

- Girder hogging and sagging, live load rating 0.85 and 0.75 respectively
- Shear and torsion, live load rating 1.05
- Deck slab live load rating 1.05

A number of options have been considered to strengthen the bridge superstructure. Options considered include:

- Carbon fibre
- External prestress
- Concrete deck overlay

Carbon Fibre Strengthening

The carbon fibre strengthening solutions involves epoxy gluing carbon fibre laminates or fabric to the surfaces of the girders and can be used to increase the moment capacity and shear capacity of the section provided adequate anchorage of the carbon fibres can be achieved. The ACI guidelines recommends carbon fibre strengthening be limited to 25% of the required LL capacity at the ultimate limit state (i.e. 75% of the live is to be resisted by the unstrengthened structure). In combination with the widening, the Sullivans Creek girders are within this requirement. Strengthening for sagging moments can be achieved by fixing the carbon fibres to underside of the bottom flange over the midspan region of the girders. Strengthening for hogging moments at the piers can be achieved by fixing the carbon fibres to the underside of the deck slab between the girders. The preliminary checks have shown there is adequate shear and torsion capacity in the existing girder webs for the widened superstructure. If shear and torsion capacity is found to be exceeded during the detailed design phase carbon fibres can be used to improve shear capacity. Carbon fibre strengthening works can be constructed from the underside of the superstructure with little impact on the road users. Traffic restrictions (speed and/or load) on the deck may be required for short periods while the epoxy gains strength. The carbon fibre strengthening has minimal impacts on the aesthetics of the bridge. The carbon fibre laminated can be rendered to provide a smooth finish and coated to match the colour of the existing concrete.

External Prestress Strengthening

The external prestress strengthening solution involves the use of external post tensioning cables. The location of the tendons can be either between the girders or within the box girders. To anchor and deviate the tendons anchor blocks are required to be constructed. To construct the anchors it is necessary to break out sections of the deck and to scabble the surface of the girders. Depending on the magnitude of the forces a positive anchorage between the scabbled surface and the anchor bloc may be required. Positive anchors could take the form of epoxy fixed bars, transverse collar beams or transverse stressing. The Sullivans Creek girders are open ended at the abutments, this would allow the construction of a plug and beam anchor block arrangement across the ends of the beams. At the piers there is an internal concrete plug providing continuity for shear and moments. For an internal tendon arrangement it would be necessary to core a hole through the plug for the tendon. The reinforcement of the concrete plug indicates there is potentially enough space between the existing bars to core the required hole.

Experience on recent projects has shown it is difficult to anchor external tendons deviators at the piers between girders without the use of a collar beam or transverse prestress. The use of a collar beam under the soffit of the girders extending across the full width of the deck either side of the piers would distract from the general appearance of the bridge. The preferred location for the external tendons would be to place the tendons within the existing girders. Although space within the box is limited it is considered feasible. The construction of the deviators and anchors within the box would require significant localised breakouts of the deck slab. For either option it will be necessary to break out sections of the deck to anchor the deviators and construct the abutment anchor blocks. The external post tension option has significant staging and traffic management issues during the construction phase. External tendon strengthening within the box would have no impact on the appearance of the bridge whereas placing the tendons between the girders would have a moderate impact on the appearance of the bridge.

Concrete Overlay Strengthening

Overlaying the bridge deck has been investigated as an option to strengthen the superstructure of Sullivans Creek. The method involves removing the asphalt surfacing, preparing the deck surface and installing starter bars into the deck followed by the construction of a reinforced concrete deck. The deck slab acts compositely with the existing superstructure, increasing the depth of the superstructure to provide the required structural capacity. For Sullivans Creek a deck overlay thickness of approximately 200-300 mm would be required to satisfy ultimate strength requirements. However stress checks under serviceability loading show the stresses across the unreinforced segment joints go into tension due to the additional dead load from the concrete overlay. Tension across the segment joints is not permitted in the bridge code, therefore this option was not considered viable for strengthening Sullivans Creek superstructure.

Substructure

The bearings of the existing bridge consist of proprietary laminated elastomeric bearings. The drawings indicated they were manufactured by Firestone, enquiries to date have not been able to establish the design properties of the bearings. During the detailed design an inspection of the bearing will be undertaken to identify the number of internal steel plates. Using this information plus the overall geometry provided on the drawings an "approximate" bearing will be created using the provisions of the AS5100 bridge code to get an idea of the capacity of the bearing. Elastomer properties will be varied to check sensitivity. Experience on other projects has shown elastomeric bearings are robust and can generally accommodate additional loading due to SM1600 loading. If the capacity is limited it is possible to relieve the longitudinal strain in the bearing from creep and shrinkage movements by lifting the girders and resetting the bearing. This increases the available strain for vertical capacity.

The load rating report identifies the approach slab has insufficient moment capacity for M1600 loading. The moment carried by the approach slab is a function of the area of support provided by the embankment behind the abutment. More or less support will change the design actions in the approach slab. The approach will crack as it reaches its design capacity and will deflect and engage a larger area of supporting soil in turn reducing the moments in the slab. As the consequences of overload will only lead to cracking and deflection of the approach slab, strengthening of the approach slab is not recommended.

The capacity of the existing piles will be assessed during the detailed design. The borehole information for the existing bridge has been located and will be used for the assessment of the existing and proposed driven steel H piles.

Recommendations

The carbon fibre strengthening of the Sullivans Creek superstructure is the preferred option for the strengthening. This option has the least impact on the existing traffic and a minimal impact on the aesthetics of the bridge.

6.0 Acton Tunnel Lighting

6.1 Acton Tunnel Lighting Design

TaMS engaged AECOM to complete an investigation of lighting upgrades to the Acton Tunnel as part of a program to progressively upgrade street lighting in the ACT. A copy of the complete report is included in Appendix A.

Acton Tunnel on Parkes Way is Canberra's longest tunnel, at approximately 190 metres long and caters for large volumes of traffic on a daily basis.

The majority of the tunnel's existing lighting infrastructure is original equipment from building of the tunnel approximately 30 years ago. The tunnel has separate carriageways for east and west bound traffic, each with three lanes and a bicycle/emergency stopping lane. The tunnel floor is concrete, and the walls clad in 9 mm thick AC sheeting. The extent of other services in the tunnel is limited to fire sprinklers. Ventilation systems only occur in the car-parks located over the tunnel.

6.1.1.1 Interior Wall Surface Finishes

To achieve the best possible lighting design for the tunnel in terms of Standards compliance, energy use minimisation, long-term maintenance and driver seeing conditions, the lighting upgrade design allows for the existing wall cladding to be replaced with new cladding which will give higher light reflectivity and greater resistance to dirt build-up. An example of an appropriate cladding material is Alpollic aluminium panels. The preferred solution of TaMS is to use 2.4 m high panelling on the lower portion of the wall, and to paint the remaining upper portion of the wall with suitable high-reflectivity paint.

6.1.1.2 Building Impacts of Lighting Works

The removal of the existing lighting will create a continuous gap the length of each tunnel on each side of the ceiling. This gap will open into the ceiling void. Remedial work to these ceilings was not included in the scope of the lighting upgrade design, and it may be appropriate to incorporate this work into the Parkes Way widening project.

6.1.1.3 Fire Sprinkler System

The state of the fire sprinkler system in the tunnel is unknown at this stage. It may be appropriate to investigate the state of repair and code compliance of the fire systems in the tunnel as part of the Parkes Way widening works.

6.1.1.4 Asbestos in Tunnel

The existing work-as-executed drawings for the tunnel indicates that the wall cladding material and ceiling panelling contains asbestos. The removal and replacement of these elements is being considered by TaMS.

A detailed tunnel lighting design has been completed by AECOM with the recommended upgrade option submitted to TAMs.

7.0 Improvements to the Intersection of the entry ramps from Parkes Way and London Circuit to Commonwealth Avenue

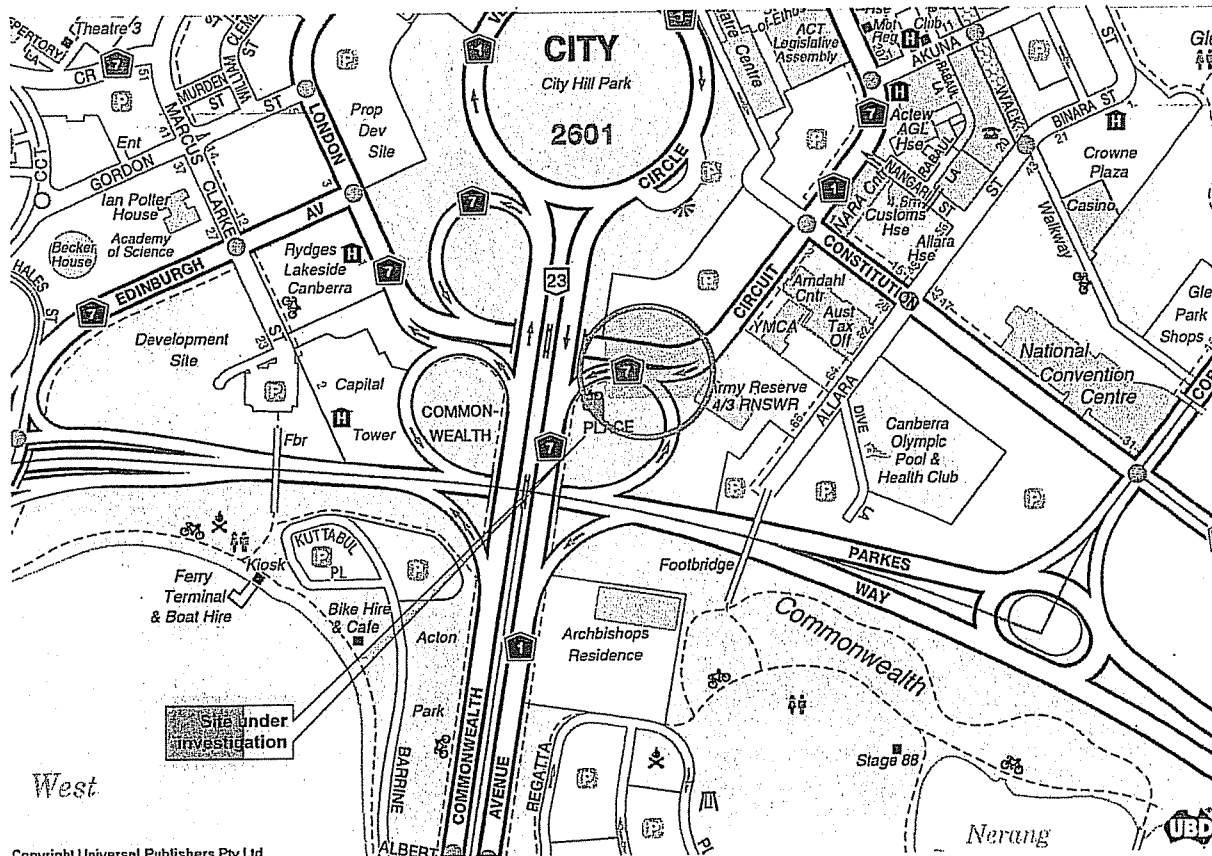
Improvements to the intersection of the entry ramps to Commonwealth Avenue from the Parkes Way and London Circuit are included in the works.

The East West corridor Study identified that queue on the ramp from Parkes Way to Commonwealth Avenue will increase with increased growth along the Parkes Way corridor primarily as a result of the development in Molonglo and also from increased demand from the GDE connection to Parkes Way at Glenloch Interchange.

This report investigates and documents the findings of a scheme to signalise the intersection of these ramps as a low cost interim measure until such time as the NCA fund an interchange that connects all movements to these two arterial roads.

7.1 Location

The location of the study is focussed on the intersection of the London Circuit and Parkes Way ramps as shown in Figure 7-1.



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Figure 7-1 Location of Study

7.2 Existing Situation

The existing situation at this interchange is that the off ramp from London Circuit to connect to Commonwealth Avenue has priority over the Parkes Way ramp connection to Commonwealth Avenue. This control provides priority for buses but results in queues onto Parkes Way.

The observed traffic volumes in February 2010 are shown in Figure 7-2.

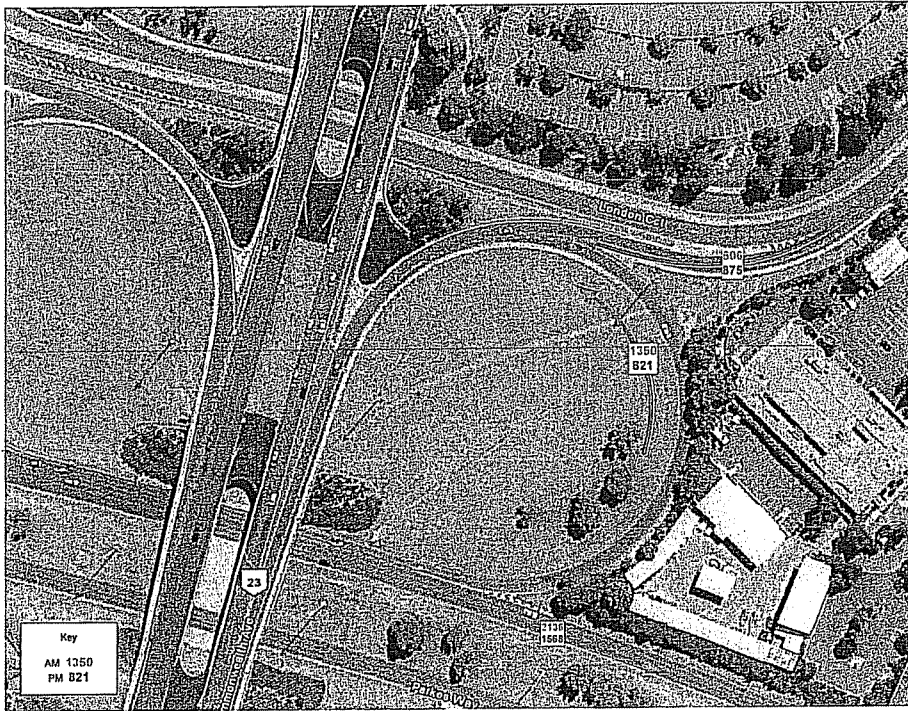


Figure 7-2 Observed Traffic volumes February 2010

Source AECOM 2010

The intersection was modelled using AA Sidra 3.2 with the 2010 existing traffic flows. On site observations showed that the queue often extends back to the Acton Hotel on ramp so as to block joining traffic. The Sidra analysis showed that the intersection is currently performing as shown in and is considered to reasonably represent the existing traffic conditions.

Performance Measure	AM		PM	
	Parkes Way Ramp	London Circuit Ramp	Parkes Way Ramp	London Circuit Ramp
Degree of Saturation	1.106	0.327	1.019	0.472
Average delay seconds	117.3	0	64.1	0
Level of Service	F	A	E	A
Queue m	599	0	222	0

This quantifies the extent of congestion and delay at this intersection and demonstrates that during peak periods there are extensive delays and queues on the Parkes Way ramp.

7.3 Proposal

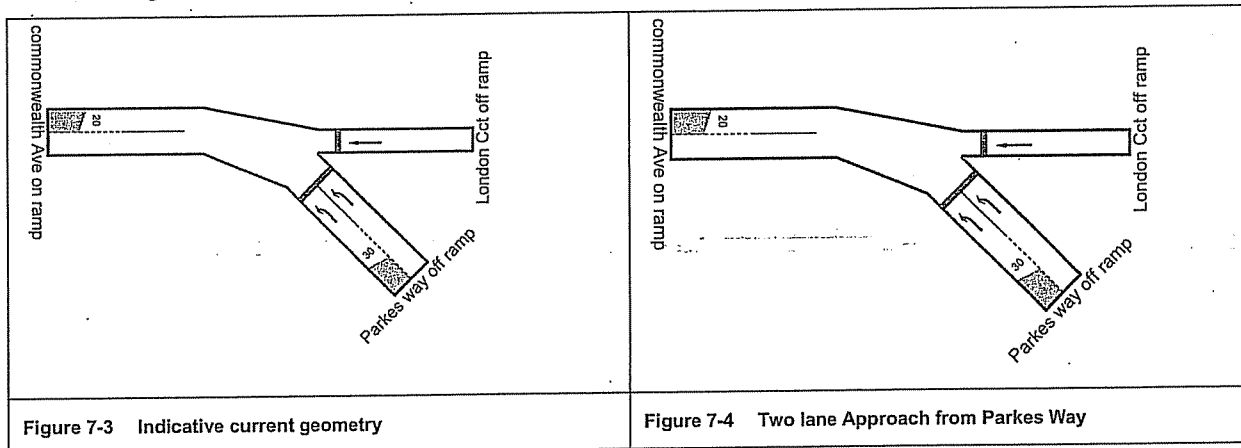
The proposal to reduce the queuing back onto Parkes Way is to channelize the intersection and create a merge from the two segregated lanes at the junction with Commonwealth Avenue.

Signalisation of the intersection was investigated. However, in order to minimise queues the SIDRA analysis indicated it was also necessary for the signal cycle times to be kept quite short. It is also necessary to ensure that buses exiting the City along London Circuit were not unduly delayed. Therefore as a result of this analysis it was shown to be necessary for the ramp signals to do four cycles to one as at the adjacent intersection of Constitution Avenue / London Circuit i.e. runs at a 30 second cycle time with a 3 second yellow and a one second all red period

Two options were tested:

- Retaining the existing lane configuration and
- Adding a short lane to Parkes Way ramp.

These configurations are shown in Figure 7-3 and Figure 7-4.



The results of the analysis are shown in Table 7-1 and Table 7-2.

Table 7-1 Intersection Performance Characteristics Signalised Existing Geometry

Performance Measure	AM		PM	
	Parkes Way Ramp	London Circuit Ramp	Parkes Way Ramp	London Circuit Ramp
Degree of Saturation	1.843	0.787	1.121	1.138
Average delay seconds	1542	2.3	248.3	254.1
Level of Service	F	A	F	F
Queue m	3416	26	571	640

Table 7-2 Intersection Performance Two Lane Approach on Parkes Way Ramp

Performance Measure	AM		PM	
	Parkes Way Ramp	London Circuit Ramp	Parkes Way Ramp	London Circuit Ramp
Degree of Saturation	1.010	1.049	0.84	0.976
Average delay seconds	57.9	99.4	24.3	25.5
Level of Service	E	F	B	B
Queue m	263	233	56	157

Note assumed that 3 second yellow and 1 second all red to take account of lower speeds in this environment

If it were possible to operate the signals more like ramp metering with very quick cycle times of 20 seconds and only a 2 second yellow period with a one second all red, then the scheme would operate very well at Los C in both

the AM and the PM. The practicality of such a scheme however would need to be assessed not only against the signal performance but also the safety aspects of very short displays which generally do not operate in Canberra – (an exception being the pedestrian signals on Bunda Street at the Canberra Centre).

The results from this assumption are shown in the table below.

Performance Measure	AM		PM	
	Parkes Way Ramp	London Circuit Ramp		
Degree of Saturation	1.028	0.866	0.840	0.854
Average delay seconds	59.1	3.4	24.3	5.7
Level of Service	E	A	B	A
Queue m	230	36	56	69

The conclusion from all of this analysis is that it is possible to improve the delays at the intersection of these two ramps from existing. In the peak periods the cycle time would need to operate at 30 seconds but with only 2 seconds yellow display period and one second all red.

This shows that the solution is extremely sensitive to the yellow and all red times and also the driver reaction times in stopping and starting.

As a result of these negative aspects a decision was made to channelize the junction adopting 4.3 m wide traffic lanes separated by a 2m wide median. The 2 m wide median allows on road cyclists to safely cross the 2 lanes near the Commonwealth Avenue as a two stage crossing.

The merge of the two segregated lanes prior to Commonwealth Avenue is 50 m long allowing a diverge rage of 1.0 m/s at a 50 Km/h design speed.

8.0 Existing Utilities

8.1 Sewer

There is a 750 mm diameter trunk sewer main (North Canberra MOS) crossing Parkes Way at a 45 degree skew between Sullivans Creek Bridge and the Action Tunnel. This main connects to two maintenance pits on the outer verge of each carriageway. This main should have sufficient cover depth so as not to be impacted on by the proposed road widening; however, care will need to be taken during construction works to ensure the integrity of the asset. There are also two 150 mm diameter risings mains, operational and decommissioned, crossing Parkes Way at Black Mountain Peninsula to the north of Garryowen Drive.

8.2 Water Supply

There is a 450 mm diameter bulk supply water main crossing Parkes Way to the west of Clunies Ross Street Bridge. There are also two 150 mm diameter reticulation mains crossing Parkes Way to the east and west of the Acton Tunnel. The proposed work should not impact on these services.

8.3 Electricity

There is a 50 mm diameter streetlight cable along the outer verge of each carriageway at the Glenloch Interchange. These cables then move to the median to service the existing street light columns between Glenloch Interchange and near Clunies Ross Street and then move back to the outer carriageway verges. The cables extend along the outer verges of Parkes Way to the Acton Tunnel. The streetlight cabling crosses Parkes Way at the following locations:

- Midway between Glenloch Interchange and Clunies Ross Street Bridge
- Either side of Sullivans Creek Bridge and
- Either side of the Acton Tunnel.

There is a second electrical cable running parallel to the existing street lighting cable located in the Parkes Way median between the Black Mountain escarpment area and the last median located streetlight immediately west of Clunies Ross Street. At present the function of this cable is unknown and therefore requires confirmation in the final stage of design.

There are two locations where HV electrical cables cross the Parkes Way carriageways, there is an overhead HV cable crossing Parkes Way to service Black Mountain Peninsula along Garryowen Drive, and the other instance the underground cable approximately 200 m east of the Acton Tunnel.

There are 6 x 100 mm diameter conduits in a 2 x 3 configuration located in the east-bound shoulder of the road through the ACTON tunnel and continuing to the end of the retaining wall. These cables do not appear to be affected by the works. Discussion will continue with ActewAGL relating to the status of this cable.

8.4 Stormwater

There is no accurate stormwater information available along Parkes Way between Glenloch Interchange and Sullivans Creek Bridge. Previous survey has identified a number of sumps within the median which will require relocation for the proposed widening.

The extent of relocation work is discussed in the carriageway analysis Section of this Report.

8.5 Communications

There are existing 100 mm PVC TELSTRA conduits located along the outer verge of the westbound carriageway between Sullivans Creek and Garryowen Drive. These services should not be impacted by the proposed widening.

8.6 Proposed Utilities

No additional provisions for utilities are proposed.

However ActewAGL is installing a HV main from the Black Mountain sub-station to the new Nishi hotel site on Edinburgh Avenue. This route of the cable is along Clunies Ross Street crossing Sullivans Creek upstream of Parkes Way prior to passing beneath the eastern bridges (within the cycle path), and continuing on the southern side of Parkes Way, clear of the road works prior to crossing Parkes Way near the Edinburgh Avenue exit ramp.

The crossing of Parkes Way at this location will be via a bored crossing.

ActewAGL have advised that these works will be carried out in June 2011.

9.0 Pavements

The existing pavement configurations as noted on the works-as-executed drawing are as follows:

Glenloch Interchange to Clunies Ross Street:

i) Traffic lanes:

- 50 mm asphaltic concrete
- 100 mm fine crushed rock
- 100 mm crushed rock base
- 300 mm select fill.

ii) Shoulders:

- 10 mm flush seal
- 100 mm fine crushed rock
- 250 mm select fill

Clunies Ross Street to Edinburgh Avenue

i) Traffic lanes and shoulders:

- 100 mm asphaltic concrete
- 200 mm fine crushed rock base
- 180 mm crushed rock base

ii) Ranges

- 100 mm asphaltic concrete
- 200 mm fine crushed rock base
- There have been at least two applications of seals to the pavement since construction as well as some crack sealing prior to the re-seals.

Preliminary pavement designs indicate that a flexible pavement with a dense grade asphaltic concrete surfacing course with a two coat seal will be used, noting the use of the seal to alleviate black ice conditions around the Black Mountain escarpment.

The adopted design for the cost estimate has assumed the need for a select fill layer in the pavement profile. However, given that the Black Mountain escarpment and Sullivans Creek sections were constructed with run-off-quarry materials when the lake was reclaimed it is likely that this layer will not be required. A geotechnical investigation is in progress to confirm the need.

The use of a stone mastic asphalt in-lieu of the dense grade asphalt will be a consideration.

Given the long lengths of widening it is considered that a flexible pavement rather than a full depth asphaltic concrete pavement will provide the optimum pavement construction, particularly when the existing pavement is a flexible pavement with a 50 mm to 100mm thick asphaltic concrete surface.

10.0 Environmental Considerations

10.1 Heritage and Ecological Aspects

Although the proposed works are actually outside of the Lake Burley Griffin heritage listed area, the works border the area in some parts, particularly in the vicinity of the Sullivans Creek outlet. Accordingly, consideration has been given to the potential implications of the proposed works, in relation to the heritage values ascribed to the area.

Lake Burley Griffin is Commonwealth owned and controlled land. It is therefore subject to the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Lake Burley Griffin possesses a broad array of heritage values which meet the threshold for Commonwealth Heritage value under criteria A (historic), B (rarity), C (scientific), D (representative), E (aesthetic), F (creative and technical), G (social) and H (associative). They also contribute to the identified National Heritage values of the Lake Burley Griffin under criteria E (aesthetic) and F (creative and technical).

This array of heritage values includes the natural values of the wetlands and aquatic habitat provided by the lake; historic heritage values relating to the shape and form of the lake as a designed landscape; its foreshore plantings; designed foreshore parklands; its role as the setting for the surrounding national institutions; its reflective qualities; lake based activities and uses; and the relationship to views and vistas of surrounding land, particularly Mount Ainslie, Black Mountain and the Parliament House Vista (land axis).

To guide the management of Lake Burley Griffin and Adjacent Lands the NCA has prepared a heritage management plan (HMP) to identify, protect and manage the heritage values. The HMP has been prepared in accordance with the heritage management principles and requirements for management plans set out in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The EPBC Act requires places with Commonwealth and National Heritage values to be managed according to established conservation principles. Schedules 5B and 7B of the *Environment Protection and Biodiversity Conservation Regulations 2000* set out seven Commonwealth Heritage management principles. They encourage the identification of a place's heritage values and their conservation and presentation through the application of the best available skills and knowledge. They also encourage community (including Indigenous community) involvement and co-operation between the various levels of government.

Within the HMP key heritage management policies and actions for Lake Burley Griffin are put forward. The following components of these policies and actions are relevant to the proposed works:

- Component 1 - The lake as a designed landscape.
- Component 2 - Water body of the lake as an ecosystem and aquatic habitat.
- Component 7 - Westlake.

Table 3 provides a response to the relevant actions identified within each of these components. A response is provided as to how the proposed works respond to these actions.

Table 3 Details of the proposed works in relation to relevant actions for the Lake Burley Griffin Heritage area

Actions	Relevance to the proposed works
Component 1 - The lake as a designed landscape	
C1-1 Conserve and manage the integrity of the formal design elements of the Study Area deriving from the Griffin plan and the later design and construction of the lake and its foreshores.	The proposed works are located outside of the Lake Burley Griffin heritage area. Notwithstanding, planning has sought to reflect the current design elements present within the vicinity of the Sullivans Creek area. Specifically, the design of the additional pile caps to be placed in stream has been matched to existing structures. As a result the proposed works are expected to have a negligible impact on the integrity of the formal design elements of the Lake Burley Griffin heritage area.

Actions	Relevance to the proposed works
C1-3 Conserve and manage the aesthetic values of the lake which are particularly valued by the community.	As noted above, the proposed works are not expected to impact on the aesthetic values of the lake, given that the works themselves are located outside of the Lake Burley Griffin heritage areas, and the design of the works has been matched to existing structures.
C1-7 Provide the public with free and open access to the lake's waters.	The proposed works would not impede the public's access to the lake. Whilst there may be some temporary difficulties accessing the lake via Sullivans Creek during works, these impacts are expected to be minor. Effective consultation with the local community and up to date information on the status of the works, and access arrangements would assist in mitigating any minor impacts during construction.
C1-8 Ensure the lake is available and accessible for a range of uses at all times.	The proposed works would likely involve some short term disruptions to access of the lake from Sullivans Creek during construction. It is proposed however to maintain access as far as practicable for recreational water craft during in stream works. Effective consultation with the local community and up to date information on the status of the works, and access arrangements would assist in mitigating any minor impacts during construction. Following construction, accessibility of the lake would remain unchanged from the current situation.
C1-10 Recognise the strong community attachment to the heritage values of Lake Burley Griffin through regular liaison on proposals affecting the future uses and development of the place.	The proposed works would involve a complimentary consultation programme that would seek to provide regular community information on the status of works, and provide opportunities for members of the public to voice concerns, raise complaints, or enquire about the status of works.
Component 2 - Water body of the lake as an ecosystem and aquatic habitat	
C2-1 Manage the lake as an aquatic habitat for a range of native species including the Murray cod.	The proposed works would have the potential to impact on the water quality of Sullivans Creek, and therefore Lake Burley Griffin, particularly during the emplacement of structures to support the pile caps. The development of site specific management measures to address potential impacts is expected to effectively mitigate potential for adverse impacts. Such mitigation measures could include the emplacement of a silt curtain around in stream works to minimise the potential for sedimentation of the lake, and the implementation of supporting construction management arrangements to manage the potential for spills, or other adverse environmental impacts. The combination of these measures would be included in a construction environmental management plan (CEMP) adopted for the proposed works.
C2-2 Manage the water quality of the lake in order to maintain recreational uses (yachting, boating, swimming, etc.).	As noted above, works would be subject to a number of site specific mitigation measures to be incorporated into a CEMP. It is expected that the implementation of these measures would effectively manage potential for adverse impacts, such that water quality would not be impacted by the proposed works.
C2-3 Ensure that Service Contracts for asset management of the lake and foreshores are consistent with the protection and conservation of identified historic, indigenous and natural heritage values.	Asset management arrangements for the proposed works would be consistent with existing arrangements. It is expected that on-going management of these assets would therefore be consistent with the protection and conservation of identified historic, indigenous and natural heritage values.

Actions	Relevance to the proposed works
Component 7 - Westlake	
C7-1 Conserve and manage the aesthetic and other heritage values of Westlake.	The proposed works would result in the addition of four pile caps in Sullivans Creek, wholly consistent with the existing pile caps currently in place. The addition of extra carriageway on Parkes Way over Sullivans Creek is expected to have negligible impact on the aesthetic and heritage values of Westlake.
C7-2 Conserve and manage the lakeside vegetation on 'soft' foreshore edges for shoreline stability, aesthetic values and visual amenity.	The proposal would not result in any changes to the current foreshore arrangements in the long term. Some construction work may involve activities that utilise access from the shoreline within Sullivans Creek. These works would be short term, and subject to controls developed in the CEMP to be implemented during the works.
C7-3 Manage the lakeside vegetation on 'soft' foreshore edges to protect and enhance habitat values.	The proposed works would not adversely impact the 'soft' foreshore edges of Lake Burley Griffin. Site specific mitigation measures developed in the CEMP would ensure that habitat values of Lake Burley Griffin would be protected during works.

Based on the consideration of the actions identified for the relevant components of the HMP for the Lake Burley Griffin heritage area, and how these might apply to the proposed works, it is expected that no significant adverse impacts to the heritage values of the lake would result from the proposed works. Based on this consideration, it is therefore not necessary to complete a heritage impact statement for the proposed works.

11.0 Staging and Temporary Traffic Management

11.1 Staging

The traffic will be diverted to the shoulder and the adjacent traffic lane. Temporary traffic management is dependent on the length of sections of the road that would be tolerable to motorists travelling at low speeds through the work area.

The works will be staged as follows:

- i) Stage 1: Glenloch Interchange to Acton Tunnel
 - Widening works within the median
 - Bridge widening works
 - Bridge strengthening works
- ii) Stage 2: Retaining wall reconstruction between east portal of Acton Tunnel and Edinburgh Avenue exit ramps.
- iii) Stage 3: Eastbound carriageway widening works east of the Edinburgh Avenue exit ramps.

11.2 Temporary traffic management

The widening into the median allows the creation of suitable work spaces by relocating the outer traffic lanes onto the existing sealed shoulders.

The through lanes are narrowed to 3.0 m in width and work spaces of 3.0 m width can be created between the edge of the construction and temporary concrete barriers flanking both sides of the median works area. A width of 1.0 m is allowed to accommodate any deflection in the barrier within the 3.0 m work zone.

The Works-as Executed drawings show the shoulders of Parkes Way between Glenloch Interchange and Clunies Ross Street as having reduced pavement layers and no asphaltic concrete surfacing, only 10 mm flush seal.

To minimise potential damage to the shoulder from trucks it is proposed to sign the left lane (shoulder) to exclude trucks.

There will be a permanent 60 Km/h speed limit through the works area. Construction works will be permitted at all times with no interruptions to traffic during the morning and evening peak hour periods Monday to Friday.

These arrangements, which are generally typical for the whole length of Parkes Way, are shown on the drawings.

11.3 Construction Site Compounds

The major construction compound is proposed to be located in the median between the Clunies Ross Street and Sullivans Creek bridges.

Secondary site compounds are proposed within the median at the Glenloch Interchange and Edinburgh Avenue ends of the project.

12.0 Landscaping

12.1 Tree Removal

The areas of removal are:

- Median: 55 trees and shrubs
- Above retaining wall: 25 trees and shrubs
- Verges between Glenloch Interchange and Clunies Ross Street: 5 trees and shrubs.

The latter nominated tree and shrub removal is required to accommodate street lighting. However, as the location of these trees has not been surveyed at present there may be opportunities to reduce the number of removals by adjusting light column positions and trimming trees once the survey has been received and interrogated.

A tree assessment report will be prepared in the coming weeks for receipt of additional survey.

12.2 New Works

Landscaping on the project is proposed as follows:

- i) Replacing the residual grass median between Glenloch Interchange and the west portal of the Acton Tunnel with stabilised decomposed granite gravel paving.
- ii) Reinstating the landscape removed above the retaining wall between the eastern portal of the Acton Tunnel and the Edinburgh Avenue exit ramp

The extent of the reinstatement is approximately 10 m behind the existing wall based on preliminary designs for the replacement walls and envisaged temporary batter slopes of 1(H) to 4(V) with soil railing stabilisation of the batter slope.

The Work-as-Executed drawings indicate that the original plantings were Eucalyptus Mannifera at approximately 8 to 10-m spacing within a rock mulch bed. It is intended to reinstate the disturbed area with the same treatment.

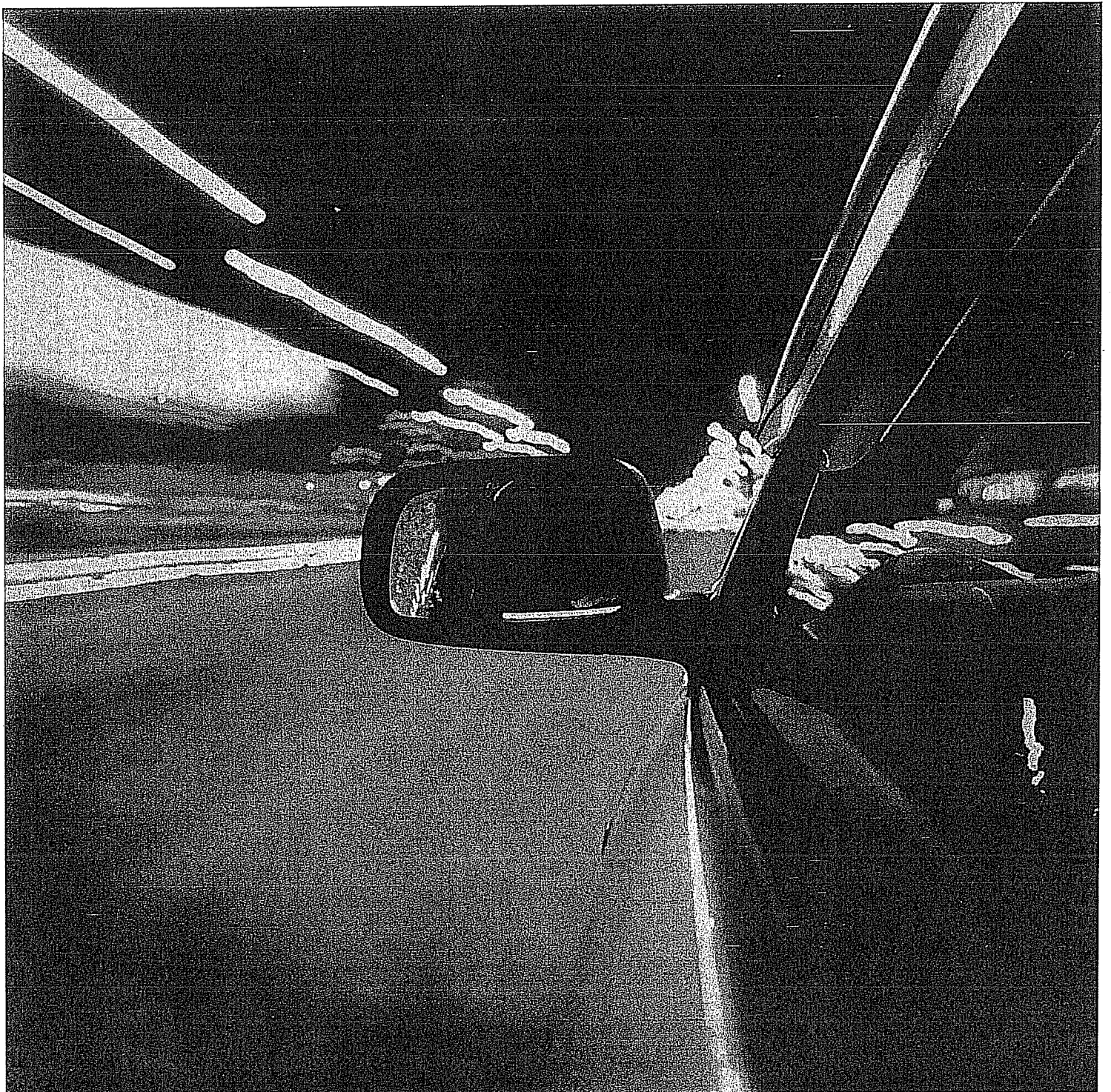
- iii) The median treatment between the Edinburgh Avenue exit ramps and the end of the G4 guardrail approximately 150 m north of the Edinburgh Avenue overpass will be stabilised decomposed granite gravel paving given the flanking guardrail and difficulties of maintaining soft landscape surfaces. At the end of the guardrail the treatment will revert back to the present dry land grass surface.

It is necessary to remove approximately 80 native trees and shrubs to enable the works to be constructed.

Appendix A

Acton Tunnel Lighting Upgrade PSP Report

Sketch Plan Report



Sketch Plan Report

Project No: 12541

Prepared for
TAMS

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Executive Summary

Preliminary investigations and design has been carried out for a lighting upgrade to Acton Tunnel. An investigation into the possible reuse of the existing lighting suggests that this is not a feasible option. A range of new lighting options have been investigated, and a preferred solution in terms of luminaire types and placement has been developed. A major factor in the upgrade that has become apparent is the surface cladding of the tunnel walls. The existing cladding has poor reflectance properties and works against an optimal design. A re-cladding of the tunnel walls with a higher-reflectivity aluminium panel is recommended. Approximate costing of the wall cladding is included.

Two design options have been developed for two solutions, one with the existing walls remaining, and one with the new higher-quality wall claddings. A second version of the latter option is also presented, with approximately half of the wall clad with aluminium and the remainder painted. For both options, estimates of costs and energy usage have been provided.

The recommended upgrade option includes the re-cladding of the tunnel walls with the higher reflectivity aluminium panels, as this gives the highest quality and lowest energy lighting installation. Estimates suggest that the extra cost would be offset completely by lower energy consumption costs over a 20 year design life.

It is recommended that a bulk re-lamping frequency of four years be implemented for the tunnel, as well as a regular cleaning regime for the walls and luminaires.

1.0 Introduction and background

1.1 Project background

The Department of Territory and Municipal Services (TAMS) has an ongoing program to progressively upgrade street lighting in the ACT, and as a part of this has begun the process of investigating the upgrade of lighting in the Acton Tunnel. Acton Tunnel is Canberra's longest tunnel, at approximately 190 metres long. The Tunnel is on the major arterial road Parkes Way, and caters for large volumes of traffic on a daily basis.

The majority of the tunnel's existing lighting infrastructure is original equipment from the building of the tunnel approximately 30 years ago. The tunnel has separate carriageways for East- and Westbound traffic, each with three lanes and a bicycle/emergency stopping lane. The tunnel floor is concrete, the walls clad in AC sheeting and the ceilings clad in Stramit strawboard faced with AC sheeting. The extent of other services in the tunnel is limited to fire sprinklers. Ventilation systems are provided in the carparks located above the tunnel.

The speed limit through the tunnel is 90 km/h, and the surrounding parts of Parkes Way are illuminated to Category V3, with metal halide light sources on the Eastern side and high pressure sodium to the West.

AECOM have been commissioned to investigate an upgrade to the tunnel's lighting. This will include an investigation into the possible upgrade or reuse of the existing luminaires as well as the design of a new lighting system that is independent of the existing arrangement.

2.0 Design methodology

2.1 Preliminary calculations

2.1.1 Assessment of tunnel against AS/NZS 1158.5

The tunnel lighting design process began with an analysis of the tunnel in accordance with the procedures outlined in AS/NZS 1158.5:2009. This determined the required light technical parameters to be met by the lighting design.

2.1.2 Computer modelling of tunnel

The next stage of the process was the creation of a three-dimensional model of the tunnel in the lighting calculation program AGI32. The model was based on the physical dimensions of Acton Tunnel and included surface reflectance properties selected based on those observed on site. Calculation points were included on road surfaces and walls as dictated by the Standard. The bicycle/emergency stopping lane has been included as part of the carriageway as per the requirements of the Standard.

2.1.3 Preliminary calculations

A number of preliminary calculations were run to determine the optimum layout and type of luminaires needed to meet the specified light technical parameters. In terms of luminaire placement, several options were trialled, including a single central row of luminaires, two side rows of luminaires (similar to the existing installation) and three rows of luminaires. Luminaires with various light output distributions were trialled, including symmetrical distribution, angled symmetrical and wall-washing to determine the best-performing arrangement to suit the tunnel's geometry. Other options were trialled as appropriate, such as tilting of luminaires to improve light distribution.

2.1.4 Development of design options

As the preliminary designs were refined, two rough design options were developed. These were based on two scenarios: the first that no internal surface treatments were to be changed in the tunnel, primarily meaning that the existing wall surfaces remain, and the second assuming that new higher reflectivity wall treatments will be added to the tunnel walls. Each scenario was developed to approximately 80% completion to prove the concept and await confirmation of design parameters for final design. TAMS will be required to choose which design option is to be taken to 100% design.

2.1.5 Development of budget estimates

For each of the two proposed design options, budget estimates have been developed to predict the upfront installation costs of each scheme as well as projected long-term running costs. These are presented in terms of monetary cost, energy usage and carbon dioxide emissions. Similar estimates are made for the existing scheme to allow a point of comparison. It should be noted that the existing scheme would not necessarily be usable for the time period of the calculations due to physical deterioration and difficulties sourcing lamps, however the comparison should be able to be used for comparison purposes.

2.2 Detailed design

Once the design parameters have been approved by TAMS, detailed design will commence for the new lighting scheme. The design will be developed to comply with the requirements of the Standard, and further details such as daytime switching levels, lighting controls, circuiting etc will be developed, and the design progressed to Tender stage.

3.0 Review of existing tunnel lighting infrastructure

3.1 General Overview

The existing tunnel lighting infrastructure is approximately 30 years old. It appears that in that time the electrical infrastructure and controls equipment have been maintained and upgraded and that the luminaires have degraded significantly. It is unknown to what Standard the tunnel lighting design was designed to, however given that Standards Australia did not have a tunnel lighting standard until 2009, it is unlikely that the design would comply even if all components were in good working order.

3.2 Existing luminaires

3.2.1 Condition and maintainability

The luminaires in the tunnel are approximately 30 years old. The luminaires are a combination of low pressure sodium (SOX) lamps and linear fluorescent. The condition of the luminaires is poor, with a general accumulation of dirt and apparent damage to some diffusers. Given the age of the installation, this poor condition is to be expected, as this is well past the expected lifetime of any luminaire constantly exposed to the elements and constantly in use. Given also that the lamp types in use (SOX) are not readily available, there is a strong case for refurbishment or replacement.

We understand that the luminaires in use were manufactured by a company named GEC. This company is no longer trading under that name, and we understand that it was taken over by Rexel in 1998. The luminaires in use are no longer produced, and photometric information is not available. Given this, refurbishment of the existing luminaires is not feasible, as calculations are not able to be performed to assess the photometric performance of the luminaires.

Given the above, to achieve an as-new, Standards compliant tunnel lighting design for Acton Tunnel, the only available option is to install new luminaires. To achieve a best-practice low energy installation, the use of new luminaires with high quality optics and best available lamp technology is required.

3.2.2 Recycling potential of existing luminaires

It was observed during a site inspection of the switch room, where spare luminaires are stored, that the existing luminaires appear to be constructed of very solid gauge of aluminium. Considering the large number of luminaires installed, and that they have reached the end of their useful life, there is potential to recover some costs by recycling the luminaire bodies.

3.3 Existing control equipment

The tunnel lighting is currently controlled by a programmable logic controller (PLC) which appears to have been installed or serviced in 1997. This equipment appears to be in good working order, however an apparent lack of documentation may cause difficulties for upgrade or maintenance. The detailed design phase of this project will look into the feasibility of keeping this equipment or replacing it with new.

3.4 Electrical infrastructure

The existing electrical infrastructure appears to be of good quality and in good condition. A previous electrical condition report (S.Sih, Oct 2008) recommended a number of rectification measures be undertaken on the

equipment, but found the infrastructure to generally be in good condition. It was also noted that there appears to be a general lack of documentation on changes that have been made to the infrastructure, including issues such as missing distribution board schedules.

In general, it appears that the electrical infrastructure is able to be retained and reused with the tunnel lighting upgrade. When the upgrade is undertaken, it will provide the opportunity to correctly balance loads across the distribution boards and accurately document sub circuit layouts.

3.5 Tunnel wall surface cladding

According to the Work-as Executed drawings the internal wall surfaces of the tunnel are clad in 9 mm thick AC sheeting. The panels are screwed onto the surface. The majority of the panels are an off-white colour, although a number of panels throughout both sides of the tunnel are a dark grey colour. All panels are dirty and have poor reflective properties. Given that compliance with the Standard required achieving certain levels of diffuse luminance (i.e. brightness) on walls, the reflectivity of the tunnel wall claddings will have a significant impact on the design of lighting in the tunnel. The wall cladding in the tunnel will be relevant for two reasons. The first reason concerns the reflectivity as mentioned, whereby the higher the reflectivity of the wall, the less illumination (and therefore less lighting energy) will be required to achieve the required levels of luminance. Secondly, the ability to resist grime and the ability to be cleaned will affect the room surface maintenance factor (RSMF) that is chosen during the design process. A surface that is more resistant to dirt build-up and is easier to clean will allow the use of a higher RSMF, thereby decreasing the amount of luminaires needed to achieve the required lighting parameters.

A similar but lower cost option for re-cladding the walls is to clad to a height of 2.4 m (standard panel height) above the concrete crash barrier with the aluminium panelling, and paint the remaining upper portion of the wall with an appropriate high-reflectance, dirt-resistant paint. This will give much of the same benefits without such a high initial cost.

3.6 Ceiling Cladding

According to the Work-as-Executed drawings the ceilings are clad in 40 mm thick Stramit strawboard faced with 6 mm thick AC sheeting.

4.0 Acton Tunnel lighting classification – AS/NZS 1158.5

4.1 Introduction

The Australian Standard AS/NZS 1158.5:2009 Lighting for roads and public spaces Part 5: Tunnels and Underpasses (hereafter referred to as the Standard) specifies performance and design requirements for lighting schemes in tunnels and underpasses. The Standard begins with procedures for determining the applicable classification of a tunnel or underpass, based on the physical properties of the tunnel and the speed limit of the road. Subsequent calculations based on various roadway and tunnel characteristics give rise to the required luminance at the entrance to the tunnel, and subsequent reductions in luminance along the length of the tunnel.

The procedures from the Standard have been followed for Acton Tunnel, and are summarised below.

4.2 Road element classification

Classification of the tunnel to determine its Lighting Subcategory is achieved by determining the Stopping Sight Distance (SSD), examining the tunnel from this distance to determine the extent of see-through, and applying the results to Figure 2.2 of the Standard.

4.2.1 Stopping sight distance

From Table 2.2 of the Standard, for a road with a speed limit of 90km/h and no corrections for grade, the Stopping Sight Distance is 140 metres.

4.2.2 Determination of see-through from SSD

A site investigation was undertaken, whereby photos were taken from the stopping sight distance at each approach to the tunnel. Figure 1 and Figure 2 show the approach view in the Eastbound and Westbound directions respectively. It can be seen that neither view has see-through.

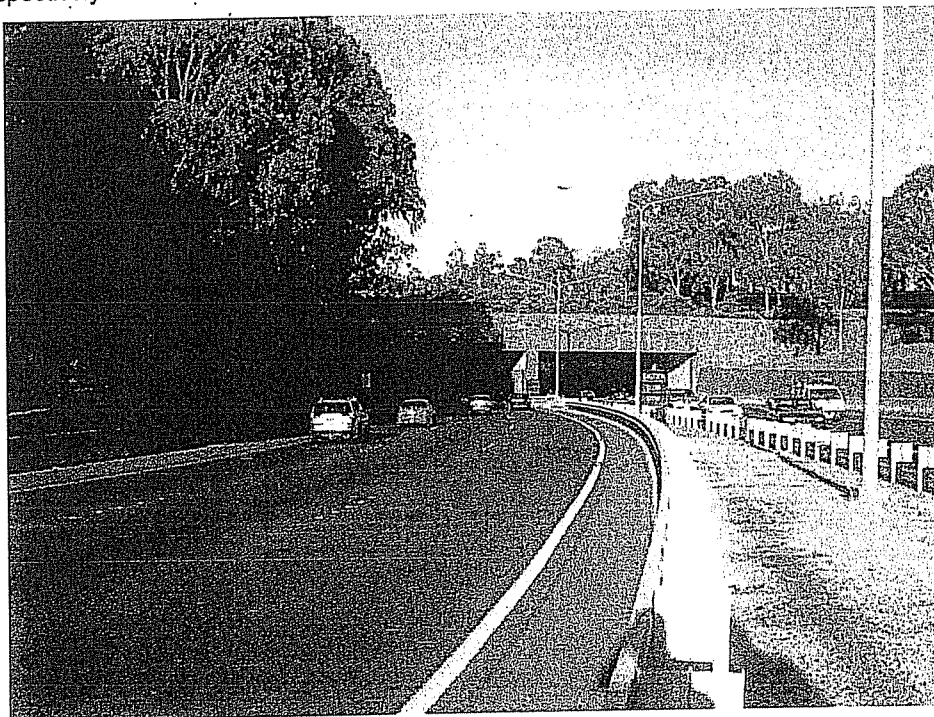


Figure 1: Eastbound view from SSD



Figure 2: Westbound view from SSD

4.3 Determination of lighting subcategory

Applying Figure 2.2 of the Standard indicates that with no see-through the road element classifies as a 'Tunnel'. The tunnel length (approximately 190 metres) is less than the transition zone (transition zone equals 450m, from Figure 3.2 of the Standard), therefore the applicable lighting category for the tunnel is **Category TU2**.

The Standard describes TU2 as follows:

"Tunnel of shorter length which requires an abbreviated tunnel lighting treatment after the threshold zone. Part of urban, high traffic volume road network for motor vehicle traffic only." (From Table 2.1 of the Standard).

4.4 Determination of access zone luminance

The access zone luminance describes the brightness of a view of the tunnel entrance, and is estimated using the technique outlined in Appendix H of the Standard. This includes the estimation of the brightness of each element in a 20° field of view of the tunnel entrance as observed from the SSD. An image of the tunnel entrance is divided into discrete areas based on the objects in that view, and luminances are assigned to each element as per the recommendations in Tables H1 and H2 of the Standard.

The calculations used in determining the access zone luminances for each carriageway are summarised in Section 11.1.

Access zone luminances calculated in each direction of travel are as follows:

Direction of travel	Access zone luminance L_{20}
Eastbound	4852
Westbound	5115

4.5 Threshold zone luminance

The road surface luminance of the threshold zone is determined by multiplying the L_{20} values by a scaling factor k . The value of k is interpolated from Table 3.1 of the Standard for a SSD of 140m to be 0.08677; therefore the threshold zone luminances to be used in the tunnel lighting design are as follows:

Direction of travel	Threshold zone luminance L_{th}
Eastbound	420.64
Westbound	443.44

These are the values that will be used as the primary design criteria on which the tunnel lighting is based.

4.6 Luminance reduction in the threshold and transition zones

Figure 3.2 from the Standard outlines the decrease in luminance throughout the transition zone. The rate of decrease is dependent on the design speed of the road, which in this case is 90 km/hr. Luminance levels are stepped down in increments corresponding to 100%, 75%, 50%, 25% and 12.5%, with the length of these zones being 70m, 35m, 20m, 35m, and 45m respectively.

4.7 Interior zone

The average road surface luminance in this zone shall not be less than the value derived from Table 3.2 of the Standard. For a SSD of 140m, the interior zone luminance shall be above 9.2 cd/m^2 . Although the Acton Tunnel is not long enough to require interior zone lighting, this value is used to determine the night-time lighting level.

4.8 Exit zone

For a lighting scheme designed to Category TU2, where the exit is reached in the threshold or transition zone, exit zone lighting is not required.

4.9 Night-time lighting

The light-time lighting is required to be not less than 50% of the lighting applicable to the road and walls in the interior zone. In this case, with the interior zone luminance calculated to be 9.2 cd/m^2 , the night-time lighting level shall not be less than 4.6 cd/m^2 .

4.10 Mains failure lighting

The Standard includes the following requirements for a Subcategory TU2 lighting scheme:

"5.1.2 Subcategory TU2 - Short Tunnels

Duplicate main power supplies plus UPS"

4.10.1 Duplicate power supplies requirements

The Standard requires that the normal entrance and interior zone lighting be provided with duplicate power supplies. This may be achieved either by having two permanent supplies from alternative sources, each supplying part of the normal lighting, or by having normal lighting fed from one supply with an automatic and practically instantaneous changeover from one supply to the other upon failure of the first.

The existing supply arrangement includes duplicate feeds from two substations and an automatic transfer switch, so complies with this requirement.

4.10.2 Mains power failure lighting requirements

Lighting subcategories TU1, TU2 and TU3 require a mains failure lighting scheme to be installed. This shall form a part of the normal night-time lighting scheme throughout the length of the tunnel and shall consist of a number of evenly spaced luminaires energised from a UPS.

The average illuminance level from the mains failure lighting scheme shall be at least 10 lux horizontal average at the carriageway surface, with a minimum of 2 lux at any location within the tunnel. The lighting shall remain active for a minimum of 30 minutes under mains failure conditions

Exit signage should be installed to the requirements of AS/NZS 2293.

4.11 Light technical parameters

A summary of the light technical parameters and tunnel properties used in the calculations is as follows:

The design parameters shall be as follows:

- Road surface CIE R1 (Concrete)
- Wall reflectance 0.25 (existing surface), 0.6 proposed new surface
- Concrete barrier reflectance 0.35
- Ceiling reflectance 0.2
- Maintenance factor (existing walls) 0.68
- Maintenance factor (new walls) 0.74
- Luminaire optical mounting height 5.35 metres
- Tunnel width: 14.8 metres
- Number of lanes: 3 lanes plus cycle/emergency stopping lane
- Design maximum speed: 90 km/h
- Stopping sight distance: 140 metres
- Traffic flow: Single directional
- Zone lengths and luminance as per AS1158.5 (2007)
- L20 value Southbound: 10000 cd/m²
- Threshold zone luminance: 500 to 550 cd/msq

- L20 value Northbound: 10800 cd/msq
- Threshold value: 540 to 600 cd/msq
- Type of tunnel lighting installation symmetrical

The tunnel lighting system switching sequence shall occur in accordance with the varying luminance levels detected in the access zone by the photometers at each tunnel portal.

5.0 Lighting technology study

5.1 Best available technology

Industry best practice and previous AECOM studies have established a current best practice combination of technologies for tunnel lighting. These include the use of high pressure sodium and fluorescent lamps. The benefits of each are outlined below.

5.1.1 High pressure sodium

High pressure sodium lamps (HPS) are among the highest efficacy lamps in general use. The latest generation of HPS lamp (Osram's Vialox NAV-T Super 4Y and similar) combines very high efficacy with long lifespan and very good lumen maintenance. HPS lamps are stable at high temperature, which is important in tunnel lighting schemes. From a practical viewpoint, HPS lamps are available in a useful range of wattages, which make them well suited for tunnel lighting designs, where graduated lighting levels are required.

5.1.2 Fluorescent

Fluorescent luminaires are very well suited to tunnel lighting at lower luminance levels, therefore are the preferred choice for night-time tunnel lighting. The ease of switching and dimming of luminaires make them flexible to use. In addition they are well suited for use as emergency lighting, due to their instant starting ability and low input power requirements. Extremely long-life T8 lamps are available, such as the Aura Ultimate long-life lamp, which is rated to a service life of 48,000 hours life when operated with magnetic ballasts or 70,000 when operated with electronic ballasts.

5.2 Energy saving techniques

Energy saving techniques available for tunnel lighting can be summarised into three broad categories, as follows:

5.2.1 Best available lamp and luminaire technology

As described above, there is an established industry best practice regarding the type of light sources that are best used in tunnel lighting. These include the very high efficacy high pressure sodium lamp and the high efficacy fluorescent lamp. Luminaire technology contributes to overall efficiency through the selection of luminaires with high quality optics and high protection from dirt ingress.

5.2.2 Optimised design of tunnel interior surfaces and luminaire layout

The tunnel lighting Standard includes requirements for the brightness levels of walls. This means that lighting must be arranged such that light is directed on the tunnel walls, creating brightness to satisfy the required levels. In addition, reflection of light off the walls can contribute to increasing light levels on the tunnel floor. The implication of both of these items is that increasing the reflectivity of the tunnel walls can decrease the amount of lighting energy that is required to be installed. Given that the existing tunnel wall coatings are not very reflective and are not resistant to dirt build-up, there is an opportunity to reduce potential energy usage by re-cladding the tunnel walls with higher-reflectivity, dirt-resistant materials.

5.2.3 Switching of light levels in response to ambient light levels

The intent of the design is to employ a total of five daytime switching levels. Switch groups would be configured such that light levels can be varied in response to ambient light levels during the day. Lower luminance levels at the tunnel opening will allow for the tunnel transition lighting to be set to a lower level. Luminance meters at each tunnel entrance will constantly monitor ambient light levels, allowing the graduated switching to take place. Switching levels of 100%, 75%, 50%, 25% and 12.5% will be used. Two extra light levels will be included, for night-time usage and for emergency lighting.

5.3 Active reactor technology

TAMS has requested that 'Active Reactor' technology be considered for use in the tunnel lighting. Active Reactor is a proprietary technology which makes use of the fact that discharge lamps require lower power at the beginning of life than they do at the end of life, therefore allowing energy savings by tailoring the delivered power to the actual requirement of the lamp. The device consists of an iron core ballast to supply a constant base of approximately 70% power, and an electronic device to supply a variable amount of power depending on the age of the lamp. The electronic component of the device has an expected life in the order of seven years (manufacturer's claim), which is temperature dependent. Higher running temperatures will shorten the life of the electronic component. Since the device combines an iron core component and an electronic component, with the former having a much longer expected lifetime, the fallback position of the Active Reactor upon failure of the electronic component will be a maximum of 70% power.

From the research we have conducted, it appears that the Active Reactor technology is well suited to outdoor and road lighting, where ambient temperatures during operation are not expected to be high. This is similar to the recommended applications of electronic ballasts. The use of Active Reactor technology in a tunnel situation may be problematic due to the expected high temperatures that may be experienced, primarily in the higher wattage luminaires (up to 400W) which will operate during the daytime. Luminaire manufacturer Schröder has indicated that they could incorporate the technology in their luminaires, but expressed reservations about using them in a tunnel situation due to temperature effects, particularly for higher wattage luminaires.

It may be possible to use the Active Reactor technology in housings separate from the luminaire to remove them from the source of heat of the lamps. In this case, the Active Reactor and ballast would be in a separate, IP-rated housing mounted next to the luminaire. This method will be explored for the detailed design.

Although electronic ballast technology is becoming more widely used in external lighting, tunnel lighting generally uses magnetic ballasts as standard due to their longevity and resistance to high temperatures. In this instance we would recommend against the use of Active Reactor in the tunnel.

6.0 Related issues

6.1 Maintenance

The planned cleaning and maintenance regime of the tunnel will have an impact on the design of the tunnel lighting. The lighting design process takes into account maintenance and cleaning through the use of Maintenance Factors, which are used to predict the light output depreciation of the tunnel lighting system in the worst case (i.e. at the point where maintenance is undertaken). The overall maintenance factor is a combination of several factors, as described below:

6.1.1 Lamp maintenance factor

This value is taken from manufacturer's data, and predicts the drop in lumen output of the lamp after a certain time period (the re-lamping period). A re-lamping period of four years has been assumed in preliminary calculations.

6.1.2 Luminaire maintenance factor

This value predicts the amount of dirt build-up on the luminaire, and is taken from tables in AS/NZS 1158.1 Appendix E. This value is dependent on the cleanliness of the environment and the frequency of cleaning. A cleaning frequency of four years has been assumed in preliminary calculations.

6.1.3 Room Surface Maintenance factor

This value predicts the amount of dirt build-up on reflective room surfaces, and is dependent on the cleanliness of the environment and the ability of the surface to resist dirt build-up. This value is estimated from tables in the Australian Lighting Standards, and has been estimated to be worse for the existing walls than it would be for new wall claddings, as new wall cladding would be smooth, therefore resistant to dirt build-up and easy to clean. The existing wall surfaces are slightly textured, therefore would be less resistant to dirt build-up and harder to clean.

6.2 Survey of tunnel

Work-as Executed drawings are available for the tunnel construction and the associated lighting and sprinkler infrastructure. Notwithstanding a survey of the existing conditions should be made to confirm the information shown on the Work-as Executed drawings.. This would also allow detailed design and as-built drawings to be produced of the lighting upgrade.

6.3 Interior wall surface finishes

As discussed in several places in this report (refer to sections 3.5, 4.11 and 5.2.2), to achieve the best possible lighting design for the tunnel in terms of Standards compliance, energy use minimisation, long-term maintenance and driver seeing conditions, it is advised that the existing wall cladding be replaced with new cladding which will give higher reflectivity and greater resistance to dirt build-up. An example of an appropriate cladding material is Alpolic aluminium panels. Details of this product are included as an attachment to this report.

6.4 Building impacts of lighting works

The removal of the existing lighting will create a continuous gap the length of each tunnel on each side of the ceiling. This gap presumably opens into the ceiling void. It is beyond the scope of this investigation to propose remedial work to these ceilings, however it may be desirable to investigate the filling of these gaps as part of the upgrade works.

7.0 Design options

7.1 Description

As discussed previously, two general lighting options have been explored to date. The two situations investigated are where the existing tunnel wall cladding is retained, and where the wall cladding is replaced with a new higher reflectivity surface. For each option, lighting designs have been refined to a level of completeness where comparisons in terms of installation and running costs and energy use can be made. Both lighting schemes have been designed using similar luminaires and lamp types.

We request that TAMS reviews the budget and energy calculations for each scheme and chose which option is preferred for use in the detailed design phase.

7.2 Design option 1: utilising existing wall cladding

This option involves changes to the lighting in the tunnel only. The existing wall cladding is retained. The reflectivity of the wall surfaces in these calculations is relatively low, and the room surface maintenance factor is lower due to the surface's texture. These factors will result in the requirement of higher light levels to achieve compliance with the Standard. This option uses approximately 1308 luminaires.

Design option 1 is shown on sketch drawing SKE01.

7.3 Design option 2: utilising new wall cladding

This option involves re-cladding the tunnel walls with new higher reflectivity materials (for example aluminium wall cladding). This will significantly increase the reflectivity of the walls, and will allow the use of a higher wall surface maintenance factor due to the improved ease of cleaning. The higher reflectivity will allow for the use of fewer luminaires, however there will be the extra cost of the installation of the new wall cladding. This option uses approximately 1033 luminaires.

Design option 2 is shown on sketch drawing SKE02.

8.0 Estimated Energy usage

8.1 Introduction and assumptions

Assumptions used in comparisons are listed in section 11.2. These estimates do not take into account energy reductions achievable through switching in response to daytime light levels, and as such are intended for use for comparison purposes.

The energy usage of the existing system is based on the documented number and wattage of luminaires listed in a previous electrical report, and assumes that lighting runs at 100% during daytime and fluorescent luminaires only at night time. This may not be representative of how the tunnel currently functions, but is intended to be used for comparison purposes.

Note that the projected design life has been chosen as 20 years for comparison purposes.

8.2 Energy usage projections

The projected energy usages of the existing scheme and two design options are presented in the table below. Estimates are presented in terms of total installed energy, and also in terms of annual and lifetime use in terms of energy, cost and carbon emissions.

	Total Installed Energy (kW)	Annual Energy Use			Design Life Energy Consumption		
		kWh	\$	kgCO ₂	kWh	\$	tCO ₂
Existing System	735	3,220,132	\$ 579,624	3,026,924	64,402,644	\$ 25,100,424	60,538
Option 1 with Existing Walls	355	1,556,455	\$ 280,162	1,463,068	31,129,098	\$ 12,132,321	29,261
Option 2 with New Walls	308	1,350,466	\$ 243,084	1,269,438	27,009,323	\$ 10,526,671	25,389

Table 1: Energy comparisons

A comparison of each of the two new design options with the existing system is given below.

Energy Consumption Comparison with Existing Installation	
Option 1: Existing Walls	48.34%
Option 2: New Walls	41.94%

Table 2: Projected savings over existing system

9.0 Budget estimates

9.1 Introduction and assumptions

Assumptions used in comparisons are listed in section 11.2. The budget estimates for the new lighting schemes allow for full construction, including luminaires, new wall claddings, labour and materials.

9.2 Initial and design life cost projections

The table below provides estimates on the estimated installation cost, single bulk lamp replacement and 20-year design life costs of each scenario including the existing situation. The projected costs of the existing installation are for comparison purposes and do not allow for the likely scenario of replacement lamps not being available.

	Initial Cost	Single Relamp Cost	Design Life Total Cost
Existing	\$ -	\$ 121,414	\$ 18,254,995
Option 1: Existing Walls	\$ 2,762,637	\$ 84,629	\$ 10,806,923
Option 2: New Walls	\$ 3,920,613	\$ 67,416	\$ 10,686,537

Table 3: Budget comparisons

A Net Present Value calculation has been prepared using the Roads ACT method, and this is shown below. The calculation shows an extra option of cladding half of the walls with aluminium panelling and painting the upper portion with reflective paint.

Option 1 Original walls	2010	2011	2012	2013	2014	2015	2016	2017	2018
	\$2,889,965	\$127,328	\$127,328	\$211,957	\$127,328	\$127,328	\$127,328	\$211,957	\$127,328
NPV									
	\$4,163,500.47								
Option 2 New walls	2010	2011	2012	2013	2014	2015	2016	2017	2018
	\$4,028,290	\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$107,677
NPV									
	\$4,687,897.20								
Option 3 New walls half painted	2010	2011	2012	2013	2014	2015	2016	2017	2018
	\$3,428,290	\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$107,677
NPV									
	\$4,127,149.54								

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
\$127,328	\$127,328	\$211,957	\$127,328	\$127,328	\$127,328	\$211,957	\$127,328	\$127,328	\$127,328	\$211,957	\$127,328
2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$1,150,323
2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$107,677	\$107,677	\$107,677	\$175,093	\$1,150,323

Table 4: NPV calculation

10.0 Recommendations

10.1 Recommended design option

A number of items are recommended, as follows:

10.1.1 Upgrade of wall cladding material

The existing wall cladding has poor reflectance properties, which will be a liability in terms of the new lighting designs. It will be possible to provide a solution with lower energy consumption and higher visual quality if the tunnel walls are re-clad with a higher-performing material. This solution will give an overall upgrade that is closer to 'as new' than would the alternative of upgrading lighting only and retaining the existing walls.

The option of cladding half the wall (to a standard panel height of 2.4m) and painting the remaining upper portion is considered as a good, lower cost alternative to cladding the entire wall.

10.1.2 Implementation of bulk lamp-changing regime

It is recommended that a bulk lamp-changing regime on a four-yearly basis is introduced. This would match the expected lifetime of the high pressure sodium lamps in use, and ensure a high standard of upkeep for the tunnel lighting.

10.1.3 Implementation of a regular cleaning cycle for walls and luminaires

A regular cleaning cycle for walls and luminaires is important to maintain light levels within design tolerances. Currently the design allows for four-yearly cleaning, however if a more regular cycle was chosen and implemented (for example annual or bi-annual), higher values of maintenance factors could be used, which would reduce the number of luminaires required and thereby reduce energy usage. It is recommended that a realistic and achievable maintenance regime be chosen based on TAMS experience and best practice.

11.0 Appendices

11.1 Access zone luminance calculations

The calculations to determine the access zone luminance as per Appendix H of the Standard are summarised below:

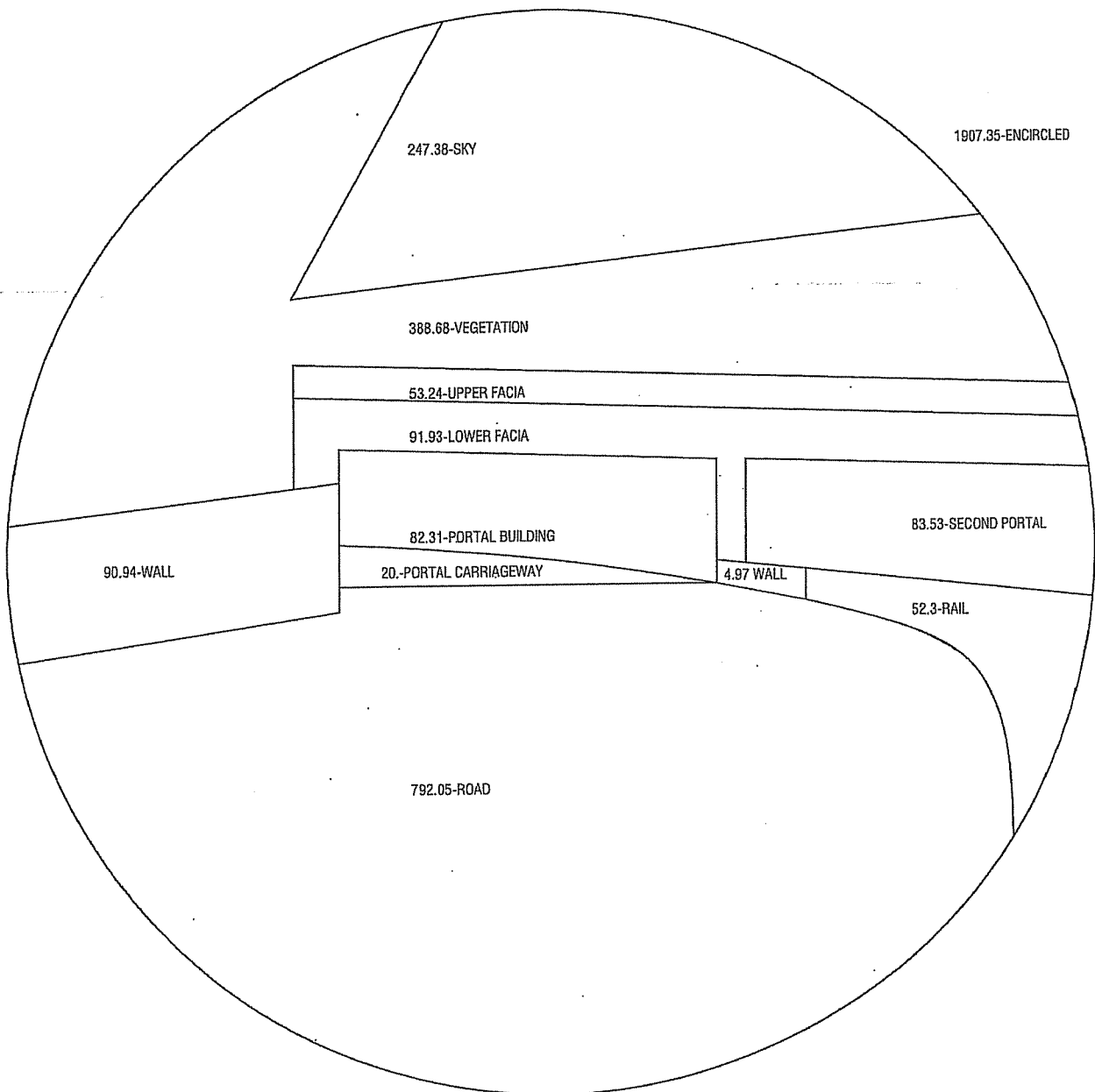


Figure 3: Eastbound 20° view divided into luminance elements (areas shown in m²)

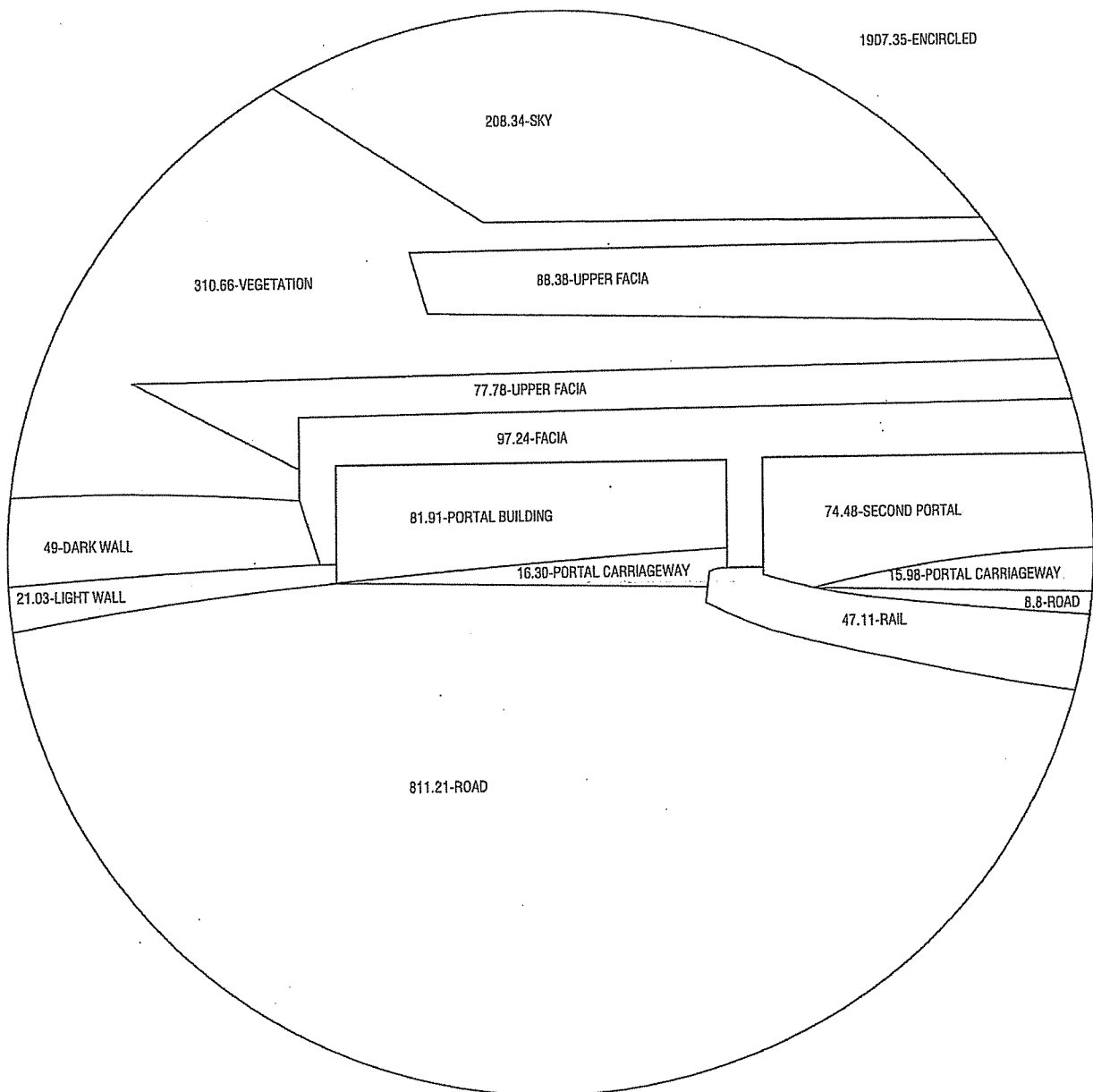


Figure 4: Westbound 20° view divided into luminance elements (areas shown in m²)

East-bound portal

Object	Area	Luminance	A x L
Sky	247.38	12000	2,968,560
Veg	388.68	2000	777,360
Upper Facia	53.24	6000	319,440
Lower Facia	91.93	9000	827,370
Wall	90.94	6000	545,640
Portal building	82.31	1500	123,465
Portal road	20	2000	40,000
Second portal	83.53	1500	125,295
Wall	4.97	9000	44,730
Rail	52.3	6000	313,800
Road	792.05	4000	3,168,200
Sum:	1907.35		9,253,860
		L20:	4852
		k	0.0867
		Lth	420.64

West-bound portal

Object	Area	Luminance	A x L
Sky	208.34	14000	2,916,760
Veg	310.66	2000	621,320
Upper Facia	88.38	6000	530,280
Upper Facia 2	77.78	6000	466,680
Lower Facia	97.24	9000	875,160
Wall upper	49	6000	294,000
Wall lower	21.03	9000	189,270
Portal building	81.91	1500	122,865
Portal road	16.3	2000	32,600
Second portal	74.48	1500	111,720
2nd portal rd	15.98	2000	31,960
Rail	47.11	6000	282,660
Road	8.8	4000	35,200
Road	811.21	4000	3,244,840
Sum:	1907.35		9,755,315
		L20:	5115
		k	0.0867
		Lth	443.44

Figure 5: Access zone luminance calculations

11.2 Assumptions used for calculations

Item	Assumed value
Night Time Mode running hours	12 Hours
Day Time Mode running hours	12 Hours
Days in a Year	365
Design in Life	20
Electrical Costs per Kilowatt Hour	\$0.12
Annual Electrical cost Increase Factor	7.00%
Maintenance Person cost Per Hour (after-hours)	\$180.00
Time to Relamp Per Fitting	30 Minutes
Equipment Cost (Flat Rate)	5000
Cost to Install Per Fitting	150
Time between bulk re-lamping	4 years
Cost per Metre of new wall cladding	\$793.60
Cost per Metre of existing wall removal	\$20.00
Metres of Tunnel Wall	800
kgCO2/kWhr	0.94