmental team that **Option 1** will be most suitable as it requires the least amount of excavation and will be the cheapest.

9. WATER QUALITY

The quality of water affects all aspects of life. Using water which is contaminated can lead to various health issues, as well as destroying the natural habitats and environments. E8 Consulting understands the importance of maintaining clean water sources and strive to ensure the sustainability of our future.

This section will firstly discuss the existing water quality conditions. It will then outline the impacts that the proposed options have on the water quality and discuss offsets to mitigate these impacts.

9.1. Existing Conditions

The current stormwater drainage design system along Hackney Road allows for all of the stormwater runoff to be fed back into the River Torrens. This is a major problem if the stormwater becomes polluted by say engine leaks from vehicles as the runoff will have the potential to damage the natural ecosystem in the River Torrens. Nevertheless, the existing water quality of the River Torrens in the area near Hackney Road is quite poor already. Perhaps this is due to the existing stormwater design. Moreover, the information provided by the Australian Government shows that a variety of algae and bacteria such as enterococci are present in the River Torrens area (Adelaide City Council 2016). The Australian Government data also shows that these bacteria are being taken downstream and into the ocean where the bacteria are found to be in the river outlet. This means that extra measures must be taken into consideration to stop the pollutants from entering the river upstream, minimising the risk of polluting the water sources downstream.

Furthermore, there is also very little Water Sensitive Urban Design (WSUD) incorporated into the current water quality management plan along Hackney Road. This needs to be addressed in order to improve water quality.

9.2. Impacts & Offsets

All solutions have common elements associated with the quality of water and the management plans that will be implemented. Section 9.2.1 will focus on the impacts which will be common to all three options, while Section 9.2.2 outlines the solutions being implemented regardless of which is chosen. For example, the widening of Hackney Road and

inclusion of the new pedestrian and cyclist bridge is a common element in each of the options. This will result in additional impermeable area to the project site. Extra impermeable area will then increase the stormwater runoff volume being captured by the stormwater drainage system, increasing the likelihood of polluted stormwater entering the system.

9.2.1 Impacts – General

Due to the potential for there to be an increase in traffic, there is also a higher chance of stormwater runoff being polluted from oil leaks. This can cause damage to the quality of the water in the River Torrens which will affect the natural ecosystem as well as any animals that drink surface water to survive. Also, due to the increase in impermeable area post construction, there will also be an increase in stormwater runoff volume which again, increases the risk of polluted stormwater entering the water drainage systems.

9.2.2 Offsets – General

Post construction, the water quality and stormwater drainage systems must comply with the *Natural Resources Management Act 2004* and the *Environmental Protection Act 1993*. This is to ensure that there will be no harm to the environment or the River Torrens through contamination or polluted stormwater runoff. In addition, this project will also comply with the *South Australian Water Sensitive* and *Urban Design Policy*. The implementation of this policy will ensure that each solution will not only have minimal environmental impact but also improve any practices that are currently in place. Hence, E8 as a company strives to improve the water quality conditions rather than just maintaining current practices.

In order to maintain high water quality and meet the aforementioned standards, a combination of various WSUD technologies will be used to in conjunction with one another. This will allow for primary treatment to filter all of the larger pollutants and litter, while the secondary treatment focuses on the finer pollutants including any dissolved matter.

The primary technology is a gross pollutant trap, to ensure that the large particles and pollution are not sent downstream. A gross pollutant trap is simply a structure that slowly filters the stormwater runoff as it is passing through, while blocking all of the larger pollutants and litter. Once the water has passed, it may still be contaminated with finer sediments or dissolved pollutants (Melbourne Water 2014a). Maintenance for the gross pollutants traps

depends significantly on the amount of pollutant being collected. It is estimated that it will require cleaning periodically every approximately 3 to 6 months (Department of the Environment, Water, Heritage and the Arts 2010a). The cost of maintenance is dependent on the amount of polluted material and can vary, but is approximately $355 per year (Melbourne Water 2014a). To certify the quality of the captured water is adequate, samples will be taken periodically over a twelve-month period.

In addition to the gross pollutant trap, an infiltration trench will be used as a secondary filtration system. An infiltration trench is a trench that is filled with material of a porous nature. As the stormwater infiltrates the soil surrounding the trench, the porous material absorbs the finer and dissolved pollutants (Melbourne Water 2014b). The aim of this system is to provide secondary treatment to the stormwater runoff. The advantage of using infiltration trenches is the replenishment of the ground water sources beneath. This means that the use of the ground water will be more sustainable and can be used for irrigation purposes, for example, to water the local sporting club's field in Park 9, the parklands or plants in the Botanic Gardens, all of which are adjacent to the project site.

Similarly, to the gross pollutant traps, the infiltration trenches will also need to be maintained regularly to ensure that the rate of infiltration is not affected over time. It is estimated that the infiltration trenches will require maintenance approximately every 3 months (Department of the Environment, Water, Heritage and the Arts 2010b). The costs of maintenance is also highly dependent on the amount of pollutant present in the material, approximating to $785 per year.

Additionally, the use of riparian buffers will also be adapted. It will not be possible to capture all of the stormwater runoff, hence, the water that reaches the River Torrens will also need to be treated. By using these riparian buffers, the quality of the water in the River Torrens within the project area will increase significantly over time as the buffers help reduce the amount of sediment, nitrogen, phosphorus and other pollutants being drained into our natural water systems (North Carolina Wildlife Resource Commission n.d).

Other methods to reduce the volume of stormwater runoff during rainy days may also need to be considered. One possible solution is to use porous paving materials on walkways or footpaths. By allowing the water to pass through the material and into the soil underneath,

the path acts as a permeable surface, no longer contributing stormwater runoff. This will mean that the quality of the water will not be compromised by pollutants from the roads and it will also allow the water to replenish the soil.

Figure 9 below shows a sketch of the layout for the WSUD technologies.

Figure 9: Sketch of the layout for the WSUD.

9.2.3 Impacts – Option 1

Since there will be only a slight increase in impermeable area as well as traffic, the quality of the stormwater runoff will not be affected significantly. This means that the current stormwater drainage systems will be operating as they currently are, and additional WSUD technologies can be implemented in order to increase the quality of the water in the River Torrens. Refer to section 9.2.1 to see the impacts this option will have.

9.2.4 Offsets – Option 1

Due to the impact of option 1 being identical to that mentioned in the general section, the solutions will also be the same. The measures being put into place will be successful in ensuring the improvement to the water quality of the River Torrens. Refer to section 9.2.2 to outline the solutions that will be implemented.

9.2.5 Impacts – Option 2

The overall impact of the overpass will not affect the volume of stormwater runoff being collected due to having a similar catchment area compared to the existing amount. With the overpass, the only water that will be collected from the impermeable surface underneath will be from the wind blowing the rain sideways. Hence, the majority of the stormwater runoff will now be collected from the new road. Thus, the integration of WSUD can be implemented into the new stormwater drainage system to ensure the quality of the stormwater is not being compromised.

9.2.6 Offsets – Option 2

Since the infrastructure for the stormwater drainage system will be new, the mitigation systems to cope with the pollutants in the stormwater runoff can also be updated with the latest WSUD technology.

In order to reduce the amount of stormwater runoff being wasted, the green wall discussed in Section 4.2.6 will use the water captured and filtered by the infiltration trenches. This will create a sustainable way to maintain the green wall, by automatically giving the plants on the wall the required amount of water necessary to ensure their growth and survival without diminishing the current ground water sources.

9.2.7 Impacts – Option 3

Option 3 has a similar impact to water quality as option 1 outlined in the general section. This is due to the increase in impermeable area being almost identical since stormwater is not able to fall inside the underpass. Hence, refer to section 9.2.1 to see the impacts this project will have on the environment.

9.2.8 Offsets – Option 3

Similar to option 2, the underpass will also have a green wall to reduce the carbon levels and increase the quality of the surrounding environment. This means that the same approach will be adopted, where stormwater runoff is filtered and collected by the infiltration trenches which will be used to water the green wall.

9.3. Costing

Table 15 below summarises the costs that will be incurred for each option when implementing the offsets discussed in Section 9.2.2, while Appendix F provides details on how the costs were derived.

Table 15: Costing for water quality - Summary.

Option 1	Option 2	Option 3
$9,936	$11,136	$11,136

9.4. Evaluation & Recommendation

The use of water sensitive and urban design technologies, as well as the riparian buffers, ensures that the water quality of the River Torrens and local ground water sources will be improved and become more sustainable. Although the water quality will improve in each option, it is E8's opinion that option 1 should be adopted since options 2 and 3 both require additional WSUD technologies, increasing the costs for virtually no added benefit.

10. ENERGY

The use of non-renewable energy has a negative impact on the environment. Hence, by reducing the amount of energy being consumed, the carbon footprint of the project will also be reduced. E8 Consulting's strive to create a better, more sustainable future means that amount of energy being consumed once the project is completed needs to be taken into consideration.

This section will focus on the energy being used, specifically for the purpose of illumination. The existing conditions will be examined, as well as the impacts and offsets that will be put into place for each option proposed to DPTI.

10.1. Existing Conditions

Currently, the energy being consumed on Hackney Road is due to the illumination of the road during the night hours. From the site-visit, it was concluded that the lamps being used at not LED's, however due to lack of information, further research in the detailed design is required to determine the exact globes currently being used.

10.2. Impacts & Offsets

This section will first discuss the impacts to the three different options. Section 10.2.4 will then discuss the solutions to all the options as they will be identical. This is because the illumination of a road, tunnel or overpass must adhere to regulations which cannot be changed, hence the amount of light required must be satisfied. Thus, the type of globes being used are the only changeable option, resulting in all solutions using globes that are the most energy efficient.

The aim of this section is to reduce the amount of energy being consumed in order to reduce the carbon footprint of the project. By lowering the carbon footprint, the project will become more sustainable as it is requiring less amounts of fossil fuels being burnt to produce the energy.

10.2.1 Impacts – Option 1

Due to the fact that there will be a minimal increase in area once the project is completed, additional lighting and energy usage will not be required. The current lighting will suffice.

The only additional lighting required is on the footbridge which is a part of all options. Also, the footbridge will only require illumination during the night, with the natural light being more than sufficient during day-light hours. Hence, the increase in energy consumption will be minimal.

10.2.2 Impacts – Option 2

The overpass will have a clear increase in energy use. This is because it will block the natural light from the existing road underneath, meaning the road under the superway will need to be illuminated to ensure the lighting levels meet those required by specifications. On top of this, the overpass itself will also require illumination at night time, further increasing the energy being consumed.

10.2.3 Impacts – Option 3

When the tunnel is complete, the energy requirements post-construction will need to be considered. The tunnel will need to comply with AS 1158.5:2014 Lighting for roads and public spaces – Part 5: Tunnels and Underpasses. This will require illumination throughout the entire period of the day, dramatically increasing the amount of energy being consumed when compared to options 1 and 2.

10.2.4 Offsets – General

To minimise the impact on the environment caused by the above energy consumptions and to align the project with future development, all lighting will comply with the Street Lighting and Smart Controls program called Roadmap. Roadmap aims to cut the cost of street lighting and maintenance by implementing energy-efficient LED lights which are smart controlled (Institute of Public Works Engineering Australia 2017).

Having smart controlled lighting, the LED's are able to be adjusted to illuminate differently depending on the time of night, as well as having motion sensors, which can cut the amount of energy being consumed by up to 72% (Institute of Public Works Engineering Australia

2017). Other advantages, such as being able to increase the amount of light during harsh weather conditions, are also possible. Therefore, in addition to implementing these lights where required for the new developments, as part of the design, E8 Consulting also wishes to replace existing lights by the new LED with smart controls to comply with the Roadmap program.

Other advantages of using LED's as opposed to the legacy street lighting technology is the amount of maintenance required. Traditional street lighting requires a replacement cycle of 3-5 years, with annual unscheduled maintenance occurring almost annually. LED lighting are designed to be replaced a minimum of 12 years, which can be extended to as much as 20 years (Institute of Public Works Engineering Australia 2017).

Due to the nature of the project, there is no area which solar panels can be installed to generate green energy. Hence, the energy that will be used will need to be sourced. Therefore, minimising the amount of energy being consumed will be critical to ensure the project remains sustainable in all aspects. Roadmap is an excellent way to achieve this. In addition, another effective method would be to implement road safety technologies such as high visibility edge line markings and retro-reflective materials where appropriate. These will not only improve safety, but will also minimise the need for lighting as they provide their own illumination. As a result, these technologies will help further reduce the amount of energy required and this will contribute significantly to the reduction of the carbon footprint of the project.

10.3. Costing

Table 16 summarises the annual energy costs associated with implementing the LED lights suggested in section 10.2.4. Please refer to Appendix G for full calculation details.

Table 16: Costing for annual energy of implementing the LED system - Summary.

Option 1	Option 2	Option 3
$596	$946	$1,618

10.4. Evaluation & Recommendation

It is the opinion of the company that option 1 is the most efficient solution in regard to the energy aspect of the project. This is due to the fact that it will be consuming far less energy than options 2 and 3, as no additional lighting will be needed along Hackney Road, other than for the pedestrian bridge – but this remains consistent across all solutions. In fact, when the upgrades are completed to the current lighting, option 1 should be even more efficient than the current situation, however this will not be the case for options 2 and 3 due to the additional lighting requirements. Therefore, option 1 is certainly the recommendation from an energy standpoint.

11. TOTAL COSTING

After devising a cost for each of the 7 environmental considerations, a total costing was developed for each of the options. These costs are listed below in Table 17.

Table 17: Total project costs for each option.

Environmental Consideration	Option 1	Option 2	Option 3
Flora	$ 582,510	$ 750,420	$ 900,420
Fauna	$ 26,400	$ 26,400	$ 26,400
Noise Pollution	N/A	$ 508,064	N/A
Air Pollution	Part of Flora	Part of Flora	Part of Flora
Soil Contamination	$ 1,874,160	$ 1,878,672	$ 2,625,840
Water Quality	$ 9,936	$11,136	$ 11,136
Energy	$ 596	$ 964	$1,618
TOTAL	**$2,493,602**	**$ 3,175,638**	**$3,565,414**

As can be seen from Table 17, option 1 has the lowest cost whilst option 3 has the highest cost. These costs will play a factor in formulating the final recommendation in Section 12 below.

12. ENVIRONMENTAL RECOMMENDATION

In order to compare the impacts that options 1, 2 and 3 have on the 7 environmental considerations discussed in the previous sections, a decision matrix was developed. This decision matrix is shown in Table 18. The matrix lists each of the 7 considerations and assigns each a weighting based on their importance. The impacts that the options have on the considerations were then given a score, with 0 indicating the solution has no impact on the environment and 10 indicates severe impact. A relative score could then be developed by multiplying the weighting by the score. The option receiving the lowest relative score will be the option that has the least impact on the environment and also the option which is most cost-effective. Therefore, the option with the lowest relative score will be recommended as the preferred design option. The results of this process are shown in Table 18.

Table 18: Decision Matrix.

Environmental Consideration	Weighting (%)	Option 1 (x/10)	Relative Score	Option 2 (x/10)	Relative Score	Option 3 (x/10)	Relative Score
Flora	20	4	0.8	6	1.2	6	1.2
Fauna	10	2	0.2	2.5	0.3	2.5	0.3
Noise Pollution	15	4	0.6	6	0.9	2.5	0.4
Air Pollution	15	3.5	0.5	3	0.5	2	0.3
Soil Contamination	15	3	0.5	5	0.8	6.5	1.0
Water Quality	15	2	0.3	2.5	0.4	2.5	0.4
Energy	10	2	0.2	4	0.4	4	0.4
Total	100	-	**3.1**	-	**4.3**	-	**3.9**

Referring to Table 18, option 1 received the lowest relative score of 3.1. Therefore, we, the environmental department recommend option 1 as the preferred design option. Nevertheless, it should be mentioned that all options were considered to be feasible and compromises may need to be made after consulting and negotiating with our other departments.

13. REFERENCES

AECOM 2015, *O-Bahn City Access Project Section 33 Development Application – Development Within the Park Lands,* AECOM Australia Pty Ltd, viewed 24 March 2017, <http://www.infrastructure.sa.gov.au/__data/assets/pdf_file/0004/193468/Section_33_-_Application_-_Within_Park_Lands_PDF,_44_925_KB.pdf>.

Adelaide City Council 2016, *Torrens River Water Quality Data for 2015-16*, Australian Government, viewed 28 March 2017, <http://data.gov.au/dataset/river-torrens-water-quality-upstream-and-downstream-from-lake/resource/693e431d-4c0d-44f6-ad62-9b0f1084a5fd?inner_span=True>.

Britton, J 2012, *Banksia marginata,* Australian National Botanic Gardens and Centre for Australian National Biodiversity Research, viewed 11 April 2017, <https://www.anbg.gov.au/gnp/interns-2012/banksia-marginata.html>.

Brooks, C 2013, *The environmental benefits of reclaimed wooden furniture,* Furniture News, viewed 09 April 2017, <http://www.furniturenews.net/resources/articles/2013/05/904725917-environmental-benefits-reclaimed-wooden-furniture>.

City of Adelaide n.d.a., *Parngutilla (Park 8)*, Adelaide City Council (ACC), viewed 14 March 2017, <http://www.adelaideparklands.com.au/parks-and-squares/parngutilla-park-8>.

City of Adelaide n.d.b., *Tidlangga (Park 9)*, Adelaide City Council (ACC), viewed 14 March 2017, <http://www.adelaideparklands.com.au/parks-and-squares/tidlangga-park-9>.

Clain, J 2011, 'Benefits of recycling Christmas Tree', blog post, *B4tea,* viewed 15 March 2017, <http://b4tea.blogspot.com.au/2011/08/benefits-of-recycling-christmas-tree.html>.

Contek, Civil & Concrete specialists, Viewed 23 March 2017, <http://www.conteksa.com.au/>

Department of Planning, Transport and Infrastructure (DPTI) 2017, *Call for tender,* UniSA, viewed 9 April 2017, <https://lo.unisa.edu.au/pluginfile.php/1336886/mod_resource/content/2/Project%20%232%20Call%20for%20Tender.pdf>.

Department of Planning, Transport and Infrastructure 2016, *O-Bahn City Access Project,* Government of South Australia, viewed 4 April 2017, <http://www.infrastructure.sa.gov.au/public_transport_projects/o-bahn_city_access>.

Department of Planning, Transport and Infrastructure 2015a, *O-Bahn City Access Project, Environment Protection and Biodiversity Conservation Act 1999 – Referral of proposed action,* DPTI, viewed 14 March 2017, <http://epbcnotices.environment.gov.au/_entity/annotation/5bb3cd0a-2a84-e511-b341-005056ba00a7/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1487289600359>.

Department of Planning, Transport and Infrastructure 2015b, *The O-Bahn City Access Project – Project Impact Report,* Government of South Australia, viewed 14 March 2017, <http://www.infrastructure.sa.gov.au/__data/assets/pdf_file/0005/175361/Project_Impact_Report_-_Complete.pdf>.

Department of Planning, Transport and Infrastructure 2014, Preliminary Environmental Impact Assessment Report, Government of South Australia, Adelaide.

Development Act 1993.

Development of Adelaide Botanic Garden n.d., *Adelaide Botanic Garden Conservation Study,* Development of Adelaide Botanic Garden, viewed 14 March 2017, <https://www.environment.sa.gov.au/files/.../3_abg2_history_conservationstudy.pdf>.

Department of the Environment, Water, Heritage and the Arts 2010a, *Water Sensitive Urban Design Chapter 9 – Gross Pollutant Traps*, Government of South Australia, viewed 10 April, <https://www.sa.gov.au/__data/assets/pdf_file/0003/16428/WSUD_chapter_9.pdf >.

Department of the Environment, Water, Heritage and the Arts 2010b, *Water Sensitive Urban Design Chapter 6 – Rain Gardens, Green Roofs and Infiltration systems*, Government of South Australia, viewed 10 April, <https://www.sa.gov.au/__data/assets/pdf_file/0011/11540/WSUD_chapter_6.pdf>.

Frost, M.W. and Ison, S.G., 2007. Comparison of noise impacts from urban transport. Proceedings of the Institution of Civil Engineers, Transport, 160 (4), 165-172.

Huanyu Noise Barriers, n.d., *6 reasons of choosing Transparent Sound Barrier,* Huanyu Noise Barriers, viewed 29 March 2017, <http://www.noisebarriers.org/noisebarrier/transparent-sound-barrier.html>.

IAC Publishing 2017, *How do you transplant wild pine trees?,* LCC, viewed 15 March 2017, <https://www.reference.com/science/transplant-wild-pine-trees-b6fa949428bfeb49#>.

Institute of Public Works Engineering Australia 2017, *Roadmap – Street Lighting and Smart Controls Program,* Australian Government Department of the Environment and Energy, viewed 10 April 2017, <https://higherlogicdownload.s3.amazonaws.com/IPWEA/86668664-2b52-4cc1-bf25-86692c04c947/UploadedImages/SLSC/4220%20SLSC%20Programme%20Roadmap%20-%20FINAL%20-%20161216.pdf>.

Maryland Cooperative Extension n.d., *When a Landowner Adopts a Riparian Buffer – Benefits and Costs,* Maryland Cooperative Extension, viewed 12 April 2017, < https://extension.umd.edu/sites/extension.umd.edu/files/_docs/programs/riparianbuffers/FS774.pdf >.

Melbourne Water 2014a, *Gross pollutant traps,* Melbourne Water, viewed 4 April 2017, <https://www.melbournewater.com.au/Planning-and-building/Stormwater-management/WSUD_treatments/Pages/Gross-pollutant-traps.aspx>.

Melbourne Water 2014b, *Infiltration trenches,* Melbourne Water, viewed 5 April 2017, <https://www.melbournewater.com.au/Planning-and-building/Stormwater-management/WSUD_treatments/Pages/Infiltration-trenches.aspx>.

North Carolina Wildlife Resource Commission n.d., *Riparian Buffers,* Stream Notes, vol.1, No. 3, viewed 10 March 2017, <https://www.bae.ncsu.edu/programs/extension/wqg/sri/riparian5.pdf>.

Panagiotakis, I & Dermatas, D 2017, 'Soil and Groundwater Contamination and Remediation', *Bulletin of Environmental Contamination and Toxicology*, vol. 98, no. 3, pp. 297-298.

Park, J & Shin, E 2015, 'Applicability of soil flushing remediation system for contaminated fine-grained soils using PVDs', *International Journal of Geotechnical Engineering*, vol. 3, no. 3, pp. 417-427.

Plant Connection Inc 2017, G-O_2 living wall maintenance & advantages, viewed 27 March 2017, <http://myplantconnection.com/green-wall-maintenance.php>.

Pugh, AM, Mackenzie, AR, Whyatt, JD & Hewitt, CN 2012, 'Effectiveness of green infrastructure for improvement of air quality in urban street canyons', *Environmental science & technology*, vol. 46, no. 14, pp. 7692.

Roote, D.S 1997, *In-Situ Flushing,* Ground-Water Remediation Technologies Analysis Center, viewed 10 April 2017, <https://clu-in.org/download/remed/flush_o.pdf >

Sinclair Knight Merz (SKN) 2013, *Management of contaminated soils in South Australia*, Sinclair Knight Merz, viewed 10 April 2017, <http://www.zerowaste.sa.gov.au/resource-centre/publications/management-of-contaminated-soils-in-south-australia >

Strategic and Environmental Planning Department 2001, *Park Land Olive Management Plan,* City of Adelaide, viewed 15 March 2017, <http://www.cityofadelaide.com.au/assets/Policies-Papers/docs/MGMT-PLAN-parklands-olive-management-plan.pdf>.

Trevino, M 2014, *Evaluation of Lightweight Noise Barrier on a Bridge Structure,* Centre for Transportation Research, Texas, USA, viewed 29 March 2017, <http://www.adc40.org/presentations/winter2015/Evaluation%20of%20Lightweight%20Noise%20Barrier%20on%20Bridge%20Structure.pdf>.

Vegetation Removal Policy.

Wang, L 2014, *North America's largest green wall is now complete in Vancouver,* Inhabitat, viewed 10 April 2017, <inhabitat.com/incredible-amazing-timelapse-shows-installation-of-north-americas-largest-green-wall/>.

Ward, L 2013, *8 low-maintenance outdoor plants for the busy gardener,* Curbly, viewed 14 March 2017, <http://www.curbly.com/15042-8-low-maintenance-outdoor-plants-for-the-busy-gardener>.

What's Upstream 2015, *The answer is simple,* What's Upstream, viewed 15 March 2017, <http://whatsupstream.com/>.

Yee Ko, KT 2012, *Lomandra longifolia,* Australian National Botanic Gardens and Centre for Australian National Biodiversity Research, viewed 11 April 2017, <https://www.anbg.gov.au/gnp/interns-2007/lomandra-longifolia.html>.

Zhang, K & Batterman, S 2013, 'Air pollution and health risks due to vehicle traffic', *Science of the Total Environment*, vol. 450-451, pp. 307-316.

Zhu, Y & Shaw, G 2000, 'Soil contamination with radionuclides and potential remediation', *Chemosphere*, vol. 41, no. 1, pp. 121-128.

APPENDIX A – PRELIMINARIES

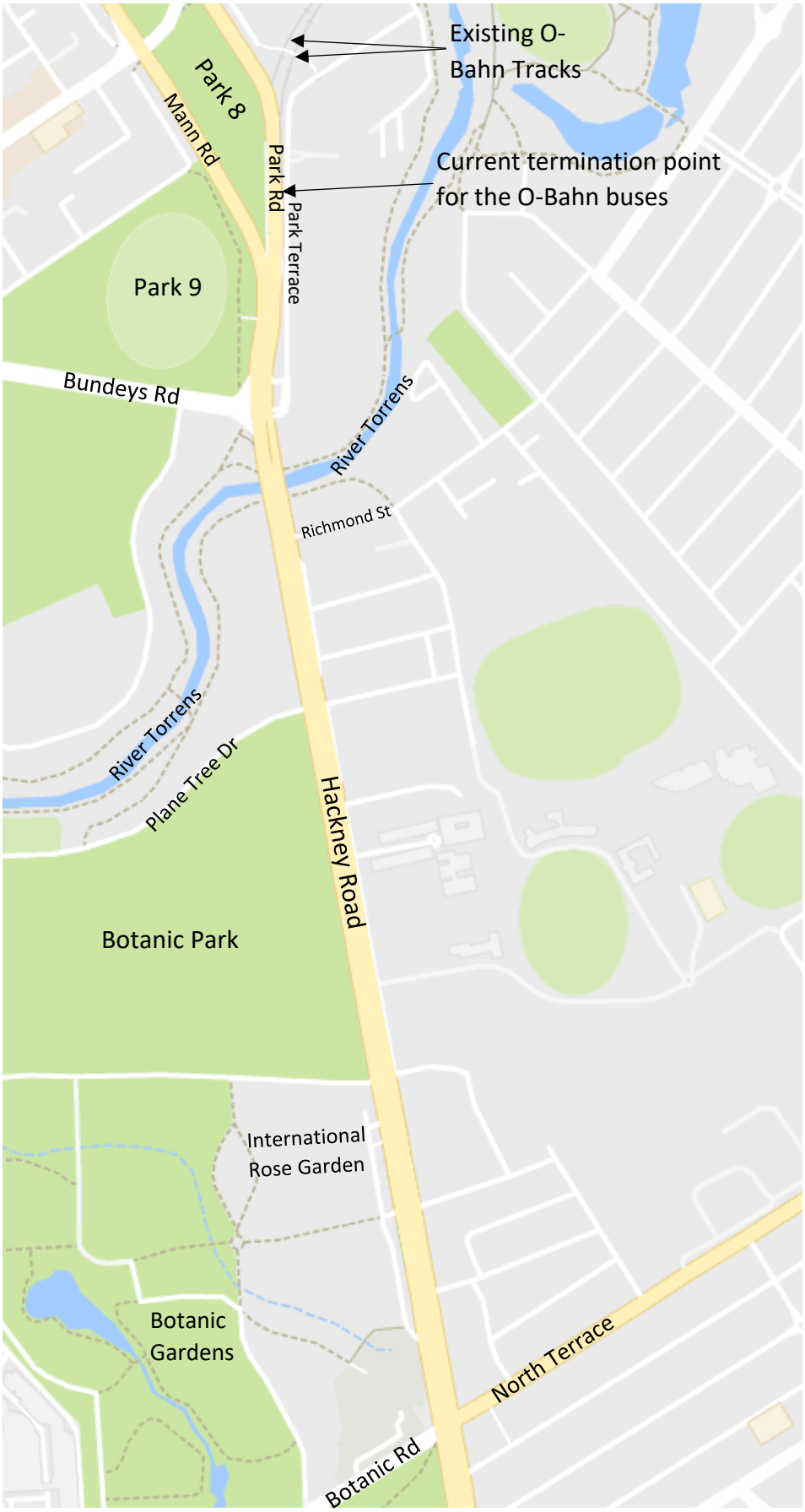


Figure 10: Project location.

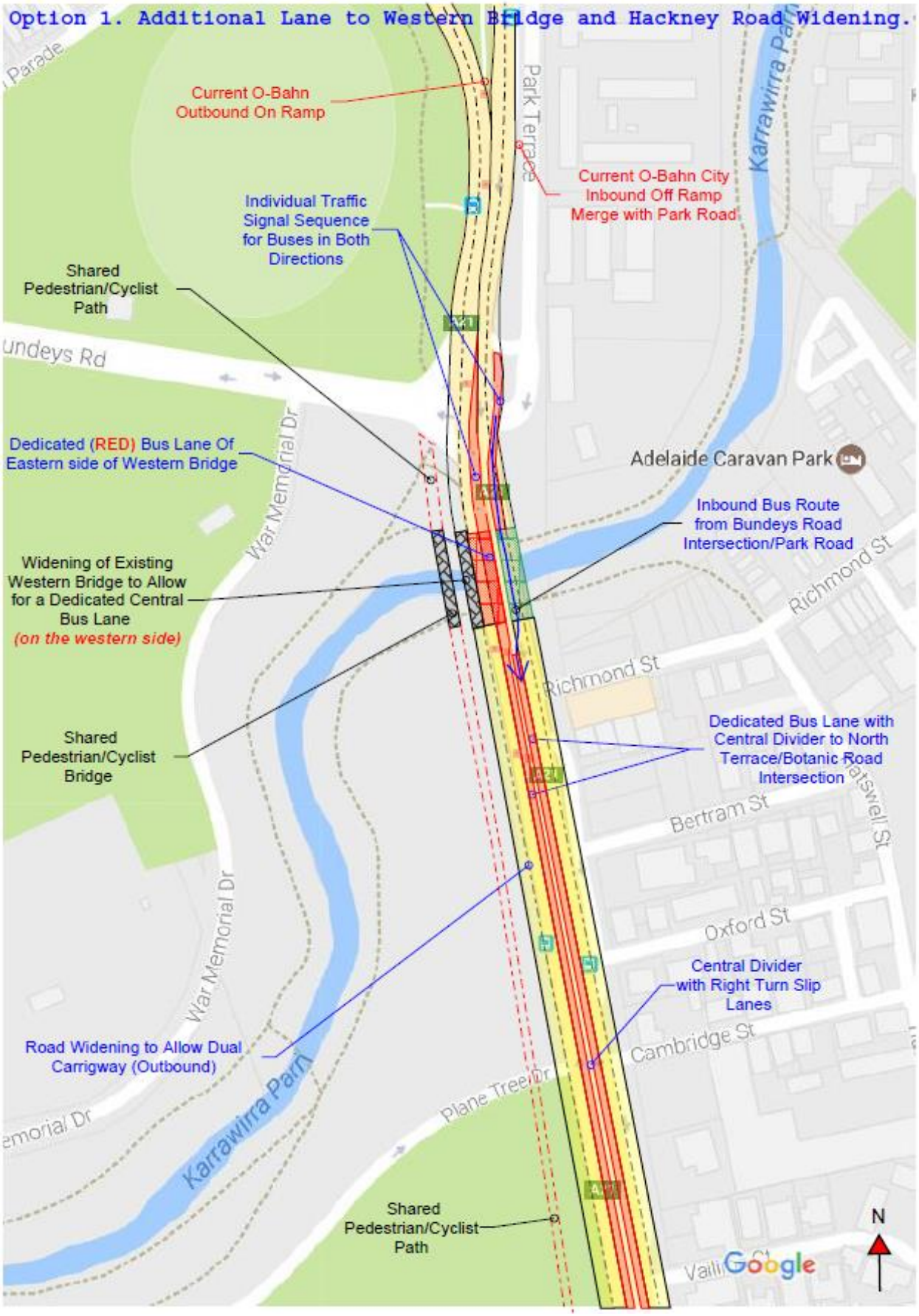


Figure 11: Option 1 – Additional lane to western bridge and Hackney Road widening.

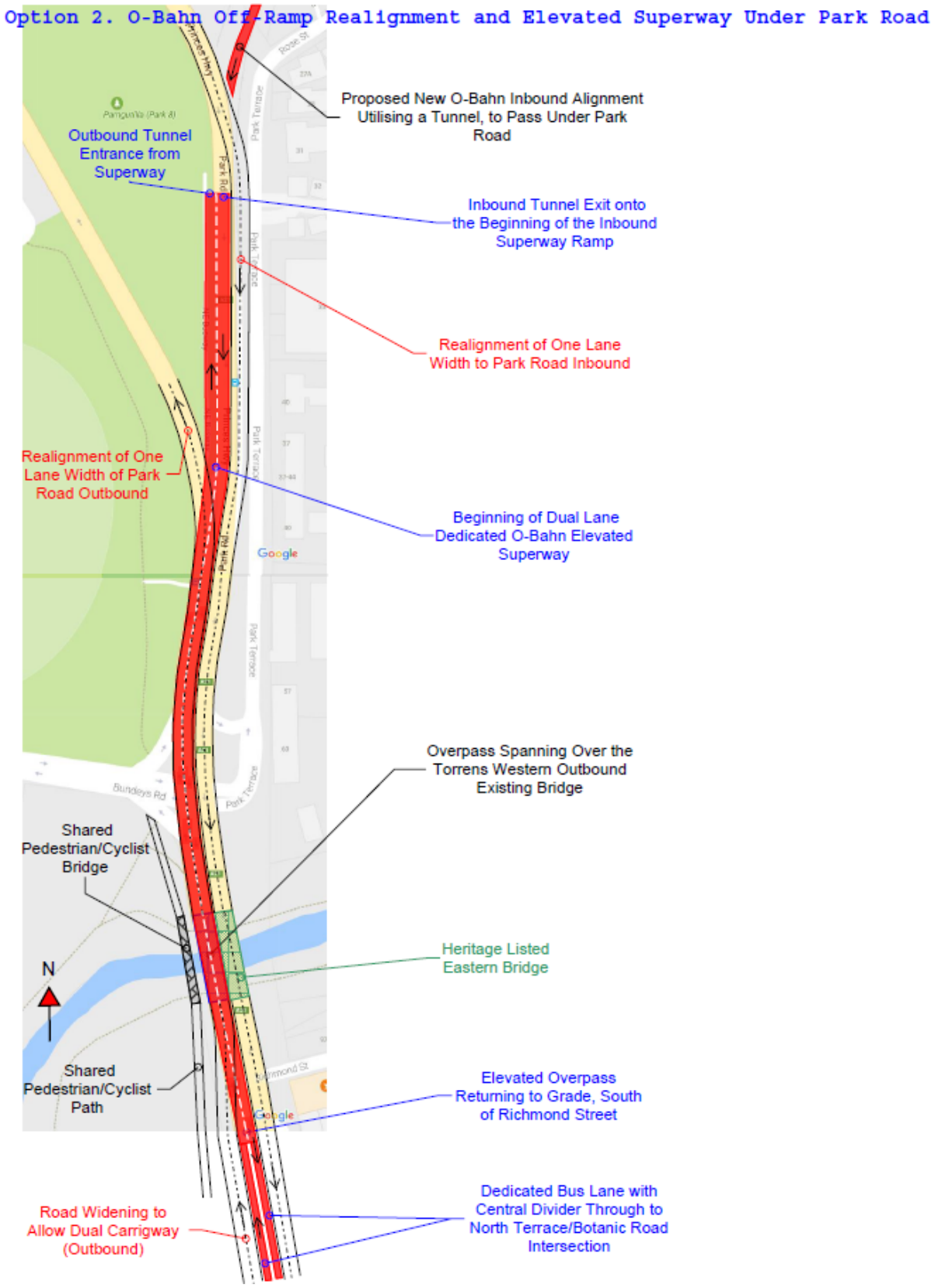


Figure 12: O-Bahn off-ramp realignment and elevated superway under Park Road.

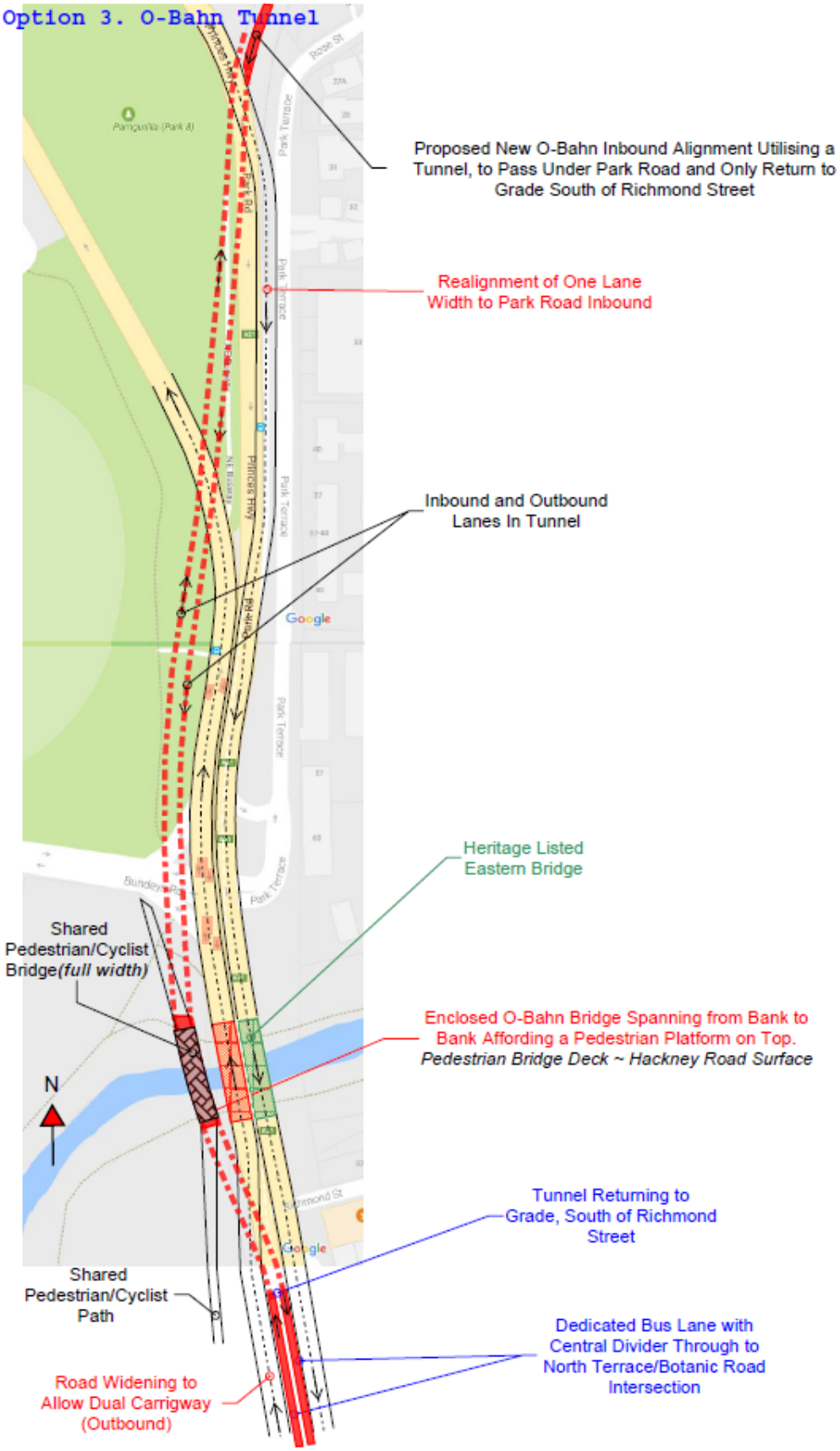


Figure 13: O-Bahn Tunnel.

APPENDIX B – FLORA

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
277	*Citharexylum quadrangulara*	Fiddlewood	12.4	1.83	1.16, 1.03	1.9, 0.94				

Age Class	Mature
Health	Good
Structure	Fair
Shape & Form	Good
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	20 years +
Recommendations	Tree identified as major impact in DPTI impact assessment
Transplant Potential	Yes
Tree Protection Zone (m)	8.10
Structural Root Zone (m)	2.64

General Comments

Tree is a small healthy specimen located 8.5 metres from the adjacent building. Showing good shape and form with a crown displaying good foliage density.

The location of the tree in relation to the DPTI reference design, identifies that an increase in existing road width is proposed, which will require excavation into the area identified as the trees SRZ, which is considered to be major encroachment.

Excavation undertaken in such close proximity to the trees structural rooting system has the potential to have a detrimental effect on its overall stability and impact on its health.

Figure 14: Tree No. 277 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
282	*Quercus ilex*	Holly Oak	11.9	2.47	2.22	2.22	8	8	4	6

Age Class	Mature
Health	Good
Structure	Fair
Shape & Form	Fair
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	20 years +
Recommendations	Tree identified as major impact in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	8.48
Structural Root Zone (m)	2.99

General Comments

Large tree situated below existing road level with a large retaining wall direct to its eastern side. Wide crown with good foliage density.

The location of the tree in relation to the DPTI reference design, identifies that an increase in existing road width is proposed, which will require excavation into the area identified as the trees SRZ, which is considered to be major encroachment.

Excavation undertaken in such close proximity to the trees structural rooting system has the potential to have a detrimental effect on its overall stability and impact on its health.

Figure 15: Tree No. 282 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
513	*Eucalyptus camaldulensis*	River Red Gum	12	2.4	1.23, 0.97	1.03, 0.96	5	5	8	5

Age Class	Semi Mature
Health	Fair
Structure	Poor
Shape & Form	Poor
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	5 - 10 years
Recommendations	Tree identified for removal in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	5.38
Structural Root Zone (m)	2.96

General Comments

Small tree showing poor shape and form due to heavy suppression from adjoining trees.

The tree is shown to be within the area identified as the proposed route, in the DPTI reference design, for the O Bahn City Access Project. The tree has been identified for removal within the DPTI impact assessment to facilitate project completion.

Figure 16: Tree No. 513 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
514	*Pinus halepensis*	Aleppo Pine	22.6	2.9	2.69	2.65	9	9	11	10

Age Class	Mature
Health	Good
Structure	Fair
Shape & Form	Good
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	20 years +
Recommendations	Tree identified for removal in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	10.12
Structural Root Zone (m)	3.20

General Comments

Large wide spreading tree showing good shape and form supporting a large crown supported on a framework of large diameter scaffold branches. Large deadwood and dead hanging branch in mid eastern crown.

The tree is shown to be within the area identified as the proposed route, in the DPTI reference design, for the O Bahn City Access Project. The tree has been identified for removal within the DPTI impact assessment to facilitate project completion.

Figure 17: Tree No. 514 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
519	*Pinus halepensis*	Aleppo Pine	26.3	2.7	2.58	2.59	8	4	8	9

Age Class	Mature
Health	Good
Structure	Fair
Shape & Form	Good
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	20 years +
Recommendations	Tree identified for removal in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	9.89
Structural Root Zone (m)	3.11

General Comments

Large tree showing reasonable shape and form, with all crown supported in the upper third of the tree. Crown form is asymmetrical due to suppression from adjoining trees giving a heavy bias to the south and west.

The tree is shown to be within the area identified as the proposed route, in the DPTI reference design, for the O Bahn City Access Project. The tree has been identified for removal within the DPTI impact assessment to facilitate project completion.

Figure 18: Tree No. 519 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
520	*Pinus pinea*	Stone Pine	17.5	2.2	2.16	2.15	0	4	12	4

Age Class	Mature
Health	Very Poor
Structure	Poor
Shape & Form	Very Poor
Fungi or disease	No
Legislative Status	Regulated Tree
Life Expectancy	< 5 years
Recommendations	Tree identified for removal in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	8.21
Structural Root Zone (m)	2.85

General Comments

Large heavily suppressed tree showing exceptionally poor form being heavily suppressed by the adjoining trees creating a crown form that extends to the south. Major deadwood and dieback evident.

The tree is shown to be within the area identified as the proposed route, in the DPTI reference design, for the O Bahn City Access Project. The tree has been identified for removal within the DPTI impact assessment to facilitate project completion.

However, the tree is showing exceptionally poor health and form and considered to have a short life expectancy and as such should be removed.

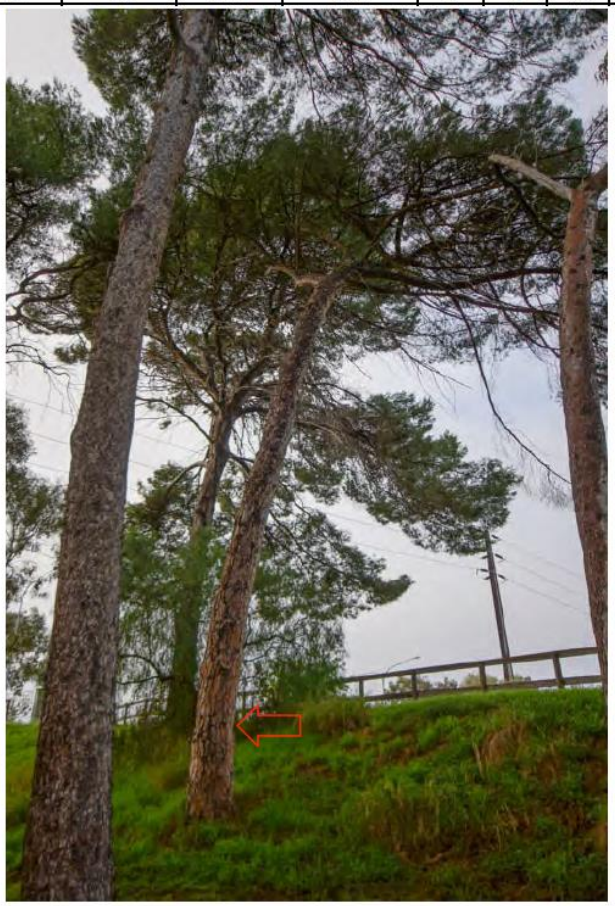


Figure 19: Tree No. 520 (regulated tree) (AECOM 2015).

Tree No.	Genus & Species	Common Name	Height	Circ @ Base	Circ @ 1m	Circ @ 1.4m	Crown Spread			
							N	E	S	W
518a	*Pinus halepensis*	Aleppo Pine	27	3.19	3.07	2.81	14	7	3	9

Age Class	Mature
Health	Good
Structure	Fair
Shape & Form	Fair
Fungi or disease	No
Legislative Status	Significant Tree
Life Expectancy	10 - 20 years
Recommendations	Tree identified for removal in DPTI impact assessment
Transplant Potential	No
Tree Protection Zone (m)	10.73
Structural Root Zone (m)	3.33

General Comments

Large mature tree with heavy stem bias to north self correcting at 17 meters where it develops a large but asymmetrical crown with heavy bias to the north.

The tree is shown to be within the area identified as the proposed route, in the DPTI reference design, for the O Bahn City Access Project. The tree has been identified for removal within the DPTI impact assessment to facilitate project completion.

Figure 20: Tree No. 518a (significant tree) (AECOM 2015).

Figure 21: Flora affected by the widening of Hackney Road.

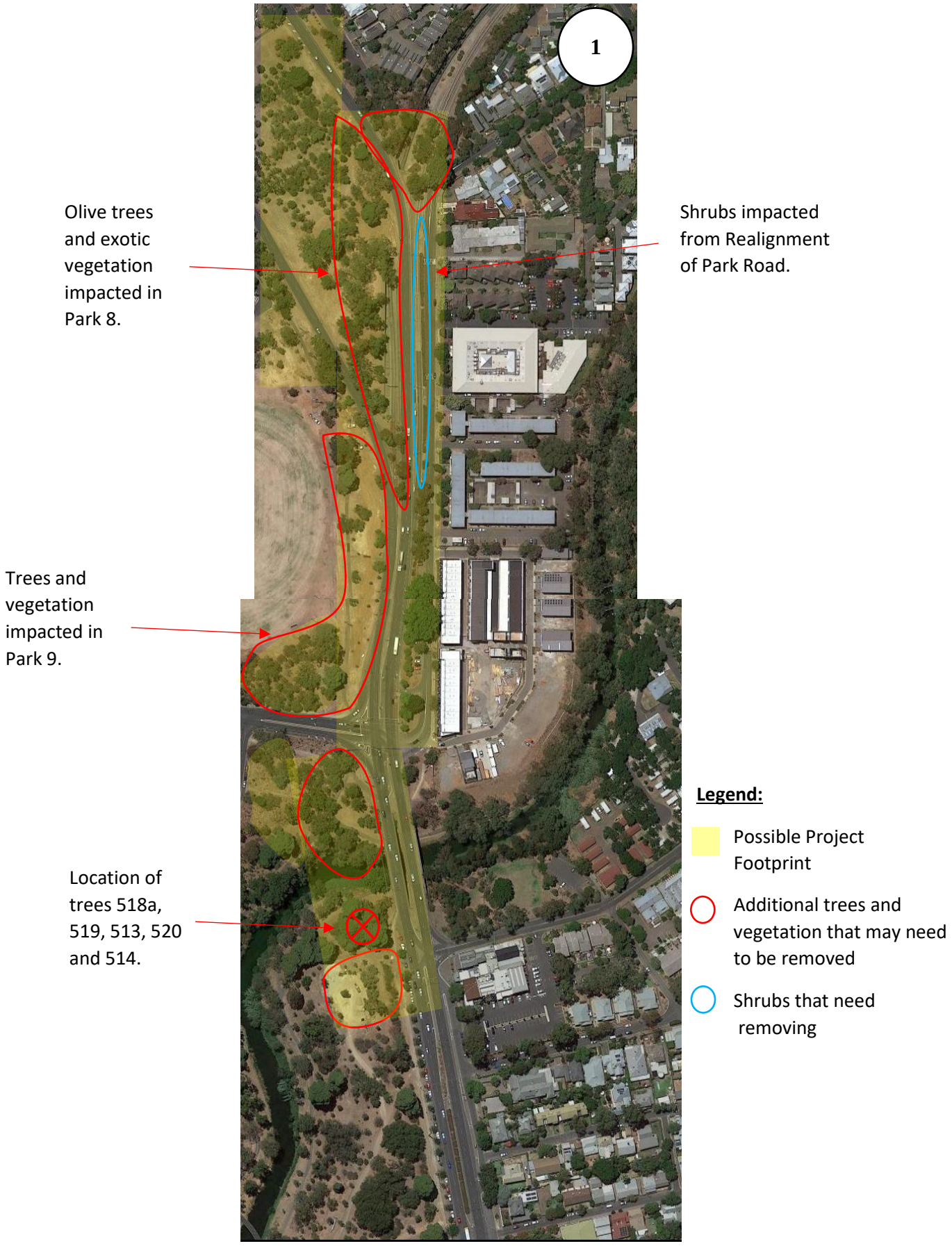


Figure 22: Flora affected by options 2 &3.

Table 19: Costing for flora impacts and offsets – full breakdown.

FLORA

ITEM DESCRIPTION	AMOUNT	UNITS	RATE/COST	TOTAL	ITEM TOTAL
General (Road Widening)					
Impacts					
Tree removal (non-significant)	140	-	$ 500	$ 70,000	
Vegetation removal (non-significant)	2528	m^2	$ 50	$ 126,400	
Pruning trees 277 & 282	2	-	$ 400	$ 800	
Offsets					
Replanting Meidiland Roses	1000	m^2	$ 50	$ 50,000	
Transplanting trees 277 & 282	2	-	$ 5,000	$ 10,000	
Trans/Replanting for Botanic Gardens vision	528	m^2	$ 150	$ 79,200	
Recycling less significant flora	500	m^2	$ 75	$ 37,500	
Using recycled material as mulch	500	m^2	$ 1	$ 500	
					$ 374,400
Option 1					
Impacts					
Removing trees 513, 514, 519, 520 & 518a	5	-	$ 1,500	$ 7,500	
Vegetation & Tree removal (non significant)	250	m^2	$ 400	$ 100,000	
Offsets					
Replant trees 513, 514, 519, 520 & 518a	11	-	$ 200	$ 2,200	
Recycling non-significant trees	15	-	$ 75	$ 1,125	
Using recycled material as mulch	200	m^2	$ 1	$ 200	
					$ 111,025
Option 2					
Impacts					
Removing trees 513, 514, 519, 520 & 518a	5	-	$ 1,500	$ 7,500	
Removing Olive Groves	30	-	$ 1,500	$ 45,000	
Removing Exotic species	360	m^2	$ 100	$ 36,000	
Vegetation removal (non significant)	750	m^2	$ 100	$ 75,000	
Tree removal (non significant)	110	-	$ 500	$ 55,000	
Offsets					
Replant trees 513, 514, 519, 520 & 518a	11	-	$ 200	$ 2,200	
Green wall construction	1	-	$ 5,000	$ 5,000	
Green wall maintenance					
- Remote monitoring system	1	-	$ 2,000	$ 2,000	
- Custom engineering rolling platform	1	-	$ 5,000	$ 5,000	
- Automated drip irrigation system	1	-	$ 2,000	$ 2,000	
- Pruning and fertilising	2	year	$ 500	$ 1,000	
Olive Groves cultural preservation	-	-	$ 10,000	$ 10,000	
Recycling non-significant trees	70	-	$ 75	$ 5,250	
					$ 250,950
Option 3					
Impacts					
Removing trees 513, 514, 519, 520 & 518a	11	-	$ 1,500	$ 16,500	
Removing Olive Groves	30	-	$ 1,500	$ 45,000	
Removing Exotic species	360	m^2	$ 100	$ 36,000	
Vegetation removal (non significant)	750	m^2	$ 100	$ 75,000	

Tree removal (non significant)	110	-	$ 500	$ 55,000	
Offsets				$ -	
Replant trees 513, 514, 519, 520 & 518a	11	-	$ 200	$ 2,200	
Green wall construction	2	-	$ 20,000	$ 40,000	
Green wall maintenance				$ -	
- Remote monitoring system	1	-	$ 8,000	$ 8,000	
- Custom engineer rolling platform	2	-	$ 7,500	$ 15,000	
- Automated drip irrigation system	2	-	$ 8,000	$ 16,000	
- Pruning and fertilising	2	year	$ 1,000	$ 2,000	
Olive Groves cultural preservation	-	-	$ 10,000	$ 10,000	
Recycling non-significant trees	70	-	$ 75	$ 5,250	
Revegetation	500	m^2	$ 100	$ 50,000	
					$ 375,950

TOTALS (INCLUDING 10% GST & 10% CONTINGENCY)	
GENERAL	**$ 449,280**
OPTION 1	**$ 133,230**
OPTION 2	**$ 301,140**
OPTION 3	**$ 451,140**

APPENDIX C – FAUNA

Table 20: Costing for fauna impacts and offsets – full breakdown.

FAUNA

ITEM DESCRIPTION	AMOUNT	RATE/COST	TOTAL	ITEM TOTAL
General (Average cost for all 3 solutions)				
Impacts				
Safe removal of habitat hollows	10	$ 75	$ 750	
Offsets				
Incorporating hollows into urban landscape	10	$ 50	$ 500	
Animal Relocation	15	$ 50	$ 750	
Rehabilitate riparian system (riparian buffer)	1	$ 20,000	$ 20,000	
				$ 22,000
SUBTOTAL				$ 22,000
Contingencies			**10%**	
GST			**10%**	
TOTAL FOR ALL OPTIONS				$ 26,400

APPENDIX D – NOISE POLLUTION

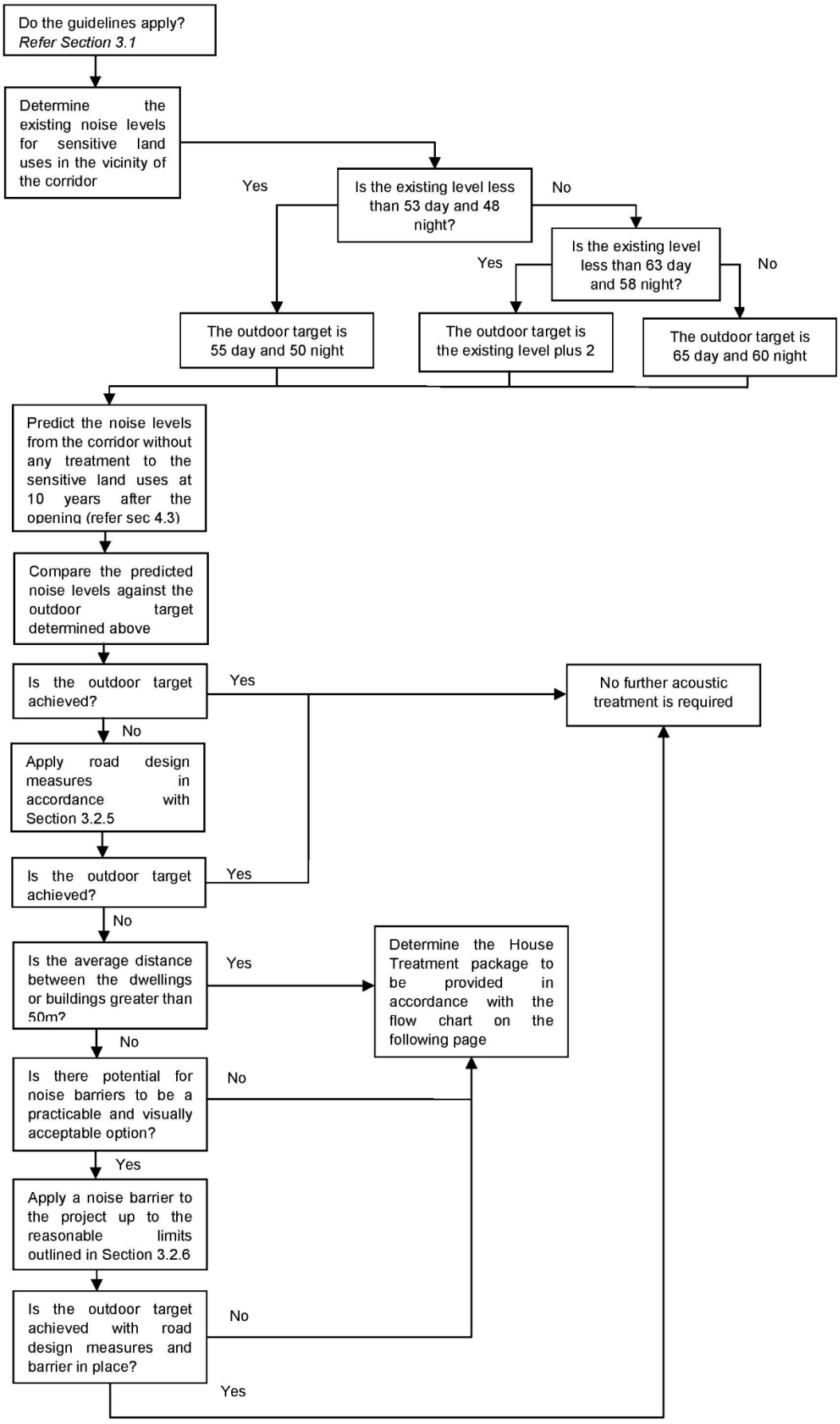


Figure 23: RTNG classification process.

Table 21: Costing for noise pollution – full breakdown.

NOISE POLLUTION			
ITEM DESCRIPTION	**AMOUNT**	**UNITS**	**TOTAL**
Option 2			
Length of Barrier	590	m	-
Height of Barrier	2.5	m	-
Area of Barrier		m^2	1475
		ft^2	15877
Cost of Barrier	32	$/$ft^2$	$508,064

APPENDIX E – SOIL CONTAMINATION

Option 1

Phase 1:

$Soil\ Volume = 3 * 0.54 * 1500 = 2430m^3$

$Unit\ weight\ of\ soil = 20\ kN/m^3$

$\therefore Weight\ of\ soil = 20 * 2430 = 48600\ kN$

$= 4{,}860{,}000\ kg\ (as\ 1\ kN \approx 100kg)$

$= 4860\ tonnes$

Phase 2:

$Soil\ Volume = 8.3 * 0.54 * 1200 = 5379m^3$

$Unit\ weight\ of\ soil = 20\ kN/m^3$

$\therefore Weight\ of\ soil = 20 * 5379 = 107568\ kN$

$= 10{,}756{,}800\ kg\ (as\ 1\ kN \approx 100kg)$

$= 10757\ tonnes$

$Total\ for\ Option\ 1 = 10757 + 4860 =$ **$15617\ tonnes$**

Option 2

$Total\ for\ Preliminary\ tunnel = 500\ tonnes$

$Column\ total\ volume = \pi * \frac{(1)^2}{4} * 20$

$= 5\pi\ m^3$

$= 628\ m^3\ for\ 40\ columns$

$Unit\ weight\ of\ soil = 20\ kN/m^3$

$\therefore Total\ weight\ of\ soil = 20 * 628 \quad = 12566\ kN$

$= 1{,}256{,}637\ kg\ (as\ 1\ kN \approx 100kg)$

$= 1256\ tonnes$

To find the amount of contaminated soil, assume top 600 mm is contaminated.

Furthermore, assume that **10 tonnes** of the preliminary tunnel is contaminated.

$$Volume = \pi * \frac{(1)^2}{4} * 0.6$$
$$= 0.47\ m^3$$
$$= 18.8\ m^3\ for\ 40\ columns$$

$$Unit\ weight\ of\ soil = 20\ kN/m^3$$

$$\therefore Weight\ of\ soil = 20 * 18.8 = 376\ kN$$
$$= 37{,}600\ kg\ (as\ 1\ kN \approx 100kg)$$
$$= 37.6\ tonnes$$

$$\therefore Option\ 2\ Contaminated\ Soil = 37.6 + 10 = \mathbf{47.6\ tonnes}$$
$$\therefore Option\ 2\ Waste\ Fill\ (clean)\ Soil = 1256 - 47.6 = \mathbf{1208\ tonnes}$$

However, the excavating in option 1 is still occurring in option 2 and must be added into the total soil.

$$\therefore Total\ Contaminated\ Soil = 47.6 + 15617 = \mathbf{15665\ tonnes}$$
$$\therefore Total\ Waste\ Fill\ (clean)\ Soil = \mathbf{1208\ tonnes}$$

<u>Option 3</u>

Again, assuming top **600 mm** is contaminated.

$$Soil\ Volume = 8.7 * 0.6 * 600 = 3132m^3$$
$$Unit\ weight\ of\ soil = 20\ kN/m^3$$

$$\therefore Weight\ of\ soil = 20 * 3132 = 62640\ kN$$
$$= 6{,}264{,}000\ kg\ (as\ 1\ kN \approx 100kg)$$
$$= 6264\ tonnes$$

Therefore, total contaminated soil for option 3 will be:

$$\therefore Total\ Contaminated\ Soil = 6264 + 15617 = \mathbf{21881}\ \boldsymbol{tonnes}$$

Table 22: Costing for soil contamination – full breakdown

SOIL CONTAMINATION

ITEM DESCRIPTION	AMOUNT	UNITS	RATE	UNITS	TOTAL
Option 1					
Impacts					
Contaminated soil	15617	Tonnes			-
Offsets					
Soil deposting	15617	Tonnes	160	$/Tonne	$2,498,720
Soil flushing	7809	m^3	240	$/$m^3$	$1,874,160
Option 2					
Impacts					
Contaminated soil	15665	Tonnes			-
Offsets					
Soil deposting	15665	Tonnes	160	$/Tonne	$2,506,400
Soil flushing	7827.8	m^3	240	$/$m^3$	$1,878,672
Option 3					
Impacts					
Contaminated soil	21881	Tonnes			-
Offsets					
Soil deposting	21881	Tonnes	160	$/Tonne	$3,500,960
Soil flushing	10941	m^3	240	$/$m^3$	$2,625,840

APPENDIX F – WATER QUALITY

Costing for WSUD:

Approximate costs for an infiltration trench is $138 per meter length (Department of the Environment, Water, Heritage and the Arts 2010b). With an estimation of three trenches approximately 10m long;

$$3 \times 138 \times 10 = \$4{,}140$$

The cost of a single gross pollutant trap is approximately $1,000 (Department of the Environment, Water, Heritage and the Arts 2010a). Requiring approximately three gross pollutant traps;

$$3 \times 1000 = \$3000$$

Hence the total cost (excluding GST) approximates to;

$$4140 + 3000 = \$7{,}140$$

The full breakdown of the costs for all options are shown in Table 23.

Table 23: Costing for water quality – full breakdown

WATER QUALITY

ITEM DESCRIPTION	AMOUNT	UNITS	RATE/COST	TOTAL	ITEM TOTAL
General (Option 1)					
Offsets					
Infiltration Trench	30	m^2	$ 138	$ 4,140	
Gross Pollutant Trap	3	-	$ 1,000	$ 3,000	
Maintenance	1	Yearly	$ 1,140	$ 1,140	
					$ 8,280
Option 2 & 3					
Offsets					
Water Pump	1	-	$ 1,000	$ 1,000	
					$ 9,280
TOTALS (INCLUDING 10% GST & 10% CONTINGENCY)					
GENERAL					**$ 9,936**
OPTION 1					**$ 9,936**
OPTION 2					**$ 11,136**
OPTION 3					**$ 11,136**

APPENDIX G – ENERGY

Calculating the annual energy consumption for the proposed LED's.

The amount of lights specified were supplied by the water and services department. It is assumed for the purpose of these calculations that the lights on the main roads and overpass will be active for 10 hours per day, whilst the tunnel will be illuminated for the whole 24-hour period. This will need to be adjusted and completed more accurately in the detailed design. Also, the rates for electricity will be assumed to be 40 cents per kWh.

Hackney Road:

34 x 100W LED lights x 10 hours/day x 365 days = 1,241 kWh/year

Overpass:

20 x 100W LED lights x 10 hours/day x 365 days = 730 kWh/year

Underpass:

80 x 40W LED lights x 24 hours/day x 365 days = 2,803 kWh/year

Table 24: Costing for energy – full breakdown.

ENERGY

ITEM DESCRIPTION	AMOUNT	UNITS	RATE/CO	TOTAL	ITEM TOTAI
General (Option 1)					
Offsets					
LED Street Lighting	1241	kWh/year	$ 0.40	$ 496	
					$ 496
Option 2					
Offsets					
LED Overpass Lighting	730	kWh/year	$ 0.40	$ 292	
					$ 788
Option 3					
Offsets					
LED Underpass Lighting	2803	kWh/year	$ 0.40	$ 1,121	
					$ 1,618

TOTALS (INCLUDING 10% GST & 10% CONTINGENCY)	
GENERAL	**$ 596**
OPTION 1	**$ 596**
OPTION 2	**$ 946**
OPTION 3	**$ 1,941**

APPENDIX H – CONCEPT DESIGNS

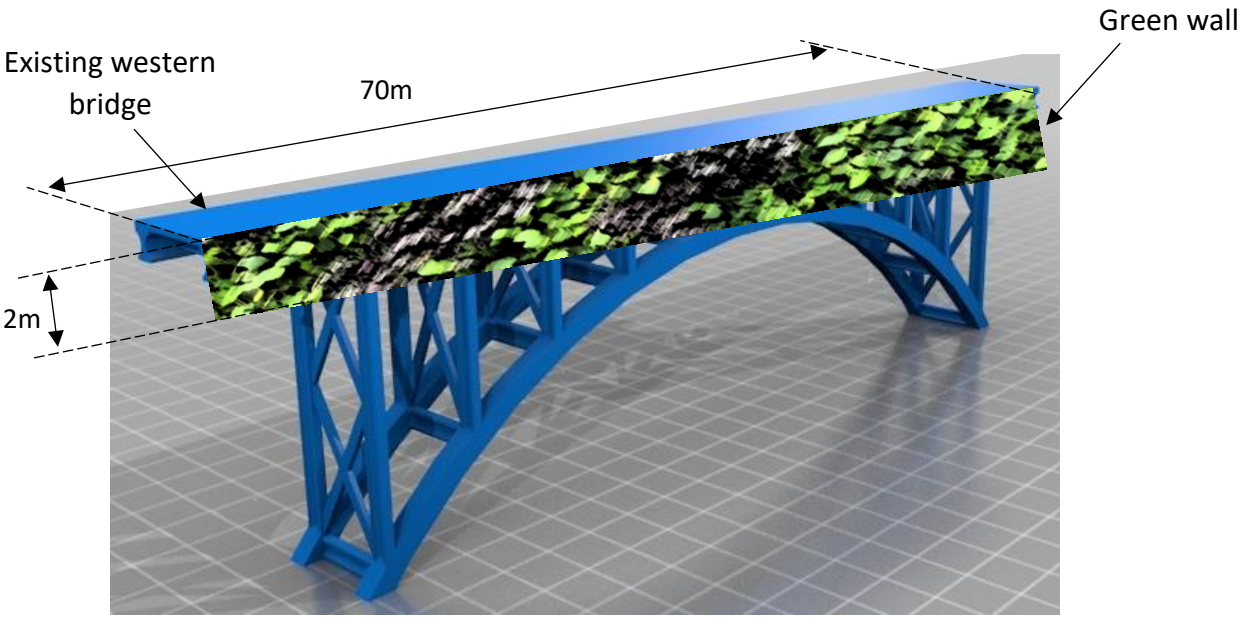


Figure 24: Green wall concept design for option 2.

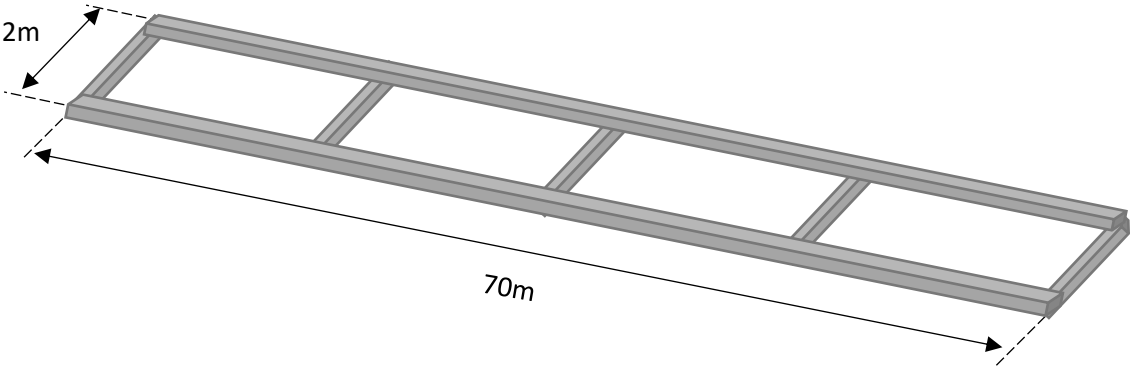


Figure 25: Custom engineered rolling platform concept design for options 2 and 3.

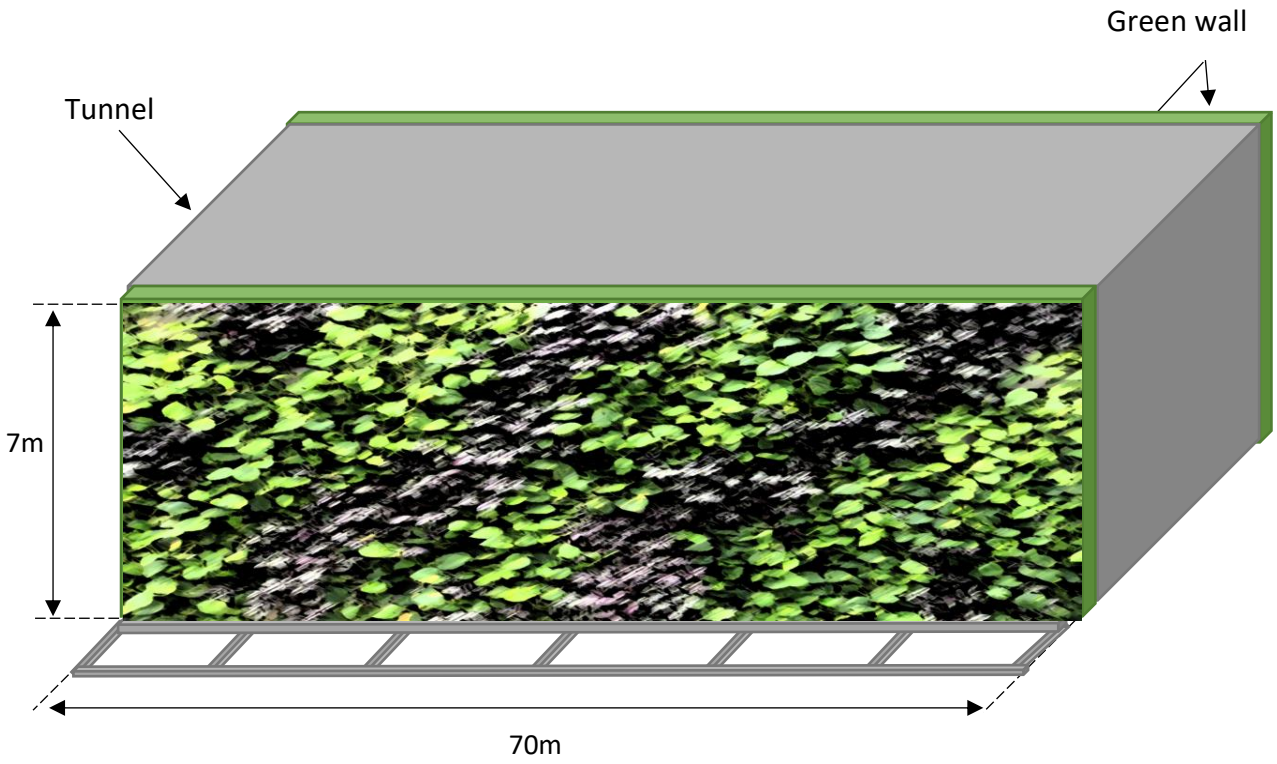


Figure 26: Green wall concept design for option 3.

APPENDIX I – COMMUNICATION RECORDS (MINUTES)

E8 CONSULTING ENGINEERS

TEAM MINUTES – ENVIRONMENTAL

DETAILS

Location: MM experience studio – UniSA

Date: 16/03/2017

Time: 2pm

ATTENDANCE

Chair: MM

Secretary: AM

Attendance: MM, AM, AK, HT

Minutes taken by: MM

Apologies: Nil

AGENDA ITEMS

1.0 Introduction

- 1.1 Develop a weekly meeting plan based on everyone's schedule
- 1.2 Ensure all members have eachothers contact details
- 1.3 Read through the marking rubric to determine what is required of us
  - 1.3.1 Ensure all members are aware of the expectations required to successfully complete the feasibility study

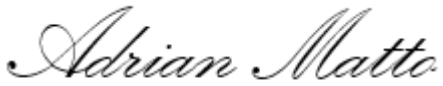
ACTION ITEMS

2.0 Main Action Items

- 2.1 HT to set up online communication via FB
- 2.2 MM to set up Onedrive to allow all group members to view and comment on the work of others.
- 2.3 All to complete the formal team agreement

SECRETARY COMMENTS/CLOSURE

3.0 Statement of Action/Closure



Secretary Meeting

1) CHAIR COMMENTS/CLOSURE

4.0 Statement of Action/Closure

Chair Meeting

E8 CONSULTING ENGINEERS

TEAM MINUTES – ENVIRONMENTAL

DETAILS

Location: MM experience studio – UniSA

Date: 22/03/2017

Time: 1pm

ATTENDANCE

Chair: MM

Secretary: HT

Attendance: MM, AM, HT

Minutes taken by: MM

Apologies: AK

AGENDA ITEMS

1.0 Introduction
- 1.1 MM to follow up on last week's action items

2.0 Main items
- 2.1 MM to communicate scope to the group
  - 2.1.1 Seek input from all others to ensure scope is comprehensive and all aspects are covered
- 2.2 MM to communicate options 1 & 2 to the group
- 2.3 MM to divide workload between group members based on skillsets
  - 2.3.1 HT to work on water quality and energy
  - 2.3.2 AM to work on noise pollution and air quality
  - 2.3.3 AK to work on soil contamination
  - 2.3.4 MM to work on flora and Fauna
- 2.4 Based on Marks email, discuss preliminary issues that are evident with the proposed solutions
- 2.5 Discuss solutions to mitigate the foreseen issues
- 2.6 Discuss when it is possible for everyone to attend a site visit to Hackney Road to better understand the project area and constraints associated with the solutions

ACTION ITEMS

3.0 Main Action Items
- 3.1 All to read through previous documentation online including feasibility study and EIS before the site visit

3.1.1 Take notes, prepare questions, critique and understand the work that is online

3.2 All to work on their respective sections

3.2.1 Write up problems associated with options

3.2.2 Write up solutions associated with options

3.3 Site visit on 26/03/2017 @10am – All to meet out the front of Harris' house

SECRETARY COMMENTS/CLOSURE

4.0 Statement of Action/Closure

Harris Tsimiklis

Secretary Meeting

CHAIR COMMENTS/CLOSURE

5.0 Statement of Action/Closure

Manuel Martins

Chair Meeting

E8 CONSULTING ENGINEERS

TEAM MINUTES – ENVIRONMENTAL

DETAILS

Location: P building Project Room – UniSA

Date: 23/03/2017

Time: 11am

ATTENDANCE

Chair: HT

Secretary: MM

Attendance: MM, AM, HT, AK

Minutes taken by: MM

Apologies: Nil

AGENDA ITEMS

1.0 Introduction
- 1.1 Distinguish between design and construction
- 1.2 Focus on what happens to the environment post construction

2.0 Main items
- 2.1 Discussion with Mark regarding scope of works

ACTION ITEMS

3.0 Main Action Items
- 3.1 Read online EIS documents
- 3.2 Split environmental considerations up amongst team members
  - 3.2.1 HT to work on water quality and energy
  - 3.2.2 AM to work on noise pollution and air quality
  - 3.2.3 AK to work on soil contamination
  - 3.2.4 MM to work on flora and Fauna

SECRETARY COMMENTS/CLOSURE

4.0 Statement of Action/Closure

Manuel Martins

Secretary Meeting

CHAIR COMMENTS/CLOSURE

5.0 Statement of Action/Closure

Harris Tsimiklis

Chair Meeting

E8 CONSULTING ENGINEERS

TEAM MINUTES – ENVIRONMENTAL

DETAILS

Location: MM Experience Studio – UniSA

Date: 29/03/2017

Time: 9am

ATTENDANCE

Chair: MM

Secretary: AM

Attendance: MM, HT, AM, AK

Minutes taken by: MM

Apologies: Nil

AGENDA ITEMS

1.0 Introduction

- 1.1 Follow up on last weeks action items
- 1.2 All to discuss what everyone has done over the last week
- 1.3 All agreed that sediment control and waste management are not part of our scope as they are more associate with construction works

2.0 Main item

- 2.1 MM to communicate the finalized option 3
- 2.2 MM to further discuss the fine line between construction and design as it applies to the feasibility study
- 2.3 MM to remind team of weekly journal entries
- 2.4 MM to remind team of costings associated with the proposed design/solutions/mitigation options
- 2.5 MM to remind the team that we must still consider how the options will be constructed
  - 2.5.1 i.e, we need to consider room for excavators etc.

ACTION ITEMS

3.0 Main Action Items

- 3.1 All to read through online documentation supplied by Mark to better understand our scope of works
- 3.2 MM to consult with transport team about intersection to ensure significant tree remains safe

3.3 MM to consult with transport team regarding whether there will be an increase or decrease in traffic for options 2 and 3

3.4 HT to consult with water team to ensure scopes do not overlap

- 3.4.1 Who is looking at:
  - 3.4.1.1 Storm water runoff
  - 3.4.1.2 WSUD
  - 3.4.1.3 Polluted storm water runoff
  - 3.4.1.4 Investigating options for storm water capture and reuse

3.5 MM to consult with urban team to determine whether heritage buildings and social is part of the environmental scope

3.6 AK to consult with Geotech team to determine where GW table is

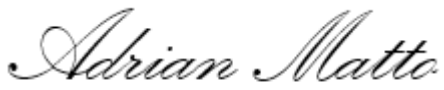
3.7 All to continue working on their respective sections

- 3.7.1 Identify existing conditions
- 3.7.2 Write up problems associated with options
- 3.7.3 Write up solutions associated with options

3.8 All to read through previous feasibility study feedback to ensure we incorporate the feedback into our study

SECRETARY COMMENTS/CLOSURE

4.0 Statement of Action/Closure



Secretary Meeting

CHAIR COMMENTS/CLOSURE

5.0 Statement of Action/Closure

Chair Meeting

E8 CONSULTING ENGINEERS

TEAM MINUTES - ENVIRONMENTAL

DETAILS

Location: MM Experience Studio – UniSA

Date: 30/03/2017

Time: 9am

ATTENDANCE

Chair: MM

Secretary: AM

Attendance: MM, AK, AM, HT

Minutes taken by: MM

Apologies: Nil

AGENDA ITEMS

1.0 Introduction
- 1.1 Follow up on last week's action items

2.0 Main items
- 2.1 Review project impact report to see if it has commuter increase values for option 1
- 2.2 All to discuss how their sections are progressing
- 2.3 All to discuss any concerns

ACTION ITEMS

3.0 Main Action Items
- 3.1 All to ensure communication between departments is maintained
- 3.2 All members to continue working on the respective sections
  - 3.2.1 Identifying constraints and incorporating **design** solutions
- 3.3 Soil contamination considerations
  - 3.3.1 Clay is good for bulk earthworks – See if the material we are removing is clay and take it to where it's needed. i.e, Northern Connector.
  - 3.3.2 Look at remediation options, whether it be on site options or offsite options.
    - 3.3.2.1 i.e, aeration of soil.
  - 3.3.3 Soil contamination – Solution = send all soil to licensed EPA landfill
  - 3.3.4 Asphalt leaching contaminates soil after construction
  - 3.3.5 Provide a price per tonne to deal with soil contamination

3.3.6 Rough volume to be removed for tunnel
3.3.7 Rough dumping cost
3.3.8 Reuse soil for ramp etc

3.4 Water quality considerations
3.4.1 Stormwater runoff increase leading to ponding and flooding of residential areas
3.4.2 WSUD – Investigate options for stormwater capture and reuse
3.4.3 Polluted stormwater runoff
3.4.4 Pump water out of tunnel

3.5 Flora and Fauna considerations
3.5.1 See where to recycle lost wood etc
3.5.1.1 Recycle material for tunnel – use it to level to road
3.5.2 How to ensure our solutions are carbon neutral, or even better, carbon negative
3.5.3 Look at offsets
3.5.4 Traffic forecast – Impact report
3.5.4.1 i.e., 5% of passengers will reduce – helping carbon footprint
3.5.5 Land acquisition and its effect on flora and fauna

3.6 All sections aimed to be completed by the end of next week DUE 12 APRIL 2017.

SECRETARY COMMENTS/CLOSURE

4.0 Statement of Action/Closure

Adrian Matto

Secretary Meeting

CHAIR COMMENTS/CLOSURE

5.0 Statement of Action/Closure

Manuel Martins

Chair Meeting

E8 CONSULTING ENGINEERS

TEAM MINUTES - ENVIRONMENTAL

DETAILS

Location: Project Meeting Room (P-Building) – UniSA

Date: 6/04/2017

Time: 9am

ATTENDANCE

Chair: MM

Secretary: HT

Attendance: MM, AK, AM, HT

Minutes taken by: MM

Apologies: Nil

AGENDA ITEMS

1.0 Introduction
- 1.1 Follow up on last week's action items

2.0 Main items
- 2.1 All to discuss how their sections are progressing
- 2.2 All to discuss any concerns
- 2.3 Finalise scope with Water and Services division
- 2.4 Finalise scope with Urban Planning
- 2.5 MM to discuss about conceptual design with Mark
- 2.6 MM to discuss flora costing/scope
- 2.7 AM to discuss with Mark regarding his sections
- 2.8 HT to discuss with Mark regarding water quality scope
- 2.9 AK to discuss soil contamination with Mark

ACTION ITEMS

3.0 Main Action Items
- 3.1 All to ensure communication between departments is maintained
- 3.2 All members to continue working on the respective sections
- 3.3 Soil contamination considerations
  - 3.3.1 Asphalt leaching contaminates soil after construction
  - 3.3.2 Provide a price per tonne to deal with soil contamination
  - 3.3.3 Rough volume to be removed for tunnel
  - 3.3.4 Rough dumping cost

3.3.5 Reuse soil for ramp etc

3.4 Water quality considerations

3.4.1 Stormwater runoff increase leading to ponding and flooding of residential areas

3.5 Energy

3.5.1 Look into Roadmaps – LED lighting system

3.5.2 Develop costing for Roadmaps

3.6 All members to finish sections by 10 April 2017 to allow MM to collate and finalise document

3.7 All sections aimed to be completed by 12 APRIL 2017.

2) SECRETARY COMMENTS/CLOSURE

4.0 Statement of Action/Closure

Harris Tsimiklis

Secretary Meeting

3) CHAIR COMMENTS/CLOSURE

5.0 Statement of Action/Closure

Manuel Martins

Chair Meeting