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Cockle Bay Park Land Bridge over the Western Distributor

Fire Safety Study

DPT and DPPT Operator Pty Ltd

28 July 2017
Revision: 3
Reference: 253427

Bringing ideas to life

Document control record

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1 Introduction

This report is a response to submissions and amended development application associated with a State Significant Development Application (SSDA) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure approval to establish concept proposal details for the redevelopment of the Cockle Bay Wharf Building and surrounding areas (now referred to as Cockle Bay Park).

As part of this redevelopment a new land bridge structure over the Western Distributor has been proposed. This land bridge would create a partial enclosure to the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, and the on grade northbound and southbound Western Distributor and northbound Wheat Rd.

This report addresses the fire safety below the land bridge between the portals it creates and forms part of Arup's precinct wide fire report.

The following describes:

1. Preliminary Computational Fluid Dynamics (CFD) modelling to describe the tenability conditions beneath the land bridge; and
2. The concept design criteria that has been proposed to be assessed in the next design stage.

The length of the land bridge is approximately 140m and the cross sections, which are indicative only, are shown in the figures below.

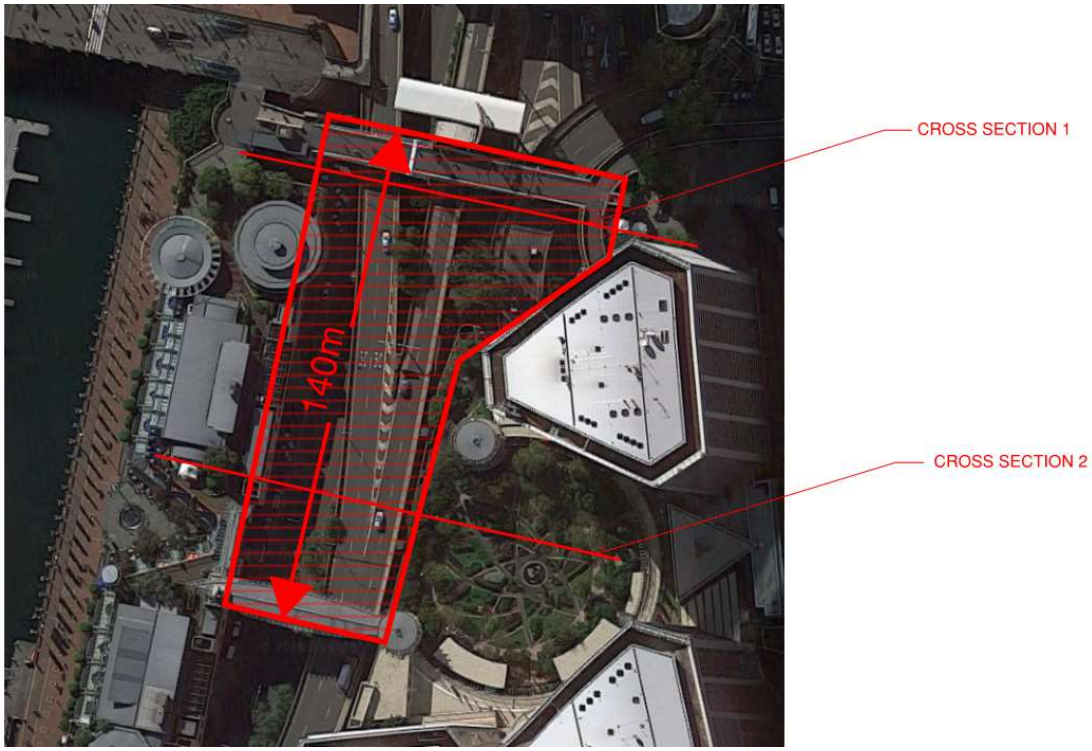


Figure 1: Extent of proposed land bridge - plan

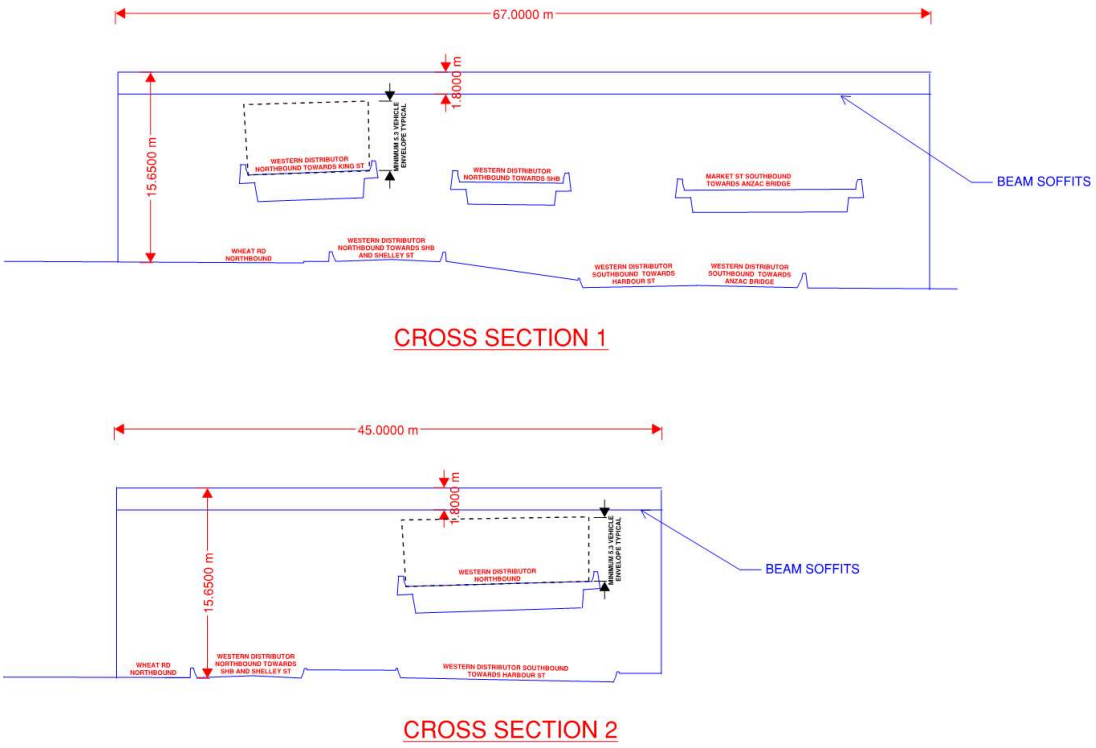


Figure 2: Indicative cross sections of roadways beneath the proposed land bridge (dimensions are approximate only)

The envelope of the enclosure created by the proposed land bridge is significantly larger than the road envelopes themselves, providing improved means of smoke and heat dissipation in the event of a fire.

In addition to the improved tenability resulting from the large enclosure, the likelihood of a fire is reduced due to all of the roadways being uni-directional.

2 Computational Fluid Dynamics (CFD) Modelling

In order to demonstrate the tenability of fire safety beneath the land bridge, a series of CFD simulations have been conducted. The simulations are able to demonstrate the conditions during a fire event and this enables assessments of the egress conditions to be made. The modelling was undertaken with the Fire Dynamics Simulator (FDS) CFD package.

3 The Fire

For a fire generated by a typical heavy goods vehicle (HGV), test results presented in NFPA 502 provide a peak heat release rate (HRR) between 20MW and 200MW. The fire scenario analysed is shown in Figure 3. It has a peak HRR of 157MW which is consistent with the representative HRR suggested by NFPA 502 as a typical design fire size without fixed water based firefighting systems. It is based on findings of the large scale fire test in Runehamar tunnel in 2003 by Technical Research Institute of Sweden (SP). The fire reached peak value within 14 minutes and contained Wood pallets (82%) and Polyurethane plastic (18%).

The fire is located in the centre of the enclosure as this is considered critical for smoke spread and infilling. A fire towards the end of the enclosure would result in smoke and heat escaping the covered area sooner. Although the egress time will be greater with the fire towards the end of the enclosure, the results from the fire at the centre indicate that the increase to egress time would not be of concern – particularly given the less severe conditions produced by the fire at the ends.

Wind influence has not been considered in the modelling as it is expected the wind will cool the smoke and push it out of the covered section and make the analysis less conservative. Having said this, we provide the following comment. In line with the assessment detailed in "Fire engineering report R1.2, 161 Sussex Street - Western Distributor Underpass" dated 15 April 2015, at the neighbouring underpass the predominant wind directions are from the south and the west.

A wind from the south is likely to improve the tenability of the northbound roadways during a fire as the smoke is ventilated in the direction of vehicle flow and is therefore pushed away from the upstream vehicles. At the lower southbound roadways, the smoke is likely to be ventilated over the vehicles behind the incident given the height of the space.

A wind from the west is unlikely to improve or worsen the conditions beneath the land bridge as the western face is closed by the building development.

No consideration has been given to the use of fire suppression systems or mechanical ventilation.

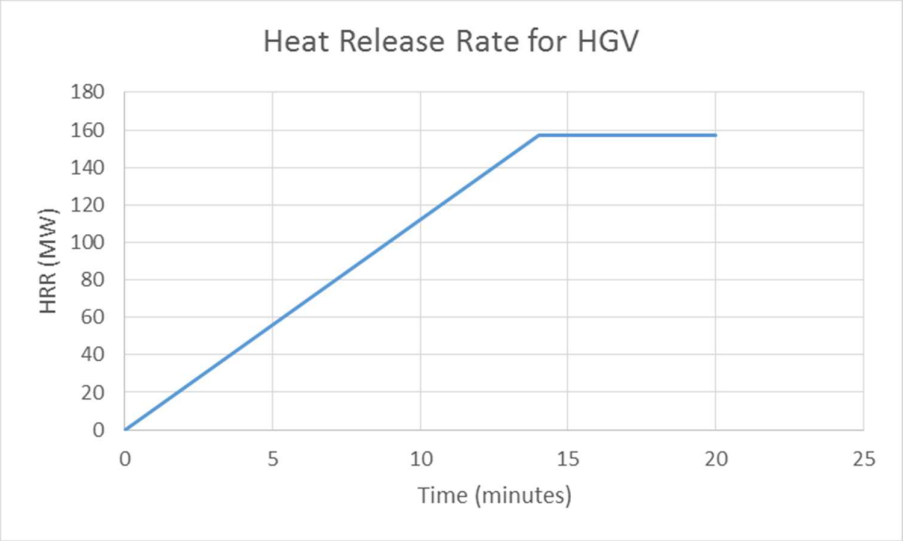


Figure 3: Heat release rate for a heavy goods vehicle

4 Assessment

Two scenarios have been considered for the purposes of this study and these are described below.

Scenario 1: A fire at mid-length of the enclosure on the elevated northbound Western Distributor.

Scenario 2: A fire at mid-length of the enclosure on Harbour St.

These scenarios are shown below in Figure 4 and Figure 5.

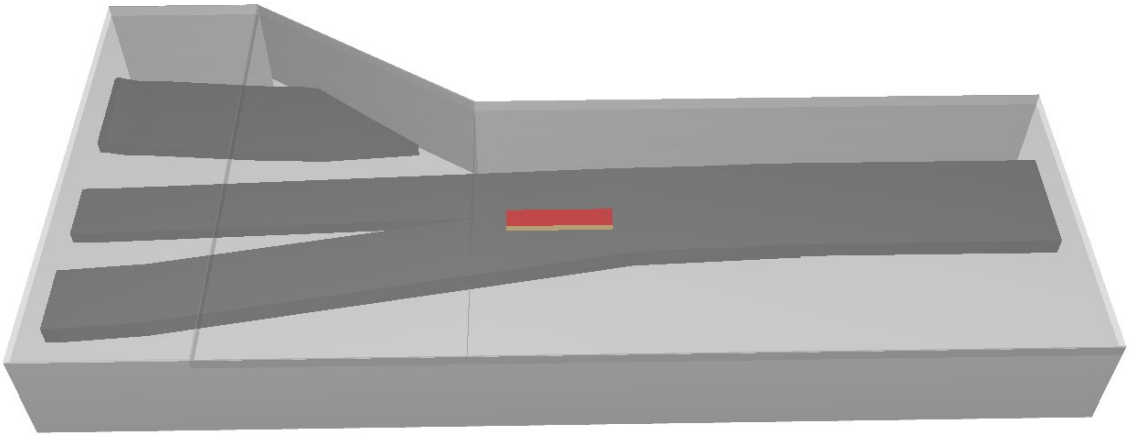


Figure 4: Scenario 1: Fire on the elevated Western Distributor

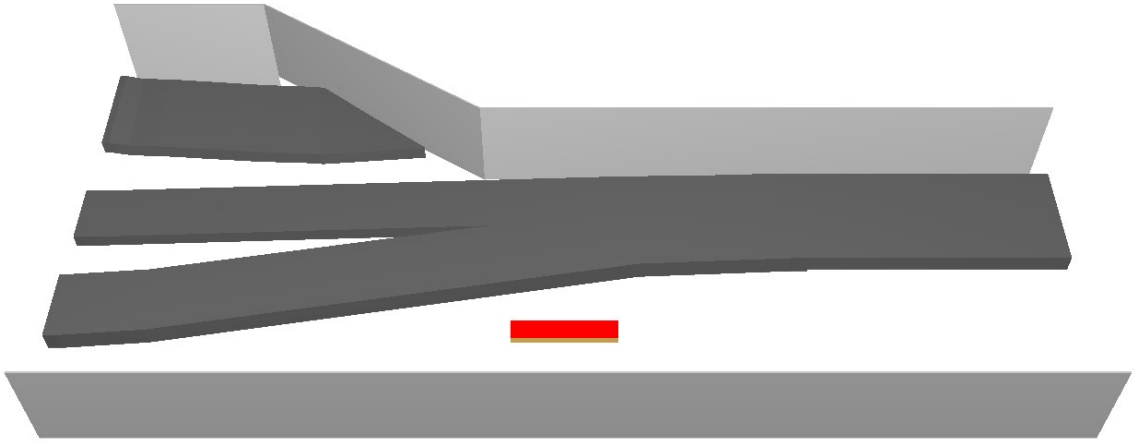


Figure 5: Scenario 2: Fire on Harbour St

Tenability conditions are measured 2m above the surface where people need to evacuate i.e. 2m above the road level. The acceptance criteria for tenability is taken from NFPA 502 as follows:

- Visibility: > 10 m
- Temperature: < 60^0C

5 Summary of Findings

The CFD assessment found the following:

Scenario 1:

- The tenability of scenario 1 is well above the acceptance criteria defined for this assessment. Given the steadiness of the visibility and temperature beyond 15 minutes, indefinite tenability can be assumed provided that the fire does not spread.
- Temperatures in excess of 60^0C are confined to the area around the fire source.
- The conditions associated with fighting the fire are acceptable – particularly as there is a 'safe' zone on the lower level of the enclosure from which firefighting efforts could be based which is unaffected by the fire on the elevated roadway.

Scenario 2:

- On the elevated roadway, tenability is achieved throughout a 20 minute period with the steady smoke and temperature conditions beyond approximately 15 minutes indicating continuing tenability beyond this time. In addition, there is the benefit that the fire itself is not on the elevated roadway.
- Localised patches of reduced visibility and increased temperature occur on the elevated roadway but these fluctuate and are not expected to be limiting to egress – particularly as there is no fire on the elevated roadway.
- Tenability is achieved at the lower road levels and could be considered to be indefinite with the large height of the enclosure allowing the smoke and heat to rise well above the roadway.
- Firefighting conditions are acceptable at both road levels – particularly at the lower level.

Refer to sections 7 and 8 below for the comparative outputs of the scenarios described above. For the temperature plots, 60^0C indicates 60^0C and above as this is the temperature which has been taken as the acceptance criteria for the purpose of this exercise.

6 Occupant Egress

The egress and human movement simulator, Pathfinder, has been used to estimate the occupant movement and evacuation times. The following parameters have been considered:

- An average of 1.5 occupants per vehicle;
- Cars are estimated to be approximately 4.9-5.2m in length and queuing at 6.7m centres;
- Each lane has been assessed to have 22 vehicles. It has been conservatively assumed that there are four full lanes of traffic along the entire length of the land bridge even though there are only three lanes at the entry;
- One passenger bus containing 50 passengers has also been included without reducing the number of cars;
- Thus a total of 182 occupants;
- The fire is assumed to be located at the northern end of the land bridge and to be conservatively blocking exit via both of the Western Distributor streams towards the Sydney Harbour Bridge and towards King St;
- Population distribution and travel speed;
    - Adults (90%): 1.2m/s
    - Child (5%): 0.5m/s
    - Disabled (5%): 0.5m/s
- Egress is via the road ways only; and
- Combined cue time and pre-movement time is taken as 1-4 minutes uniformly distributed over the occupants.

Our analysis indicates that the required egress time for upstream users to safely evacuate in the above scenario is 8 minutes.

Were only one of the northern exits to be blocked the egress time would reduce to 7 minutes.

In the case where the fire is located in the centre of the elevated roadway beneath the land bridge (as assessed as being the most critical case for the fire simulations), and exits were available at either

end, the egress time has been determined as 5 minutes. Users downstream would continue to drive and exit the underpass as normal and are not expected to be affected by the fire.

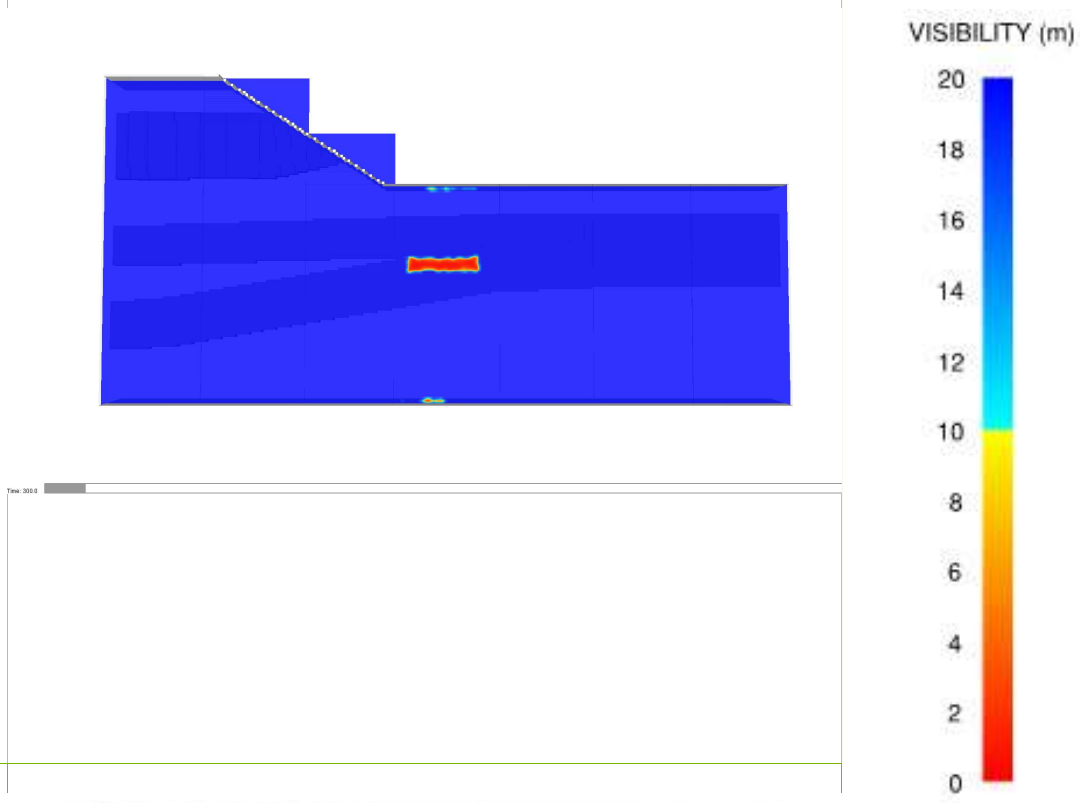
Each of these required safe egress times are less than the available safe egress times determined from the CFD modelling.

7 Fire on the Elevated Western Distributor

7.1 Visibility – after 5 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road



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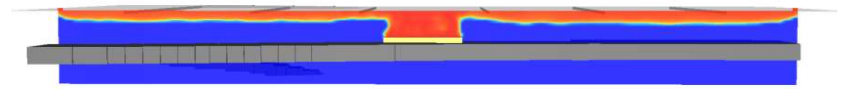
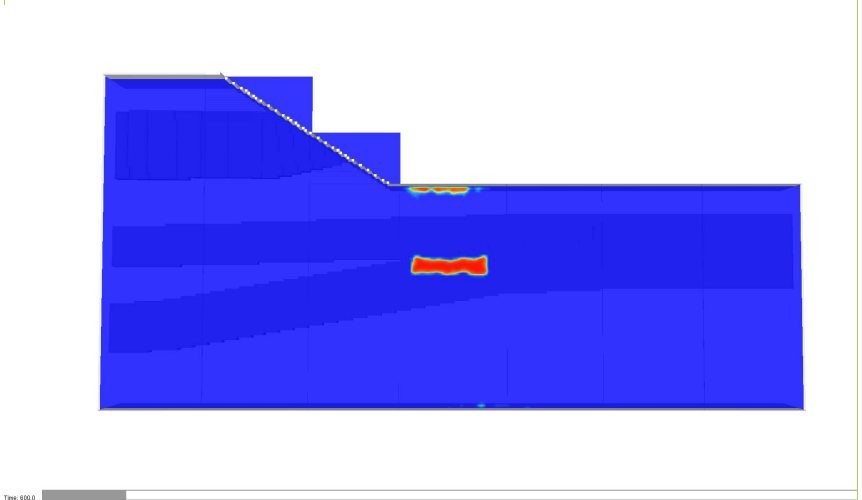


7.2 Visibility – after 10 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road



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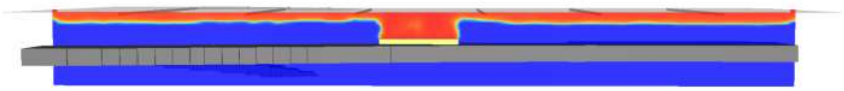
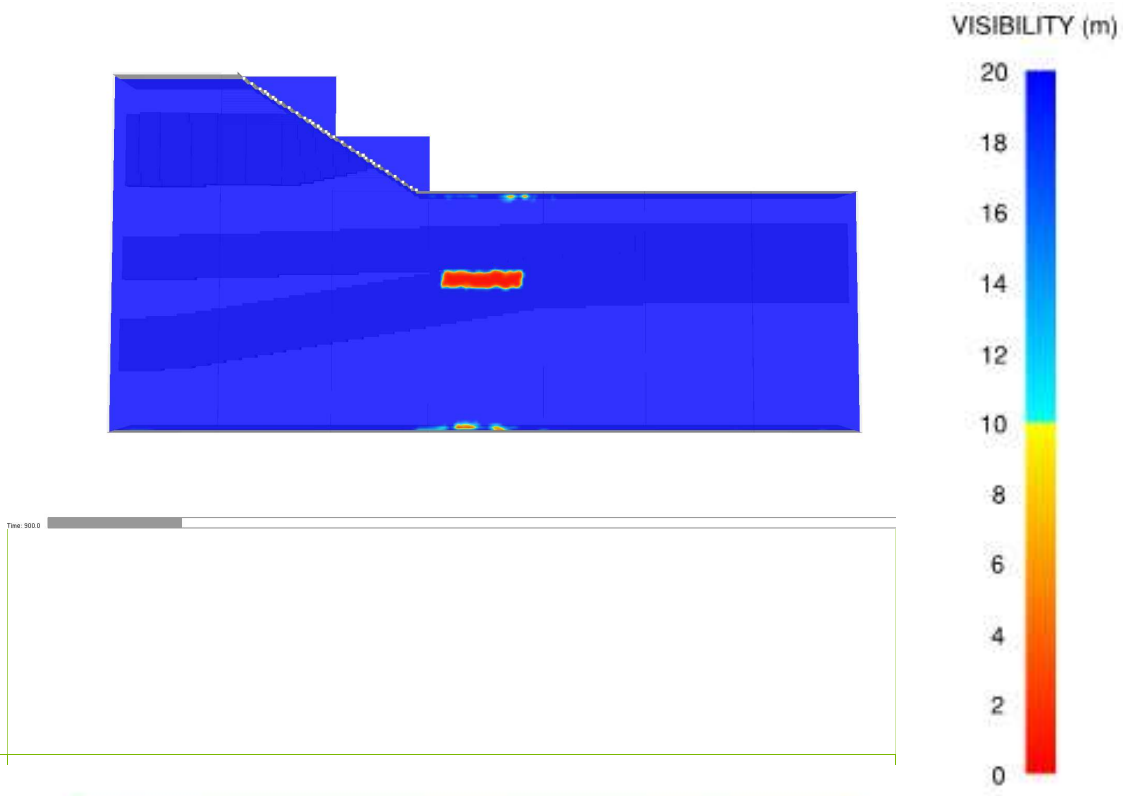


7.3 Visibility – after 15 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road

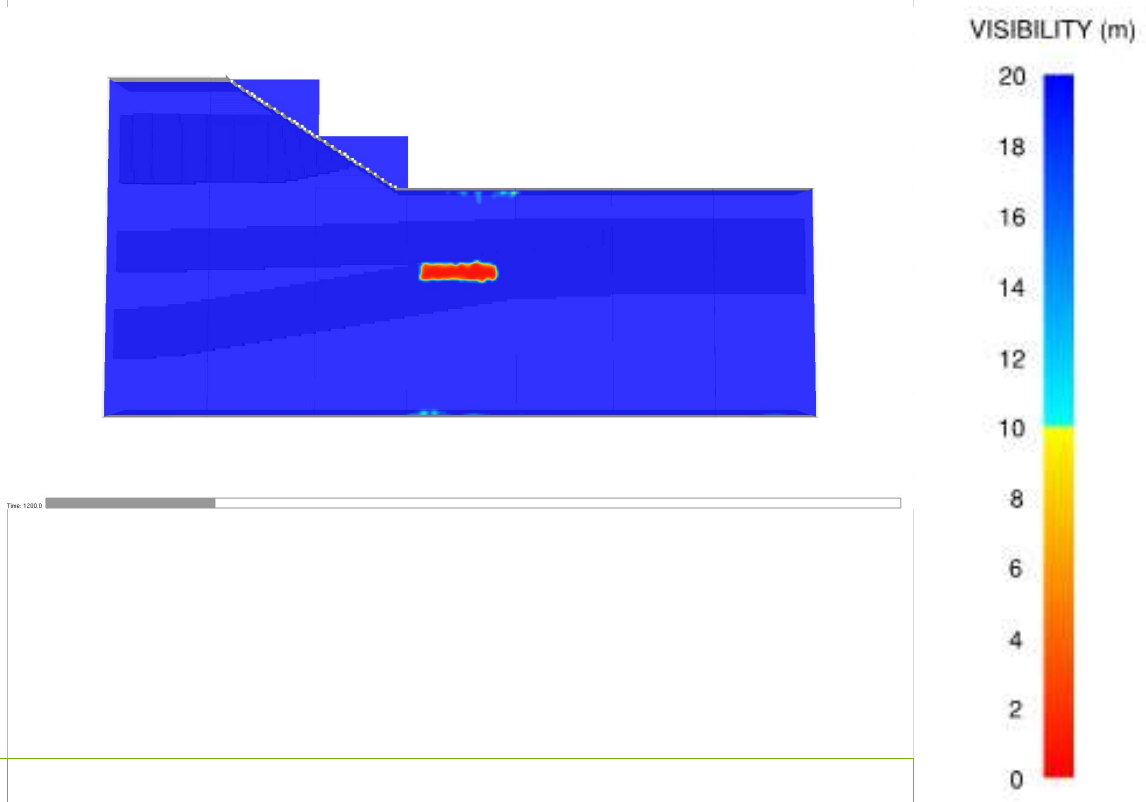


Long Section

7.4 Visibility – after 20 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road

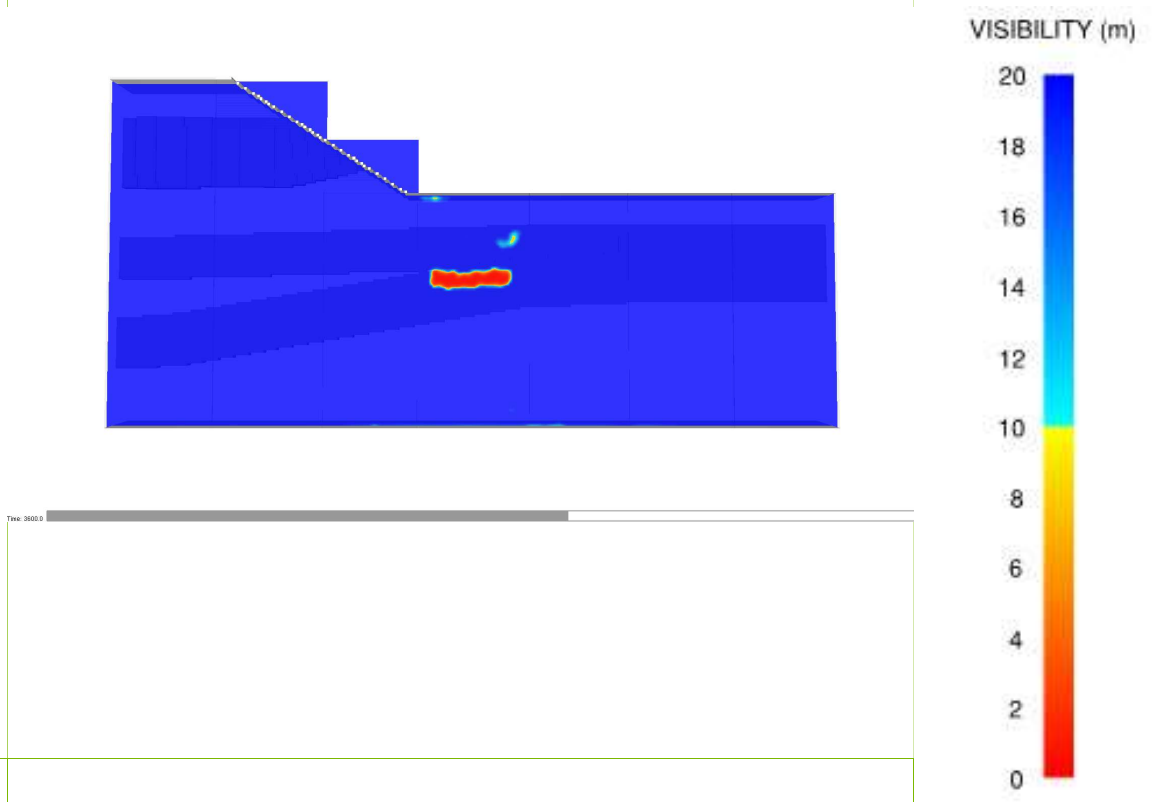


Long Section

7.5 Visibility – after 60 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road

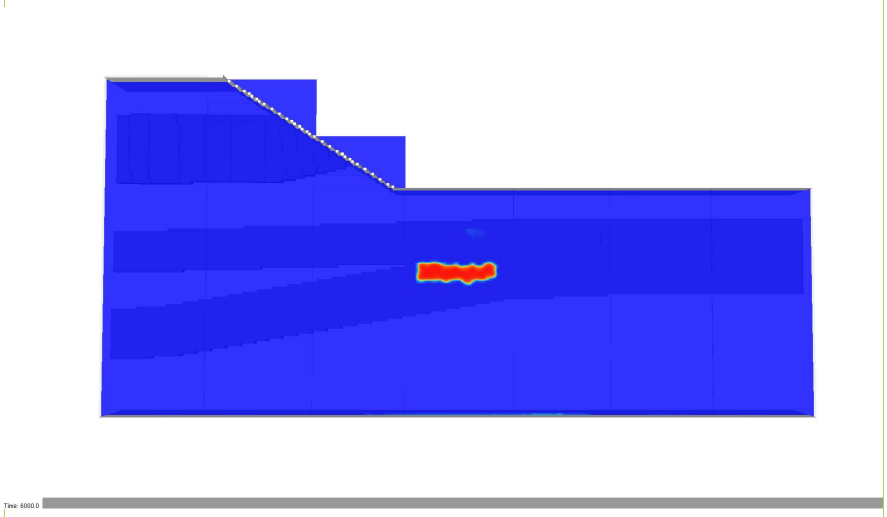


Long Section

7.6 Visibility – after 100 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road



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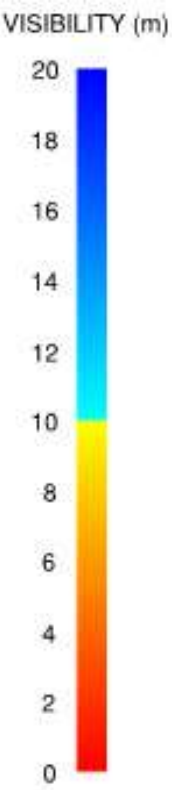
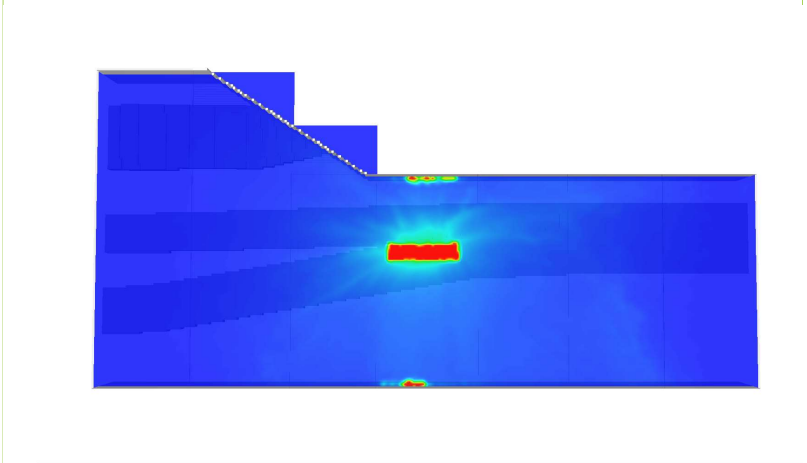
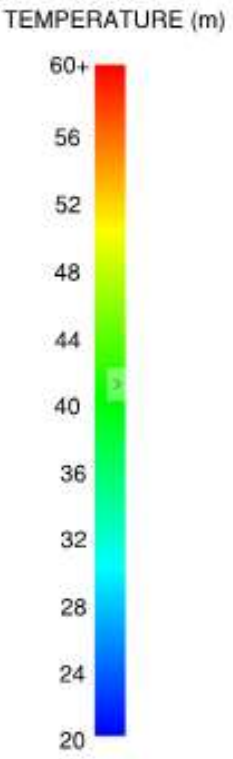
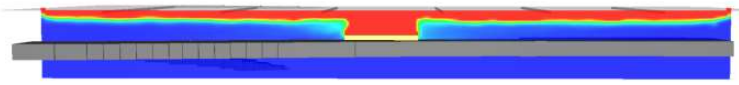


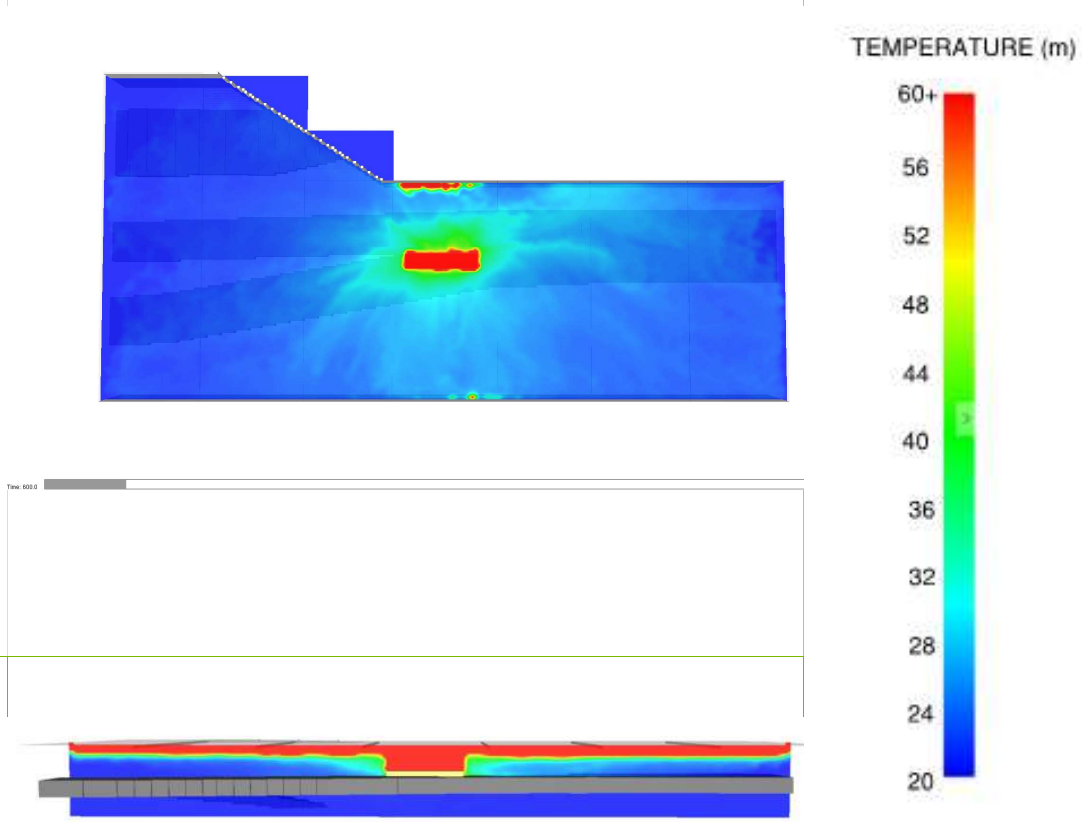
7.7 Temperature – after 5 minutes

	Scenario 1 – Fire on the elevated Western Distributor	
Plan - 2m above road		
Long Section		

7.8 Temperature – after 10 minutes

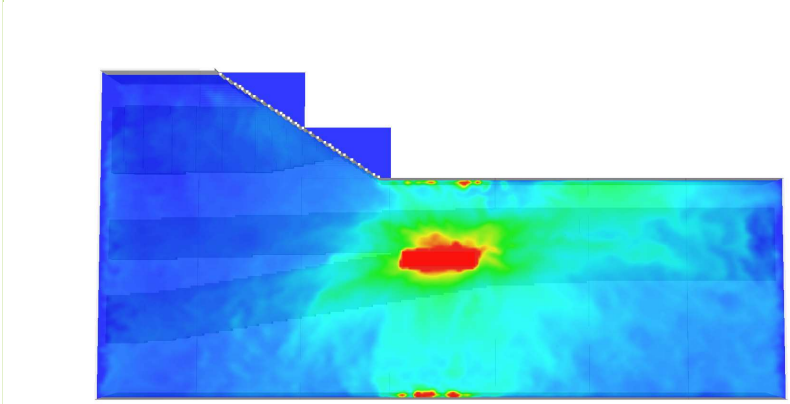
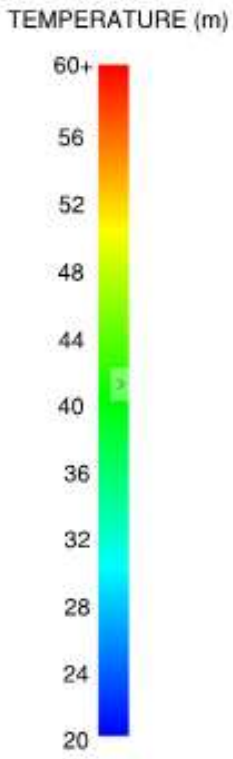
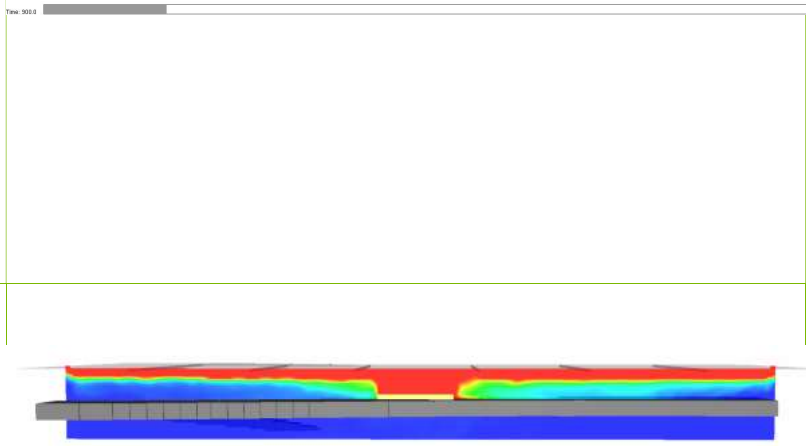
Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road

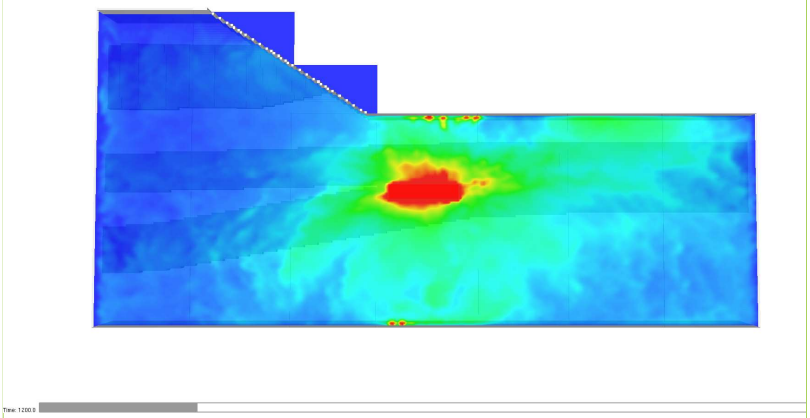
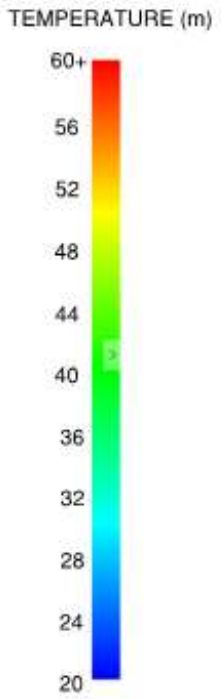
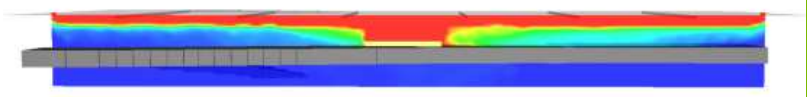


Long Section

7.9 Temperature – after 15 minutes

	Scenario 1 – Fire on the elevated Western Distributor	
Plan – 2m above road		
Long Section		

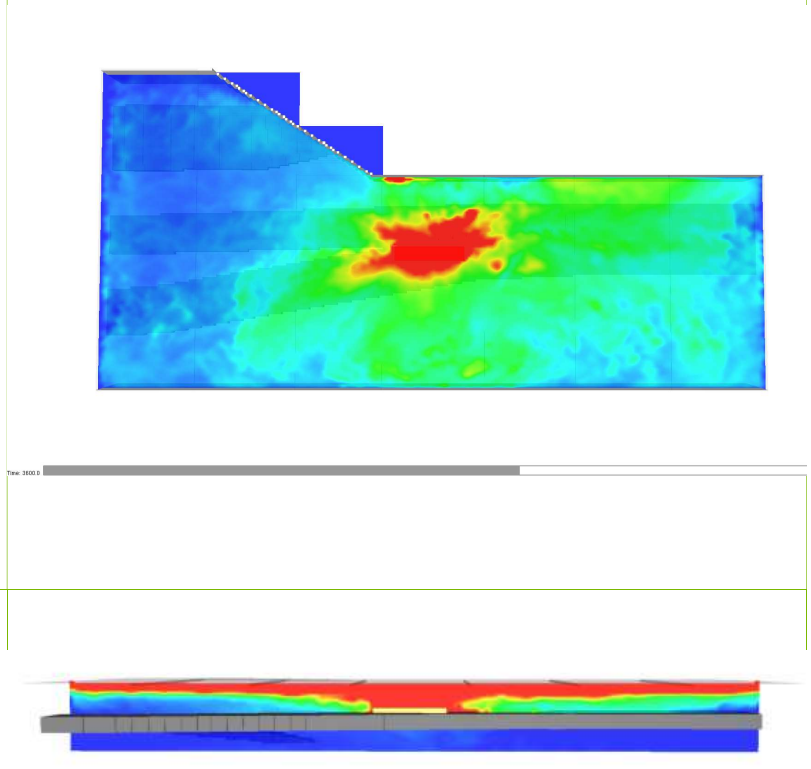
7.10 Temperature – after 20 minutes

	Scenario 1 – Fire on the elevated Western Distributor	
Plan – 2m above road		
Long Section		

7.11 Temperature – after 60 minutes

Scenario 1 – Fire on the elevated Western Distributor

Plan – 2m above road



Long Section

7.12 Temperature – after 100 minutes

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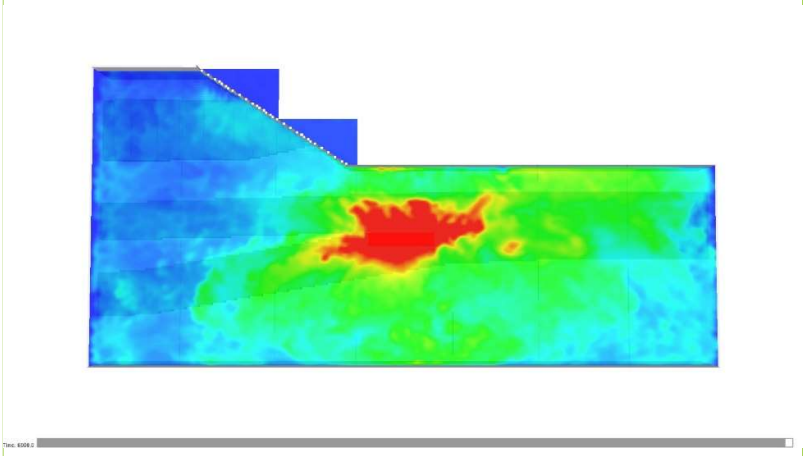
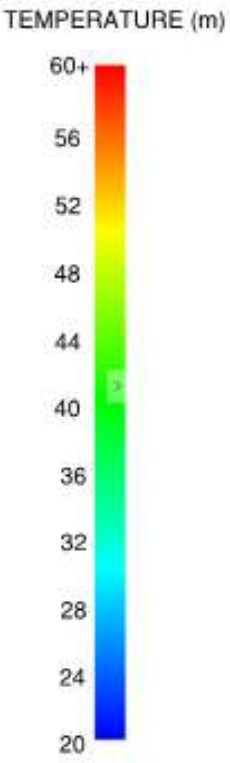
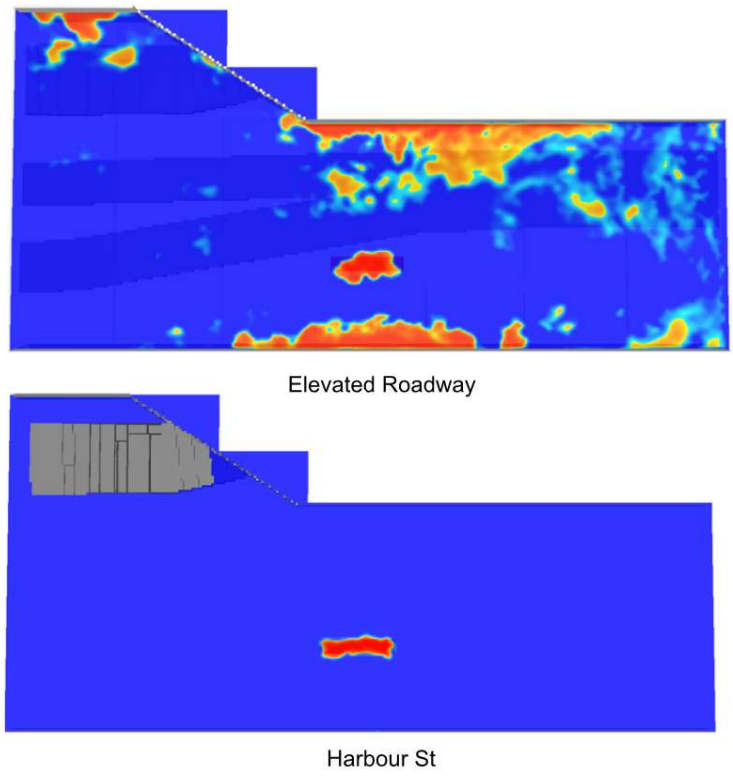
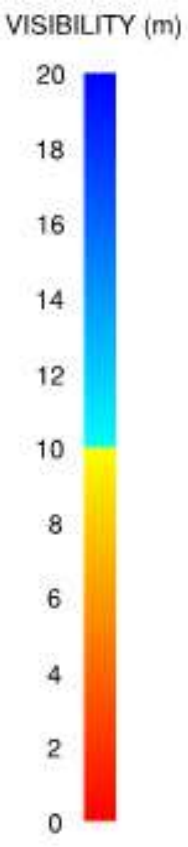
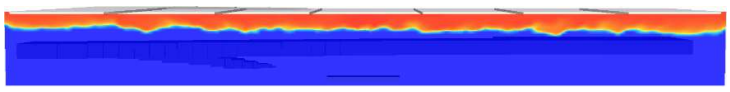
Plan – 2m above road		
Long Section		

8 Fire on the Northbound Harbour St

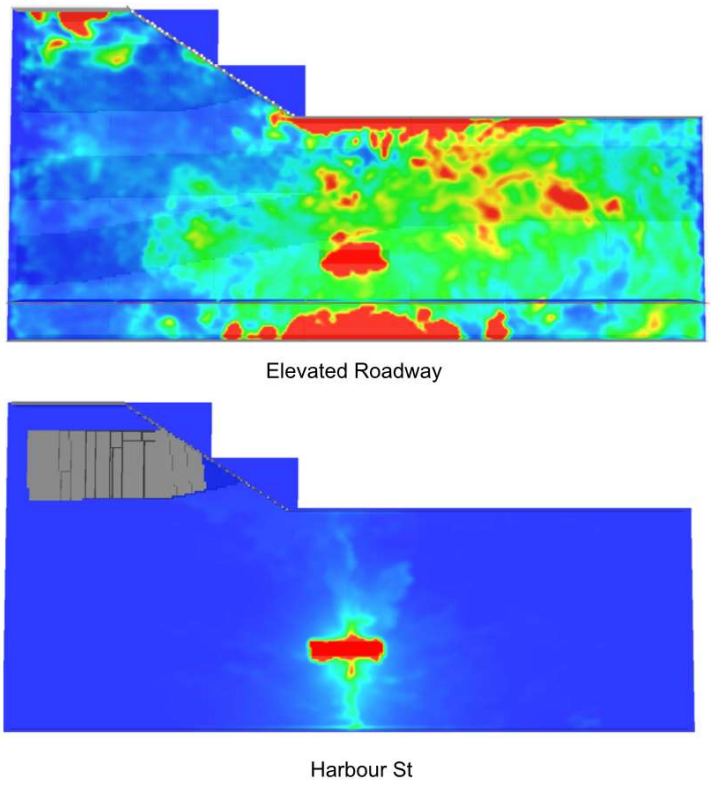
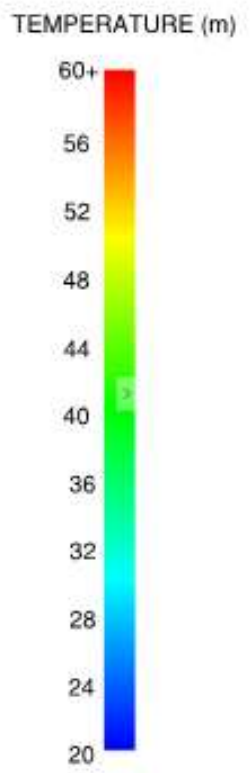
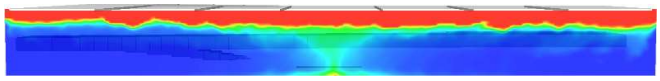
8.1 Visibility – after 20 minutes

(Simulations indicated stable conditions in the underpass after this time)

	Scenario 2 – Fire on the northbound Harbour St	
Plan – 2m above road		
Long Section		

8.2 Temperature – after 20 minutes

(Simulations indicated stable conditions in the underpass after this time)

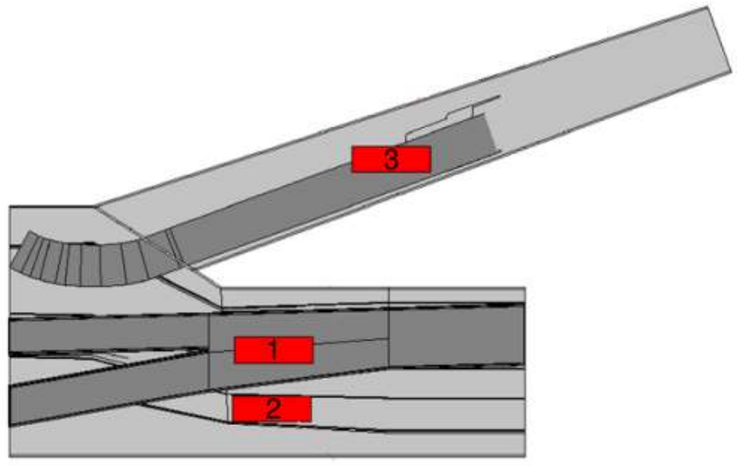
	Scenario 2 – Fire on the northbound Harbour St	
Plan – 2m above road		
Long Section		

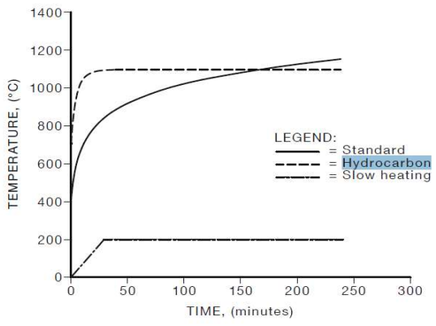
9 Proposed Concept Design Criteria for the Next Design Stage

In order to progress the concept beyond the preliminary assessment undertaken and documented within this report, a concept design criteria has been developed and coordinated with Roads and Maritime Services. This criteria expands the assessment to consider the impact of a fire event on surrounding infrastructure.

The design development in the next stage of design is to be assessed against this criteria which has been included in the following pages.

Design Item	Design Parameters	Acceptance Criteria	Reference

1. Fire Load for Tenability	• Heavy Goods Vehicle (HGV)
	• Peak heat release rate (HRR) 157MW
	• Peak value reached after 14 minutes at which point it remains constant
	• 82% wood pallets, 18% polyurethane plastic
	•
	• Soot yield 0.1g/g
	• Heat transfer: radiation 35%, convection 65%
	• Ambient temperature 20°C
	• Three fire locations to be assessed separately:
	  ○ 1. Mid-length of the enclosure on the elevated Western Distributor viaduct
	  ○ 2. Mid-length of the enclosure on the northbound Harbour St
	  ○ 3. Mid length of the existing Darling Park underpass
	 
	
		Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria:
		• Visibility greater than 10m (2m above the evacuation surface)
		• Temperature less than 60°C (2m above the evacuation surface)
		• Fractional effective dose of toxic gases, FED_{co} less than 0.3
			• Based on findings from the large scale fire test in Runehamar Tunnel in 2003 by Technical Research Institute of Sweden (SP)
			• Buchanan, April 2001

Design Item	Design Parameters	Acceptance Criteria	Reference
2. Egress Conditions	• Cars approximately 4.9 – 5.2 m in length queuing at 6.7 m centres in all lanes • Average 1.5 people per car • One passenger bus with 50 passengers • Population distribution and travel speeds: 90% adults 1.2m/s, 5% children 0.5m/s, 5% disabled 0.5m/s • Combined cue time and pre-movement time is taken to be 1-4 minutes uniformly distributed over the occupants • Egress path via the existing roadways with safe places to be nominated in conjunction with the assessment • The conditions in non-incident areas such as within the existing Darling Park underpass during a fire incident on the elevated roadway within the new enclosure and vice versa are to be assessed • The ability of the road user to identify their location in the event of a fire incident is to be addressed in the assessment	Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria: • Visibility greater than 10m (2m above the evacuation surface) • Temperature less than 60°C (2m above the evacuation surface) • Fractional effective dose of toxic gases, FED_{co} less than 0.3	NFPA 502
3. Emergency Services Response	The access strategy and incident response for emergency services, and the return to service requirements after a fire event are to be workshopped with RMS and the relevant emergency services once they become involved in the design development	To be workshopped with RMS and emergency services	
4. Hydrocarbon Fire Load Event	Fire Resistance Level (FRL) 120/120/120 to the hydrocarbon curve 	Demonstrate that the land bridge structure can avoid collapse and explosive concrete spalling	AS 1530.4: 2014
5. Fire Detection		Under NFPA 502, fire detection is not a mandatory requirement for an enclosure less than 240m long with the exception of a means to stop approaching traffic from entering the underpass. The extent of fire detection is to be agreed between Fire and Rescue NSW (FRNSW), RMS and the Developer during the FER process.	NFPA 502: Table A.7.2
6. Fire Suppression	Provision for FRNSW firefighting connections and means of containment and collection of water required for FRNSW firefighting.	The fire engineering solution proposed above will be provided to demonstrate tenable conditions without the requirement for a fixed suppression system such as deluge. Under NFPA 502, a fixed suppression system is not a mandatory requirement for an enclosure less than 240m long. Demonstration of adequate facility for FRNSW firefighting of the above fire loads including provision of adequate water supply, hydrants etc..	NFPA 502: Table A.7.2

Design Item	Design Parameters	Acceptance Criteria	Reference
7. Smoke Ventilation	Flow of smoke within the enclosure.	CFD assessment to demonstrate that reliance on natural ventilation will allow tenable conditions to the criteria described in item 1.	Refer to item 1
8. Smoke Flow and Air Temperature Outside the Enclosure	Parameters as described in item 1 except that the fire event occurs at the ends of the enclosure.	CFD assessment to show the flow of smoke as it exits the portals and demonstrate that the air temperature and smoke content at adjacent infrastructure (including the 161 Sussex St underpass) is below limits appropriate to the façade materials and functionality of space during a fire event.	
9. Separation of Land Bridge and 161 Sussex St Underpass	Lighting assessment to encompass the driver journey that includes the adjacent 161 Sussex St underpass in addition to the length of road beneath the proposed land bridge and their approaches. This is in order to demonstrate that the adjacent developments may remain separated and that the parameters and acceptance criteria outlined in item 7 are adequate to assess the interaction in a fire event.	Demonstrate that the lighting conditions over the journey provide acceptable light adaptation between internal and external areas without the need for additional measures between the 161 Sussex St underpass and the land bridge	• AS 1158.5 • RMS specification R158

10 Conclusion

The preliminary CFD modelling undertaken indicates that the likelihood of untenable conditions being present within the egress pathways on the roadways beneath the proposed land bridge over the Western Distributor is low.

In undertaking the simulations no means of external provision was used to improve the tenability condition. Tenability was shown to exist by natural means alone.

The criteria for further assessment of the impact of a fire event beneath the land bridge on the road user's and on the associated and surrounding infrastructure in the next design stage has been workshopped and agreed with Roads and Maritime Services.

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