Section B
Structural Design

Engineering Revised Concept Design Report

11.1.3 Engineering

RailCorp

Redfern Station Redevelopment

Revised Concept Design

Engineering Report

July 2009

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1 Introduction

Redfern station currently provides an interchange between most of the suburban lines in Sydney although it is currently underused as a starting or arriving station, with students being one of the main user groups.

There are currently issues with emergency egress and emergency services access particularly from the Eastern Suburbs and Illawarra lines and also with accessibility. The narrow platforms make it difficult to site stairs, lifts and escalators, while still retaining enough space to safely move along the platforms. This is a key issue at Redfern as vertical circulation between platform and concourse is at one end only.

As well as these specific issues which currently need to be addressed, there are aspirations to use the station as an integral part of the redevelopment of the area, increasing its use as a destination station.

As is usual with a redevelopment of an existing site there are constraints in terms of space and budget. In this case there are also heritage issues to be addressed. The station location in the railway corridor means that the platforms are curved and widths are restricted. Signal sighting and the location of supports for overhead line equipment need to be taken into account. Part of the station dates from the 19th century and as well as addressing heritage issues the redevelopment needs to be sympathetic to the needs of the surrounding community.

Crimes against the person and acts of vandalism are another of the challenges in this area and crime prevention through design through the use of lighting, and by enhancing sight lines, will be important features of the design.

Budgetary constraint, particularly during the current economic downturn, means that value for money and the ability to phase the redevelopment are key issues. The other key issue for a railway development is constructability. Any design engineering solution must be capable of construction alongside a live railway and operating station. This means that consideration should be given to:

- those elements which would interfere with railway operations and must be carried out during engineering hours;
- implications of redevelopment on operating infrastructure e.g. signal sighting and overhead line modification arising from the station works; and
- future maintainability of the redeveloped station within the railway environment.

1.1 Background

In April 2008, the Minister for Planning announced funding of up to $98.8million for the redevelopment of Redfern Station in concert with the development aims of the government's Redfern Waterloo Authority (RWA). RWA is a government agency whose role is to revitalize the Redfern town centre and surrounding precincts. RailCorp's multiple rail tracks create a physical barrier between the north and south sides of the station and RWA and RailCorp are looking to create a link between these sides to improve accessibility. The Redfern Station also requires upgrading to comply with its own patronage and design requirements which include compliance with fire and life safety and disability standards.

RailCorp and the Redfern-Waterloo Authority have worked together to carry out a Concept Design Study for Redfern Station, prepared in 2007, by Jackson Teece Architects. The aim of this study was to address the following concerns:

- pedestrian capacity and flow that meets patronage targets;
- safety and security including emergency egress;

- integration of Station Management with potential adjacent development opportunity;
- ease of Station Management control over safety, revenue protection, efficiency of staff resources, etc;
- disability and Discrimination Act 1992 (DDA) compliance (including subsection 31 – Disability Standards for Accessible Public Transport 2002 (DSAPT)); and
- efficient rail to rail interchange and station access to meet future demand.

And also to provide the following benefits:

- image of the station as an address for the future Redfern local area;
- heritage conservation;
- quality of pedestrian and cycle connections;
- quality of the interface between the station and its connectivity with Redfern Town Centre and other evolving development opportunities; and
- commercial development opportunities immediately adjacent that may offer cost, design and constructability advantages to Redfern Station.

The Concept Design Study provided 3 options:

Option C – Full station redevelopment

In this option the long term planning needs for the station upgrade, satisfaction of the user requirements, and improved safety and security have been met. This option provides a new elevated concourse above the centre of the platforms and allows for easier passenger flow through the station and population of the concourse. It includes a pedestrian access across the rail line for non-rail users through the overall station concourse structure.

Option D- Easy Access and Fire and Life Safety Upgrade

This option provides the minimal requirements for a station upgrade, however it does not provide a long-term solution to passenger crowding and flow. This option provides minimal easy access and upgrades the underground platforms to improve emergency egress times during an evacuation.

Option E – Upgrade/Interface Works in addition to Option D

Option E involves the expansion of the existing concourse to accommodate lifts and reduce pedestrian conflict. This option provides fire and life safety improvements and a separate pedestrian bridge to the south of the station. This pedestrian bridge does not provide a link to the platforms, but a link between North Eveleigh and the Australian Technology Park.

RailCorp requires further understanding of these options to progress this project to a Business Case.

1.2 Project Team

RailCorp appointed the following project team for the revised concept design, which commenced in January 2009:

- Bovis Lend Lease Consulting: Project Manager, Cost and Construction Planning
- Cox: Architecture and Urban Planning
- Arup Sydney: Civil / Structural Engineering, Fire and Life Safety and Railway Systems
- Arup Melbourne: Crowd Modelling

1.3 Engineering Scope of Services

The Engineering scope of services, undertaken by Arup Sydney, is as follows:

- Structural / Civil Engineering
- Railway Systems
- Fire and Life Safety / Fire Engineering

1.4 Engineering Scope of Works

The Engineering scope of works, undertaken by Arup Sydney, is as follows:

1. Undertake a peer review of the Concept Design Options C, D and E (Jackson Teece, 2007) including a review of the following (recognising previously developed RailCorp User Requirements):
   - adequacy in meeting RailCorp's fire life safety requirements, including emergency evacuation;
   - engineering and structural constraints imposed by the 'exclusion zone' for the proposed metro west dive;
   - engineering and structural constraints imposed by building over operating rail track and minimising scope and scale built structures and functions in this area; and
   - capacity to accommodate cost effective design improvements that address the results of crowd modelling, constructability/architectural input and other stakeholder inputs, taking into account the whole of life cycle costs.
2. Prepare revised engineering concept design (including key structural and design elements) for preferred and other options incorporating an alternative pedestrian/cycle connection. Confirm, revise or otherwise, the concept design (including key structural and design elements, taking into account the whole of life cycle costs) for the preferred option incorporating an alternative pedestrian/cycle connection. Together with the Architectural contractor develop other options to the point they can be considered as alternative options for assessment in the Business Case. Options to be developed to 30%concept design level.
3. Workshop revised concepts with the contractor team, as directed by the project manager and determine drawing/ documentation outputs that are adequate to prepare cost estimates (circa -10, + 30%) by the QS / Cost engineer contractor (number, type, scale, presentation standard, detail of drawings).
4. Provide advice and details necessary for the QS / Cost engineer contractor and the Project Manager to review options, including construction methods / types, layouts and services (both utilities and Rail) taking into account the railway possessions regime.
5. Participate in value engineering, constructability and risk workshops.
6. Provide input into the engineering report as determined by the Project Manager.
7. Liaise regularly with the Project Manager and other contractors as required by the Project Manager.
8. Provide input into the preparation of the Business case, as determined by the Project Manager.

1.5 Scope of Engineering Concept Design Report

The Engineering Peer Review Report was issued in February 2009. It explored the advantages and disadvantages of the three previous options. The review concurred that Option C was the preferable outcome over both options D and E. A range of issues and opportunities for improvement that would enhance the outcome were identified.

These opportunities have been developed and value engineered. The Value Engineering Report was compiled by Bovis Lend Lease Consulting and issued in March 2009.

This Engineering Concept Design Report addresses the conceptual structural/civil, railway systems and fire and life safety/fire engineering design of the revised preliminary concept design for the redevelopment of Redfern Station.

1.6 Reference Documents

The following reference documents were provided for the Revised Concept Design:

	Author	Title	Rev	Date
1	Acer Wargon Chapman	Standard Guidelines for Fire and Life Safety in the Construction of Underground Railway Facilities	A	Oct 1992
2	Engineered Fire and Safety Solutions Pty Ltd	SRA Guidelines for Fire and Life Safety	Draft	X 2000
3	Paul Davies Architects / Wayne McPhee and Associates	Heritage Conservation Report		Feb 2006
4	Connell Wagner	Redfern Station Survey 050401 A02492 001_0 to 010_0		Mar 2005
		Redfern Station Survey 050401 A02492 001_0 to 010_0 pdf and CAD		
5	RailCorp	Security Design Criteria		X 2005
6	RailCorp	Station Design Guide		Jul 2006
7	Redfern Waterloo Authority	Built Environment Plan (Stage One)		Aug 2006
8	RailCorp	Redfern Base Patronage Spreadsheets		Aug 2006
		Redfern Base Patronage Spreadsheets		
		Redfern Base Patronage Spreadsheets		
9	RailCorp	Redfern Station Redevelopment Project - Practical considerations and constraints during construction	2	Dec 2006
10	RailCorp	Safety Specification for Service Providers		Jan 2007
11	Australian Centre for Value Management	Redfern Station Upgrade - Principal Options Assessment Workshop		Feb 2007
12	RailCorp	Redfern Station Redevelopment Project - User Requirements in Support of the Concept Design Study	1.2	Mar 2007
13	Paul Davies Pty Ltd	Redfern Station Heritage Assessment		Apr 2007
		Email dated 15 March 2007		
14	Tenix	Cost, Constructability and Programming Review	3	Apr 2007

15	Jackson Teece	Concept Design Study - Part A - Urban Design Report		Apr 2007
16	Connell Wagner	Concept Design Study - Part B - Engineering Reports		Apr 2007
		Section 1 - Preliminary Services Recommendations		Mar 2007
		Section 2 - Requirements for vertical circulation under peak normal AM loads		Apr 2007
		Section 3 - Pedestrian Evacuation - Fire Engineering Report		Mar 2007
		Section 4 - STEPS Pedestrian Simulation Modelling Results		Jul 2007
		Section 5 - Structural Engineering Report		Mar 2007
		Section 6 - Scope for OHW Traction Option-C		Apr 2007
		Section 7 - Signalling Concept Option-C		Apr 2007
17	RailCorp - Major Projects Division	Status Report and Way Forward		May 2007
18	Connell Wagner	North Eveleigh Dive Drawings SK100 to SK34	Draft	Oct 2007
19	Maunsell	Preliminary Economic and Financial Evaluation of Redfern Station Upgrade		Jan 2008
20	Tenix	Redfern Station Review - Review and Clarifiation to Apr 2007 report		Feb 2008
21	Urbis	North Eveleigh Concept Plan		Mar 2008
22	ArupSustainability	Environmental Assessment - Eveleigh Heritage Walk - Pedestrian and Cycle Bridge ATP and N Eveleigh		Jul 2008
23	RailCorp	Major Closedowns and Weekend Possessions Programme 2010/2011 to 2014/2015		Aug 2008
24	Jefferey and Katauskas	Geotechnical Investigation for Proposed Pedestrian and Cycle Bridge at N Eveleigh Rail Yards and Australian Technology Park (Draft) Ref: 21823SB2rpt		Sep 2008
25	Redfern Waterloo Authority	RWA User Requirements		Jan 2009
26	W K Wotton & Partners	Survey Report 125-127 Little Eveleigh Street		Oct 2008
27	RailCorp	Redfern Station - Plan Room Drawings		various

Structural / Civil Engineering

2.1 Major Design Constraints

2.1.1 Ground Conditions

The draft Jefferey and Katauskas geotechnical investigation report associated with the proposed pedestrian and cycle bridge over the rail corridor to N Eveleigh was made available to Arup by RWA for use in this study (Ref. 24). It is noted that this information relates to ground conditions at least 60m away and is therefore not necessarily representative of the ground conditions under the proposed new foundations. The borehole location plan from this report is reproduced in Figure 1.

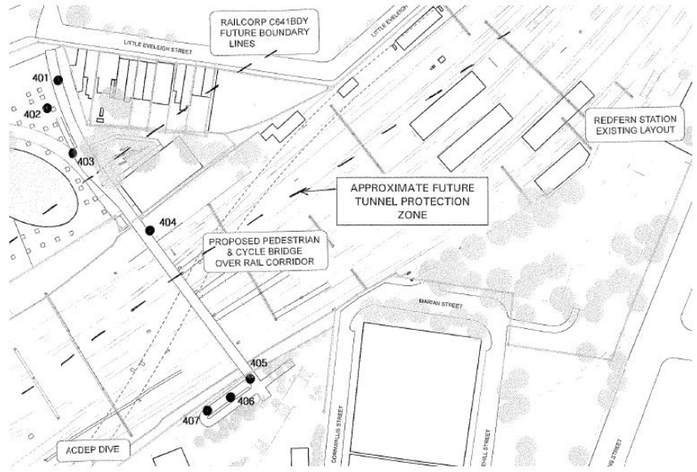


Figure 1 - Location of boreholes – Reproduced from Jefferey and Katauskas Geotechnical Investigation Report

Boreholes logs carried out at the south end of the station indicate:

- (BH 404) on the west side, from ground level at RL 25.5mAHD: 1.2m Fill overlying 2.8m of hard to very stiff Silty Clay overlying very low to extremely low strength Shale at RL 21.5m AHD. Medium strength Shale is encountered at RL 10m AHD.
- (BH 405) on the east side, from ground level at RL 27.0mAHD: 1.2m Fill overlying 3.4m of low to medium density Silty Sand overlying 2m of hard Silty Clay/Shaly Clay over very low to extremely low strength Shale at RL 20.3 AHD. Medium-High strength Shale is encountered at RL 12m AHD.

The geotechnical report recommends an allowable bearing pressure of 200kPa for shallow foundations on medium density sand or very stiff clay or 700kPa allowable end bearing pressure for piles founded in Class V Shale.

No Class II Shale (with allowable end bearing pressure of 3500 kPa) is indicated on boreholes BH 404 or BH 405. These boreholes suggest that medium strength Shale (with an allowable end bearing pressure of 1000 to 1500kPa (Class IV-III)) occurs at RL 10-12m.

Shale is clearly visible in the base of the excavation (at approximately RL 17-18m) between platforms 10 and 11. This is consistent with boreholes BH 404 and 405. However there has been no geotechnical assessment and the rock strength classification at RL 17-18m is not acknowledged

The Connell Wagner Concept Design Study assumed piles of 7m length founded at RL 18mAHD on Class II Shale with allowable end bearing pressure of 3500 kPa. Boreholes BH 404 and 405 suggest that considerably longer piles may be necessary to reach Class II Shale. Therefore the pile design would include skin friction and end bearing to minimise the pile length.

In the concept design piled foundations are not restricted from being within 2.7m of the platform edge due to platform clearance requirements. This is because the pile top will be below platform level and a temporary platform can be constructed at platform level during non-work periods. The restriction on pile location will most likely be governed by live OHW, and any critical platform services that may be present under a platform.

2.1.2 ACDEP Engine Dive

The ACDEP engine dive tunnel runs underneath platform 1. The tunnel location in plan and the reduced levels of the tracks and the tunnel crown are not shown on the topographic survey, although an approximate plan position was shown on drawings produced for the previous study and a typical cross section through the tunnel was provided (reproduced in Figure 2). The approximate position is indicated on Figure 1 and conceptual structural design drawing SK1 (in Appendix A3).

The tunnel construction is shown as closely spaced 300mm deep RSJ spanning between brick side walls and embedded in concrete with 40mm bottom and 75mm top cover with bitumen on top for waterproofing. The brick side walls are 0.9m thick at the top and 1.9m and 1.5m thick at the base on the east and west sides respectively. Since the tunnel passes under the tracks at the south end, and based on the typical cross section, the top of the concrete crown must be 1.5 - 2m below platform level (RL 24 – 24.5mAHD) and the foundation level is about 9-10m below platform level (RL 16 – 17mAHD), which would put it about 3 - 4m into the (Class V) Shale.

The typical cross section suggests that the tunnel was constructed immediately adjacent to the (pre-existing) Little Eveleigh Street retaining wall, allowing no clear space to provide new foundations at the back of platform 1.

Foundations will need to be located in Little Eveleigh Street on the west side of the retaining wall. Alternatively, it may be feasible to install a strip foundation onto the west brick side wall of the ACDEP engine dive, should investigation confirm adequate load capacity of the brickwork and foundation bearing stratum. The ACDEP engine dive lies within the west metro dive protection zone and is likely to represent far more of an impediment to construction than foundations to the new concourse.

The Little Eveleigh Street retaining wall is presumed to crank 120° to follow Little Eveleigh Street along the boundary of Nos 125-127 Little Eveleigh Street. South of the crank in the retaining wall, it should be possible to install a strip foundation beside the west brick side wall to the ACDEP engine dive Note that additional lateral pressure from surcharge may result on the brick side wall, presuming the founding level is above the base of the wall and the Shale is extremely low strength. This will need to be investigated at the next stage of design.

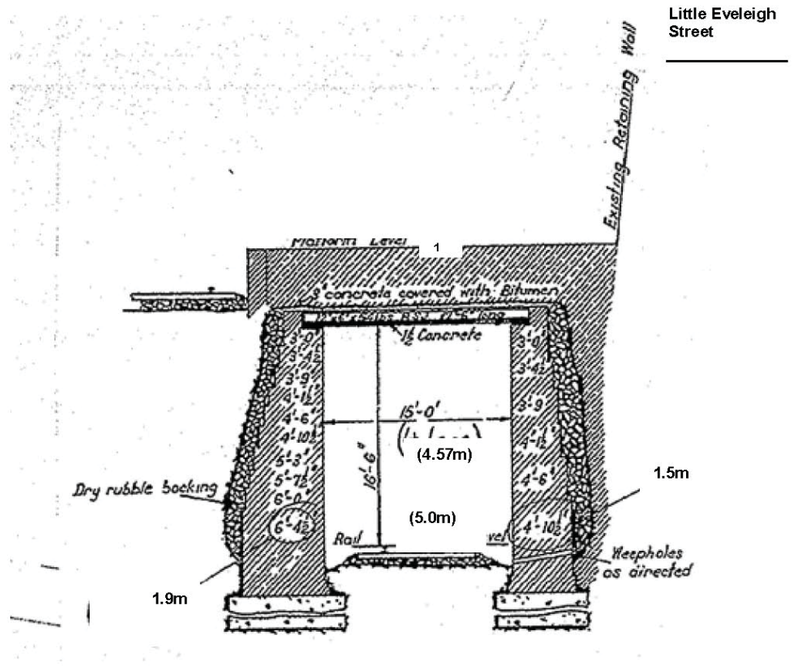


Figure 2 - Section through ACDEP engine dive tunnel (RailCorp Drg EDMS CV0076572)

2.1.3 Metro West Dive Protection Zone

RailCorp have provided 'draft' concept design drawings for the North Eveleigh dive and tunnel alignment corridor protection prepared by Connell Wagner (Ref. 18). RailCorp confirmed that the information shown on these drawings is current. Railcorp also advised that the protection zone in this location allows for a future station. In this case it would be of considerable benefit to understand how the interface between the underground and overground stations is proposed to be achieved.

Refer to Figures 3 and 4 for extracts from these drawings indicating the extent of the protection zone affecting Redfern Station. Foundations are allowed above the green zone. Piles may pass through the turquoise or green zones. No foundations are allowed on, in or through the pink zone.

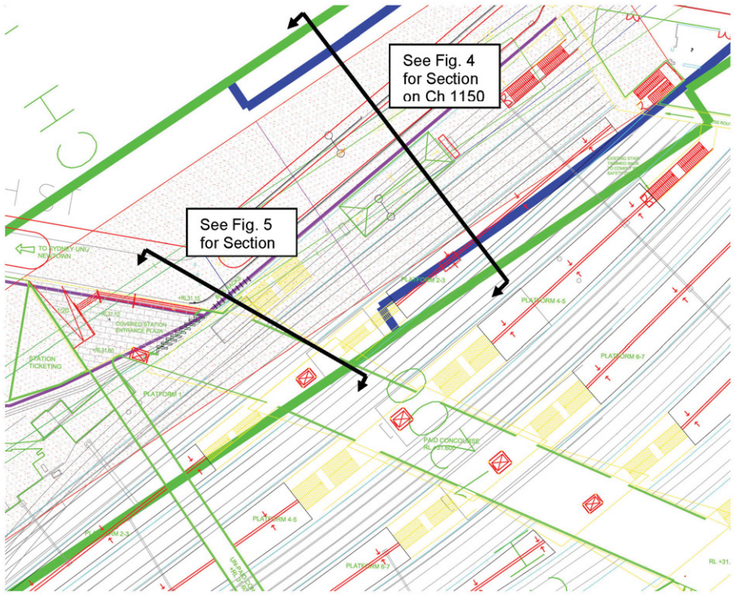


Figure 3 - Metro West protection zone overlayed on Revised Concept for Redfern Station Redevelopment

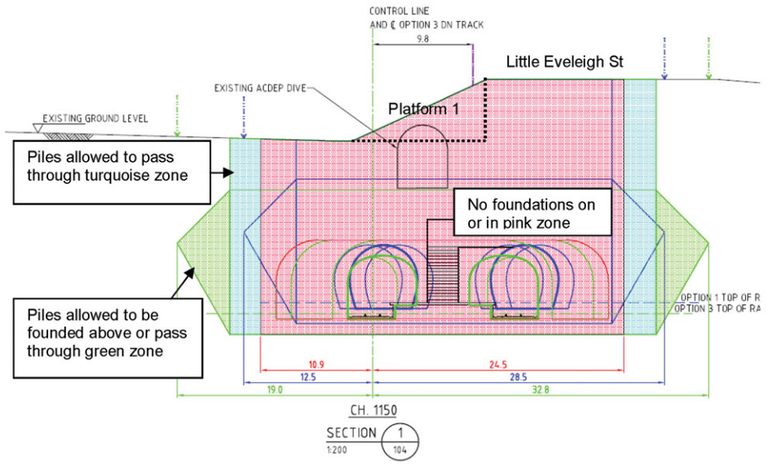


Figure 4 - Section through the Metro West protection zone at CH 1150 towards the north end of Redfern Station (Extract from Connell Wagner Drg SK130 - Ref 18)

The northern edge of the Metro West protection zone (toned turquoise) lies north of Little Eveleigh Street and includes Nos 125-127 Little Eveleigh Street. Platform 1 lies entirely within the protection zone. The southern edge of the protection zone (toned turquoise) affects the majority of Platform 2 and the north eastern end of platform 2/3 beyond the heritage building, but the remaining part of the station is not affected.

Hence, the support structures to the paid concourse and unpaid bridge on Platforms 1 and Nos 125-127 Little Eveleigh Street and also Platforms 2/3 fall within the pink full protection zone for the proposed Metro West dive. However the foundations for the paid concourse and unpaid bridge on platforms 2/3 are over the green protection zone, which restricts the toe level of piles to above or below the restricted zone.

For those foundations required in the pink full protection zone, initial advice received from Railcorp (via the Project Manager) is that the concept design should proceed on the basis of shallow foundations 'on rock' rather than piles. Our understanding is that Railcorp believe rock is at a higher elevation in this location than the boreholes at the south end of the station suggest. However, if rock is 4m below existing ground level (as at BH 404) this would require substantial excavation and it would be preferable to spread the load via a capping beam onto a line or group of closely spaced piers founded in the upper part of the Class V shale.

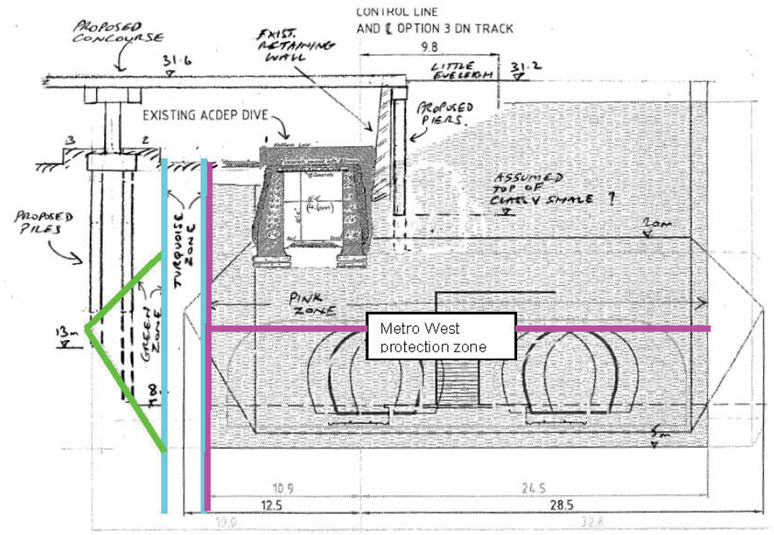


Figure 5 - Section through northern support to the concourse showing relationship to ACDEP dive and Metro West dive protection zone at the north side of the concourse

The Metro West exclusion zone potentially creates a significant constraint to the Redfern station upgrade project. Discussion and negotiation will be essential between the key stakeholders (both functions of RailCorp) as the Redfern Station Upgrade design is developed, as both projects have the potential to be mutually beneficial with the right design solution. The status of the metro west protection zone needs to be closely monitored during

the life of the project due to the development of other rail projects in Sydney. These projects may impact on the proposed use of the protection zone currently in place.

2.2 Concourse Structure (Options 1 and 2)

Drawings SK1, SK2 and SK4 (Refer Appendix A3) show the structural concept design for the concourse.

2.2.1 Paid Concourse - Platforms 1 to 10

The paid concourse floor structure between Platforms 1 and 10 consists of five approximately equal spans across each pair of tracks.

Supports on the island platforms comprise three 1100mm diameter reinforced concrete columns on 3-pile pilecaps, one at each side of the concourse, supporting insitu reinforced concrete headstocks. Each headstock comprises an 800mm x 1000mm deep insitu reinforced concrete beam each side of the lift opening spanning between 1200mm x 1000mm deep insitu reinforced concrete crossheads on top of the columns.

The deck consists of 600mm x 600mm prestressed precast concrete planks, laid side by side, spanning approx. 15m across each pair of tracks on to the 800mm x 1000mm deep headstock beams. A 150mm thick insitu reinforced concrete topping ties the planks together, increases the load capacity and provides for spread of load across adjacent planks.

The offset headstock arrangement, either side of the lift openings, results in large eccentric moments on the columns due to different loadings on adjacent spans. The worst case is during construction with the concourse erected on only one side. This could be significantly mitigated by providing temporary support under the end of the headstock beams onto the pile caps. Alternatively, each column could be replaced with a pair of columns located under each end of the headstock. However, this would not be able to be achieved for platforms 2/3 and 8/9 due to the narrow platform width.

In the normal design case the columns provide full lateral stability to the concourse, with the eccentric moments on the columns mainly due to pattern live loading on adjacent spans.

The concourse enclosure consists of a series of steel portal frames, one portal on each side of the platform stairs/lifts. This provides stability across the width of the concourse. Each pair of portals is also portalised over the stairs to provide stability along the length of the concourse. The roof structure consists of cold formed Z section purlins over raking steel beams supported on the portal frames. The structural model for the paid concourse is shown in Figure 6.

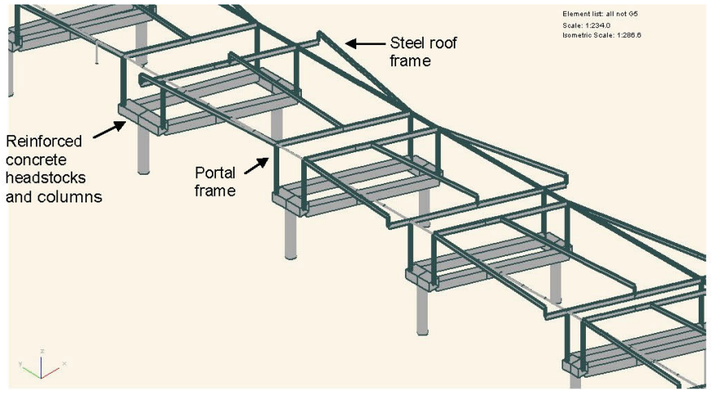


Figure 6 - Structural model of paid concourse (Option 1)

2.2.2 Combined Paid Concourse With Unpaid Bridge (Option 2)

The structural concept for the unpaid bridge within the paid concourse consists of a pair of steel trusses with precast concrete planks or panel flooring between the bottom chords. This maximises the headroom underneath. The unpaid bridge aligns with the south side of the concourse so that on the south side the steel trusses span between the portal frame posts. On the north side of the unpaid bridge the steel trusses span 3-4m further, between steel columns supported on the headstock beams, adjacent to the SE corner of the lifts. The structural model of the combined paid concourse and unpaid bridge is shown in Figure 7.

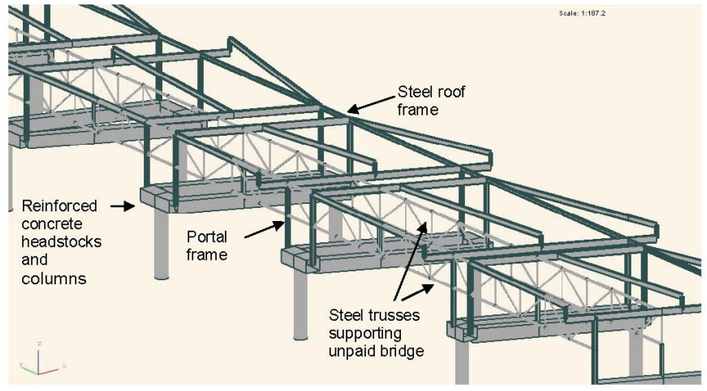


Figure 7 - Structural model of combined paid concourse and unpaid bridge (Option 2)

Apart from the additional structure required for the unpaid bridge (steel trusses and bracing, precast concrete planks and steel columns adjacent to the SE corner of the lifts), the headstock beams, RC column and foundations and southern steel portal frame posts and southern prestressed precast concrete plank are required to have increased load capacity.

2.2.3 Concourse Floor Structure – Platforms 1 to 125-127 Little Eveleigh Street

The brick and timber buildings at 125-127 Little Eveleigh Street will be demolished down to basement level which is at approx. platform level. The retaining wall along the Little Eveleigh Street boundary is assumed to be located outside the property boundary and does not rely on the basement structure for support.

It is proposed that the new concourse structure in this area will be steel framed with reinforced concrete deck on permanent metal formwork and pad foundations, to minimise the load on the foundations (and the North Eveleigh dive protection zone). The distributed weight of the new concourse structure should be less significantly less than the existing buildings.

2.2.4 Paid Concourse and Mezzanine Floor Structure - Platforms 10 to 11/12

To minimise cost, the concept re-uses the existing steel beams in the excavation void as support structure for station manager's office and ticketing at concourse level and below this, back of house station services and pedestrian link between platform 10 and Illawarra intermediate concourse.

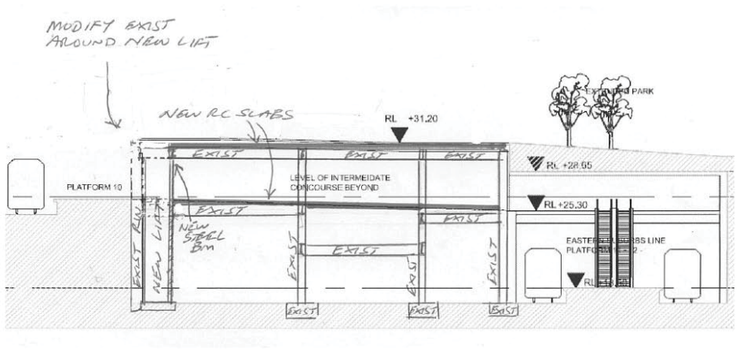


Figure 8 - Typical section through concourse linking Platform 10 to Platforms 11/12

A thorough assessment of the extent of corrosion of the existing steelwork will be required. However the steel section sizes are much larger than required to support the proposed new loads and some loss of section could be tolerated. The beam connections are the area most likely to require attention since they are the area most susceptible to corrosion. Provision should be made for welding /replacement of bolts or alternative seating arrangement. The steelwork would require grit blasting to remove excessive corrosion products, wrapping with FGW41 and then concrete encasement to prevent further corrosion and provide fire rating.

The existing car parking area south of the excavation void is partially supported on the existing southern rail tunnel and partially on natural ground or backfill. The concourse in this area is assumed to consist of blue metal over compacted ground under a 150thick ground slab.

2.2.5 Stairs and Canopies

The stairs are shown as precast concrete treads on steel stringers on the concept design drawing SK4 (refer Appendix A3), but could be precast in one piece as for the previous (Jackson Teece/ Connell Wagner) concept design study. The stairs will be supported on new piled foundations, similar to the previous concept design study.

New steel framed butterfly canopies are provided along the platforms similar to the previous concept design study, with central steel support columns bolted to the top of single 600mm diameter piles.

2.2.6 Lifts

There would be structural advantage in utilising the lifts to provide intermediate support for the headstock beams and the unpaid bridge and to provide lateral stability to the concourse. In the concept design the new lifts are independent of the concourse structure to enable the use of lightweight steel frame and glazing.

The lift on platform 1 is located outside the west brick side walls to the ACDEP dive. The reinforced concrete lift pit is constructed on mass concrete over Class V Shale.

2.2.7 Platform Works

A study was undertaken to investigate whether the impact of modifying the platform falls to fall away from the platform edge. It was concluded that this could be achieved by raising the platform edge with a single cross fall away from the platform edges or more easily with a 'W' profile cross fall, as illustrated in Figure 9.

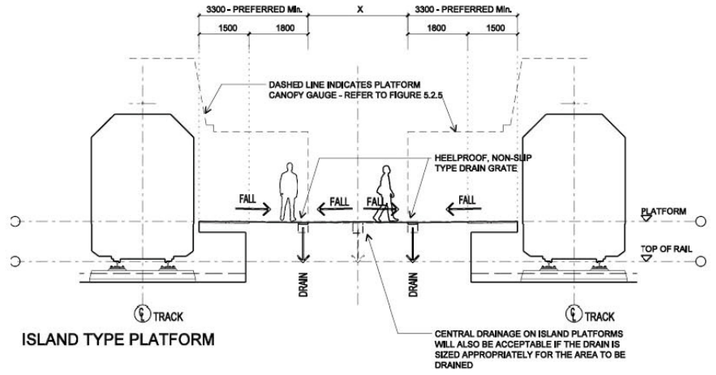


Figure 9 - Platform fall requirements (Fig 3.2.9 - Station Design Guide)

2.3 Unpaid bridge (Option 1)

Drawings SK1, SK2 and SK4 (Refer Appendix A3) show the structural concept design for the stand alone unpaid bridge.

The stand alone unpaid bridge is of similar construction to the paid concourse, except that supports on each island platform require only a single 900mm diameter RC column on a 3-pile pile cap supporting a 900mm x 900mm deep insitu reinforced concrete crosshead.

The deck consists of 600mm x 600mm prestressed precast concrete planks with 150mm thick insitu reinforced concrete topping, laid side by side, spanning approx. 15m across tracks 3/4 and 5/6 on to the headstock beam. Each headstock provides lateral stability for the portion of bridge, to allow completion of any span in the absence of installation of subsequent spans.

The width of platform 8/9 beneath the bridge, at only 3.7m, is too narrow to allow support structure. Hence, the bridge is required to span approximately 25m across tracks 7/8 and

9/10. This is too great a span for the 600mm deep planks. Alternative structural concepts for the 25m span are:

- Two 1200mm deep prestressed precast concrete Super Tee beams, with 150mm reinforced concrete topping. This would necessitate the height of the bridge to be raised by 600mm to achieve the required clearance and would be an extremely heavy lift.
- Two 1500mm deep prestressed precast concrete I-section upstand/downstand beams placed on either side with precast concrete planks spanning between. This was not pursued due to concerns that the height of the upstand would reduce visibility to the bridge.
- Steel truss structure with precast concrete planks, which fits comfortably within the 750mm O/A structural depth. This is the preferred concept, although there are maintenance issues with exposed steel.

The first span across tracks 1/2 is at least 20m, since the foundation has to be located on the west side of the ACDEP dive and the heritage building on platform 1. Alternative structural concepts are:

- Insitu (or precast) concrete beams with a 5-6m cantilever over the heritage building so that the typical precast concrete plank span of 15m is maintained. The back span of the cantilever beams would form part of the new suspended reinforced concrete concourse where the existing brick and timber buildings at 125-127 Little Eveleigh Street are to be demolished.
- Steel truss structure with precast concrete planks identical to the east side, with the foundation moved 5m west to provide ample clearance to the ACDEP dive and heritage building.

2.4 Modifications to Lawson Street Concourse for New Stair to Platform 2/3

Structural modifications are required to accommodate the new Platform 2/3 egress stair opening in the Lawson Street Concourse.

Structural drawings showing the structure of the concourse in this area have not been located so the structural works required are only indicative at this stage. Figure 10 shows the indicative structural works required to form the new opening.

The steel beams that currently support the southern edge of the concourse are supported on two steel columns at the end of Platforms 2/3. The column on Platform 3 is required to be removed to provide access to the new egress stair. It is desirable that the column on Platform 2 is also removed to improve access to the end of the platform. It is proposed to replace both existing columns with a new steel column or RC blade wall on new foundations (possibly utilising the existing column foundations), and to extend/strengthen the existing steel beams along the southern edge of the concourse for the new support condition. However, if strengthening is not feasible, it may be necessary to install new (upstand) trimmer beams along the southern edge of the concourse (on the south side of the new stair) spanning between supports on platforms 1 and platform 4/5.

The existing steel beams within the new stair void will be removed along with the RC slab. The parts of the existing steel beams that are to be retained would require new connections to the new steel trimmer beams.

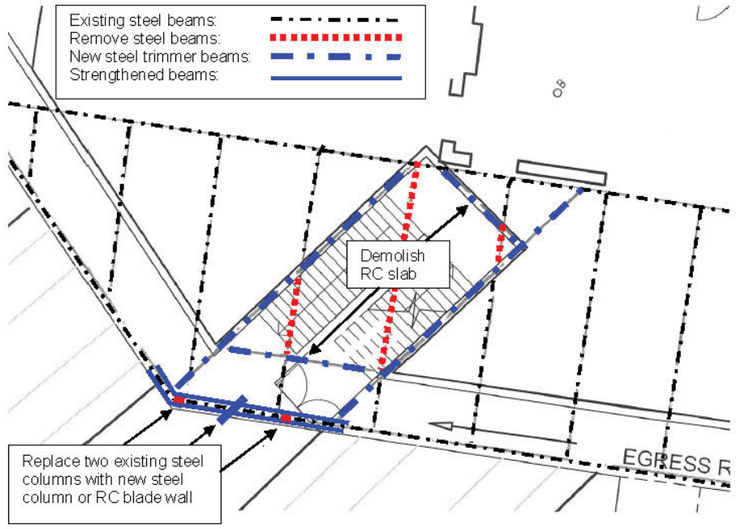


Figure 10 – Indicative structural works required for new Platform 2/3 egress stair opening in Lawson St Concourse

2.5 Structural Modifications to Illawarra Line Station Box

Drawing SK1 to SK3 (refer Appendix A3) show the structural concept design for modifications to the Illawarra line station box.

Structural modifications required to the Illawarra line structure comprise:

- Cutting openings in the concrete capping slab for the skylights / smoke exhaust shaft venting. The steel beams supporting the capping slab will need to be retained and circular reinforced concrete walls will be used to trim the openings and retain the backfill.
- Installation of a new egress stair to street level at the south end of the platforms. Some steel beams supporting the capping slab will need to be removed and the opening trimmed with reinforced concrete beams. Retaining walls will be required around the opening to retain the backfill.
- Installation of a new reinforced concrete egress stair between platform and intermediate concourse / mezzanine level
- Installation of a lightweight steel glazed lift within the existing escalator pit servicing between platform and intermediate concourse / mezzanine level. The original drawings suggest that the existing pit may be deep enough for the new lift. An opening for the lift shaft will need to be cut in the intermediate concourse. This will require cutting of the reinforced concrete slab and one or two steel beams and trimming of the opening with new steel beams.
- Installation of a new escalator servicing platform and intermediate concourse / mezzanine levels in the location of the existing stair, which is to be demolished. This will require excavation to construct a new pit below platform level and new

extension of the intermediate concourse into the existing stair void to support the new escalator and form the escalator landing, requireing new fire rated steel beams and reinforced concrete slab.

2.6 Commercial Development Enabling Works

The commercial development site has been located clear of the Illawarra line structures to remove the requirement for extensive enabling works to be carried out to the Illawarra line structures.

Retail development at concourse level is located to the north of the station manager's office and ticketing would require infill structure within the existing excavation void. The southern rail tunnels to the north of the void are likely to have adequate load capacity to support single storey retail.

2.7 Summary of Issues and Risks

The structural issues and risks are as follows:

1. Concourse and platform structures on 125-127 Little Eveleigh Street, Platform 1 and some parts of Platform 2/3 are located over the proposed North Eveleigh Dive / Metro West protection zone. Foundations are required that do not comply with the protection zone conditions.
2. Geotechnical site investigation is required in the vicinity of the proposed foundations. This information is crucial in order to determine the cost and practicality of the foundation options and progress the design.
3. A detailed services survey for the existing services within the Redfern Station boundary was not available. A Dial-Before-You-Dig enquiry was undertaken, but this was insufficient to identify services that are in close proximity to the proposed foundations.
4. Topographical survey is required to locate the ACDEP engine dive plan position and levels.
5. Structural survey is required to verify that the structure of the ACDEP engine dive is consistent with the available documentation.
6. Structural survey is required of the Illawarra line structures in the areas subject to structural modification to determine the existing structure and/or verify existing documentation.
7. Structural survey is required to assess the structural condition and determine the remaining load capacity of the existing exposed rusted steelwork in the excavation void (to determine whether it is cost effective to retain).
8. Structural survey is required of the existing southern rail tunnels and associated suspended structures to assess the structural condition and determine the load capacity.

3 Fire and Life Safety / Fire Engineering

3.1 Regulations, Design Criteria, Data and Assumptions

There are two acts that are relevant to the design and construction of railway stations: the Rail Safety Act; and the Environmental Planning and Assessment Act. The design and operational requirements are also determined by the Occupational Health and Safety Act and the Disability Discrimination Act.

The Rail Safety Act requires accreditation for the ownership and operation of railway systems. Fire safety in stations is typically addressed through the EP&A Act (and so the BCA). The Environmental Planning and Assessment Act requires BCA to be used as the applicable benchmark standard for the construction of buildings and structures.

The prescriptive (Deemed to Satisfy) Provisions of the BCA do not adequately address rail stations; however, they can be used as guidance for some issues, providing a bench mark for fire safety in buildings. The fire safety objectives and performance requirements of the BCA can be used as the basis to assess fire safety. However, RailCorp have objectives in addition to the BCA. The BCA limits its objectives to the life safety of occupants, facilitating fire fighting, and avoiding fire spread to adjacent properties. The covered concourse leads to a requirement that the station be assessed under the terms of the BCA, as far as practical.

RailCorp has its own guidance for fire safety in underground stations. The current issued version is 'Standard Guidelines Fire and Life Safety Underground Stations, Revision A' (1992), known as SGFLS. This has recently been updated, to take into account major changes to the BCA or the fire engineering process generally. A draft has been developed, 'Standard Requirements for Fire and Life Safety in Underground or Enclosed Railway Stations' (20 August 2008), (SRFLS 2008) which is under review and revision by RailCorp.

The new standard is intended for new build stations, however, compliance is not required if the relevant performance standards (to be drafted by RailCorp) can be met. The standard can also be used as a benchmark for fire safety in existing stations.

This has been used as the basis for a compliance review, instead of the BCA or the earlier SGFLS (1992), being the most relevant and up to date for station fire safety.(need to include something to show that we asked RailCorp which standard to be used and they told us this one)

NFPA 130 Standard Guidelines for Fixed Guideway Transit and Passenger Rail (2007) may be utilised as a general reference, and where a subject is not separately defined within the SRFLS. However, there is no requirement to comply with this code, in part because it is based on North American fire safety design standards and rail industry practice.

Full compliance with the current legislative requirements is not a reasonably practicable objective for the existing building. A holistic fire engineering approach needs to be used to rationalise the fire safety provisions within the building, whilst achieving an acceptable level of fire and life safety. Clauses 94 and 143(3) of the Environmental Planning and Assessment Regulations state the broad objectives that should be considered, where an existing building undergoes alteration or extension. Authorities require buildings to be upgraded where any proposed building work represents more than half the total volume of the building; however, an upgrade may be required if the measures contained within the building are inadequate to protect occupants, to facilitate egress, or to restrict the spread of fire from the building to other buildings nearby.

As part of any assessment to demonstrate non-compliance with current building codes, risk analysis methods may be required to demonstrate that there is a tolerable level of risk in the station. This would be subject to agreement with RailCorp and other authorities.

3.2 Design Criteria and Assumptions

The design is based on the following assumptions:

- Patronage to 2061
- Target egress time of 8 minutes from the above ground, uncovered platforms, Platforms 1 to 10. The awnings do not make the platforms covered.
- Target egress time of 4 minutes from the below ground, covered platforms, Platforms 11 to 12.
- Smoke control designed to protect Platforms 11 and 12 from a 20 MW design fire.
- Compliance with the relevant sections of SRFLS (2008) and the BCA (2009).
- Other assumptions are discussed in the text.

3.3 Fire and Life Safety Recommendations - Platforms 1-10

The following section summarises the requirements for egress and smoke control on platforms 1 to 10 and the associated concourse areas of Redfern Station.

3.3.1 Egress Strategy

The stairs are open to air and the proposed new concourse will only cover a short length of the platform (approximately 12 m). In the event of a fire at these platform levels, it is not expected that occupants would be subject to hazardous smoke conditions. However, the following must be addressed by adequate exit provision in order to reduce the risk to occupants.

- Limit queuing times for egress in an emergency in order to avoid crushing and associated crowd safety incidents, and
- Avoid passengers being trapped at one end of a platform, which could lead to some climbing down to track level, before it is certain that all trains have halted.

Occupants to the open platform areas can undertake the following options to egress to a place of safety (refer to Figure 11 for an illustration):

- From the north end of the platforms, they can take the northern egress route leading to Lawson, Little Eveleigh, and Gibbons Street.
- From the south end of the platforms, occupants can egress via the new concourse, travelling either to Little Eveleigh or Gibbons Street.

Until recently, open stations have not received detailed egress modelling attention. However, at a busy train station such as Redfern (11 train line services), consideration needs to be given to these issues.

RailCorp do not have a published standard that specifically addresses open stations such as this, although the draft "Standard Requirements for Fire and Life Safety in Underground or Enclosed Railway Stations" can be used as guidance.

As an existing station, there is a limit to what may be practicable to be implemented at the station to improve egress, and this is recognised in legislation. The key principle is that egress is improved as much as practicable. If this were to be assessed using cost benefit analysis, then it is likely to be found that keeping the existing stairs would be cost effective.

3.3.2 Platform Travel Distances

In an open station, where there is a choice of direction, the distance to an exit is not critical given that the smoke hazard is relatively low. However, consideration must be given to limiting the distance to a point of choice (dead end distance) to reduce the possibility that passengers may not be able to pass the incident train to reach the stair. At Redfern station, there is currently a distance to a point of choice of travel of over 150m. This is addressed by

the proposed new concourse which will be centrally located. This will reduce the single direction of travel to approximately 60m. If the existing stairs are kept on the north end, then the distance to a point of choice will be less than 20m from the north end of the platforms. At the south end the distance to a point of choice will remain as approximately 60m. Refer to Figure 11.

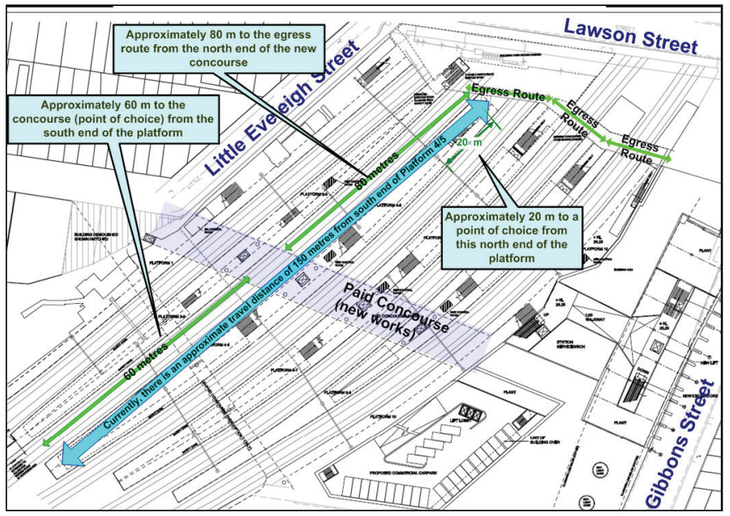


Figure 11 - Travel distance from open platforms

3.3.3 Platform Exit Width

In open air facilities, the typical target maximum calculated queue time is 8 minutes. A preliminary review of the required exit capacity and stair width is shown below. This is based on a peak loaded train (1,200 people) arriving at Redfern Station, and disembarking passengers onto a platform. The platform load is calculated as 2x normal peak, to account for a missed or delayed service.

The new stairs alone provide the required exit width for Platforms 1, 4/5 and 6/7.

Table 1 – Required Platform Stair Widths

Platform	Occupant Load	Required Exit Width for 8 min queue
1	1240	3.6 m
2 / 3	2153	6.3 m
4 / 5	2256	6.5 m
6 / 7	2261	6.6 m
8 / 9	1911	6.2 m

Table 2 – Comparison: Required Stair Width and New Stair Width

Platform	Required Exit Width for 8 min queue	New Stair Width	Shortfall in width
1	3.6 m	4.40 m	Nil
2 / 3	6.3 m	1.87 m 2.10 m	2.3 m
4 / 5	6.5 m	4.15 m 4.15 m	Nil
6 / 7	6.6 m	3.08 m 3.59 m	Nil
8 / 9	6.2 m	3.00 m	3.2 m

Table 3 – Comparison: Required Stair Width and New plus Existing Stair Width

Platform	Required Exit Width for 8 mins	New Stairs Width	Existing Stair Width	Total Width (new + existing)	Shortfall in width (new + existing)
1	3.6 m	4.40 m	2.85 m	7.25 m	Nil
2 / 3	6.3 m	1.87 m 2.10 m	2.25 m	6.22 m	0.1 m
4 / 5	6.5 m	4.15 m 4.15 m	2.45 m	10.75 m	Nil
6 / 7	6.6 m	3.08 m 3.59 m	2.85 m	9.52 m	Nil
8 / 9	6.2 m	3.00 m	1.5 m	4.5 m	1.7 m

The existing station platform stairs to Lawson Street do not provide sufficient capacity to meet the target queue time.

With the new concourse the stair width is generally increased; however, Platforms 2/3 and 8/9 is less than required (see Table 1). By retaining the existing platform stairs, there is adequate exit capacity for most platforms. However, the 8 minutes queue time is a maximum, and that where practicable, a larger stair capacity (i.e. larger stair width) be adopted.

It is assumed that Platform 10 is not used. The provision of stairs (or at least indentifying possible locations) should be considered, if the platform is to be safeguarded for future use.

3.3.4 Restrictions due to Platform Width

The platforms are narrow (with a typical width of about 7 to 8 m towards the centre of the platform houses), and in some cases the existing stairs encroach on the platform edge safety zone (refer to Figure 12). The existing stairs leading to platform 2/3 has the largest encroachment to the platform, but has a large shortfall in width (as in Table 1 above).

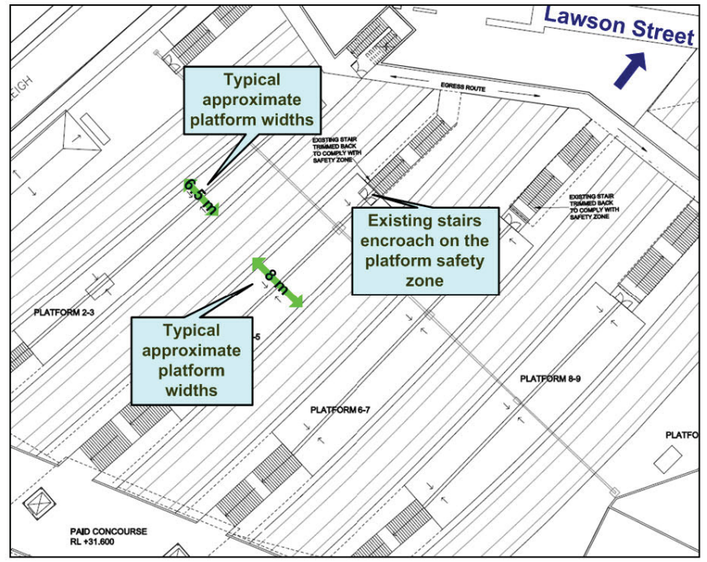


Figure 12 – Platform widths

There is a balance between increasing the platform exit width, and increasing the width of the safety zone. The benefits of the safety zone are applicable on a day to day basis, whereas the benefits for the stair width, relates more to an emergency incident (subject to general passenger flow being adequate).

The proposed reduction in width of the existing stairs to increase the width of the safety zone either side of the stairs should be considered and agreed with RailCorp.

In determining whether the existing stairs should be removed, we recommend that this be considered on a risk basis. RailCorp's input should be sought, because they will have had the relevant experience associated with this issue at Redfern.

3.3.4.1 Application of the BCA

If applying BCA DtS Provisions (the prescriptive provisions of the BCA) to Redfern Station Platforms 1 to 10, as a new build station, end of platform stairs would be needed at both ends of the platforms, because occupants need to walk through the covered walkway, the building (i.e. are not in open air all the time). The covered concourse creates the building of interest. Occupants need to escape through it, so this gives rise to the non-compliance for travel distance and exit widths. The canopies are buildings, although that is not the driver, because people can walk in open air next to these.

3.3.4.2 South End of Platforms

The south end of the platform will have dead end distances of up to 60 m when the new concourse it built. The construction of a new set of stairs and concourse at the south end of the platform may be prohibitive. If it is considered that there is a significant risk that passengers may attempt to cross the tracks in the event of an emergency, then management procedures could be implemented to avoid this. This can include network procedures to stop trains as early as possible.

3.3.4.3 Conclusion

NSW regulations do not force existing buildings to be upgraded if impracticable (and reasonable level of safety can be demonstrated); therefore, a new set of stairs and exits would not be required at the south end of the platform. But, there are existing stairs at the north end, and so, it would be considered practicable to retain these stairs.

This is the starting point; and the code and regulations for this issue are open to interpretation. There is scope for an alternative approach, if agreement is made by relevant parties (in part through the risk workshop). Part of the solution is for RailCorp to develop a well structured, enforceable emergency response plan. We will also refine our calculations to help further define the egress capacity limits.

The existing stairs to Redfern Station Platforms 1 to 10 would need to be retained based on compliance with BCA (prescriptive provisions) and NSW building regulations. Therefore, at this preliminary stage, it is recommended that the existing stairs are retained, subject to a wider risk assessment of the benefits, adverse affects and cost (capital, maintenance and loss of retail area) implications.

Platform 10 requires no special measures, based on its current status.

3.4 Fire and Life Safety Recommendations - Platforms 11 & 12

The following section summarises the requirements for egress and smoke control in the Illawarra platform 11-12 and associated concourse areas.

These platforms are below ground. There is no smoke extract and all of the exits (and access) points are close to one end of the platform.

3.4.1 Egress

The design basis for a new platform would be:

- target queue time from the platform of 4 minutes;
- travel distance on the platforms 60m maximum, where there is a choice of direction; and
- distance to a point of choice 20m.

There are fewer passengers at Platforms 11 / 12 (estimate at 500), and a full train (1,200 people), to achieve a queue time of 4 minutes would require a total exit width of 9 m. This cannot be accommodated within the station. It is possible that up to 6m exit width may be accommodated (one stair at 2m, one stair at 3m and one 1m wide escalator (stopped). This may be increased subject to review by the design team.

3.4.2 Platform Smoke Extract

To allow for a longer queue time, platforms 11 & 12 will require a good standard of smoke control to protect the exit paths. The smoke control concept design is based on:

- A maximum 20 MW design fire (RailCorp typical design fire size);
- A platform to underside of beams height at 6 m (and other dimensions as per the sketches).

The options assessed include allowance for the central concrete wall with arches that acts as a barrier to smoke spread, so that the distribution of the smoke extract either side is required.

See sketch concepts in Figures 13 to 17 below.

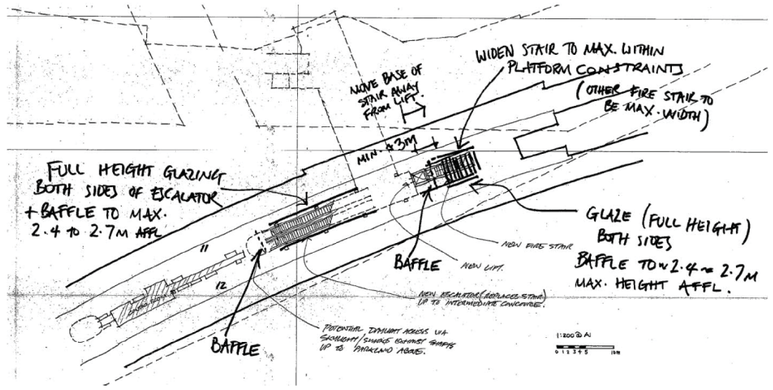


Figure 13 - FLS concept for platforms 11/12

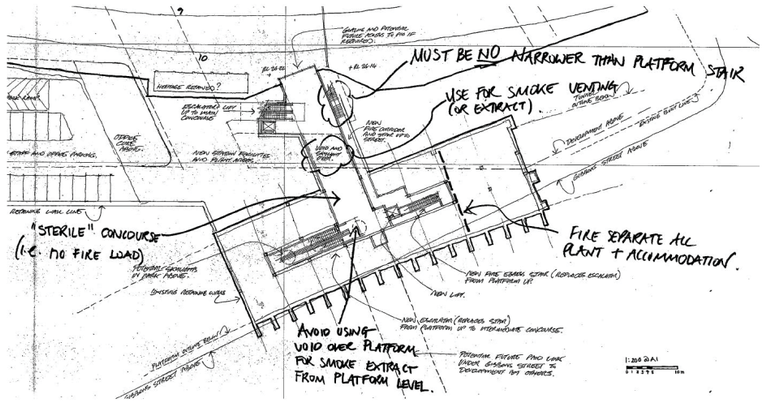


Figure 14 - FLS concept for concourse above platforms 11/12

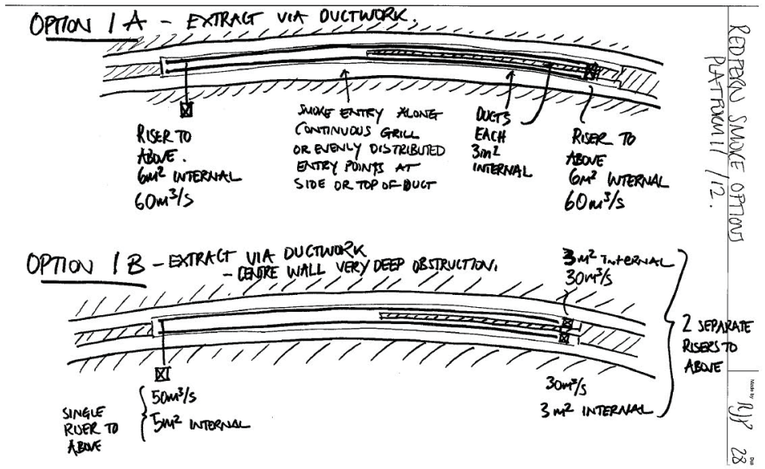


Figure 15 - Smoke extract concepts for platforms 11/12 – options 1A and 1B

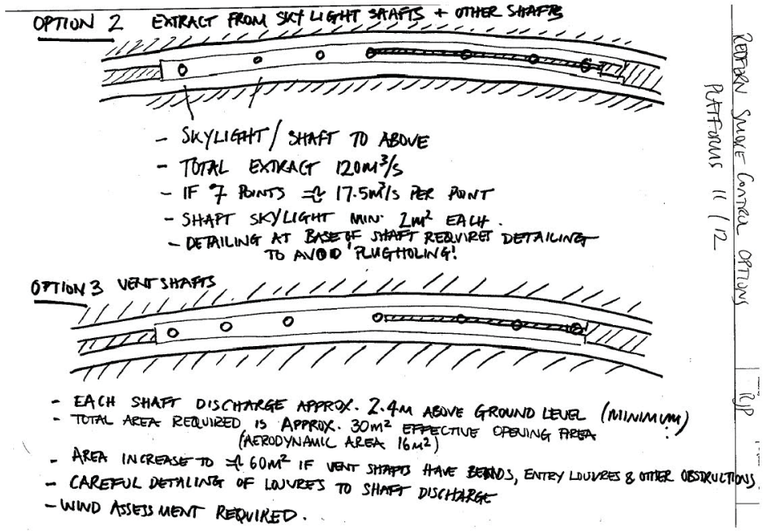


Figure 16 - Smoke extract concepts for platforms 11/12 – options 2 and 3

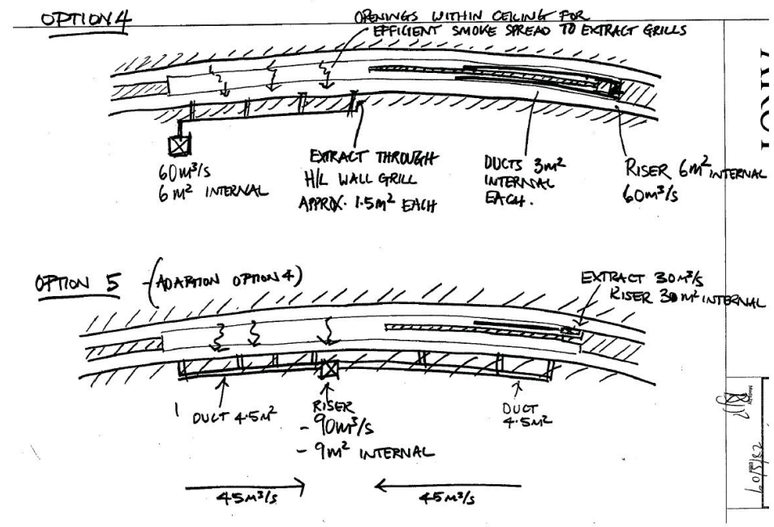


Figure 17 - Smoke extract concepts for platforms 11/12 – options 4 and 5

3.4.3 Platform Fire Isolated Stair Pressurisation

At this stage, allowance should be made to pressurise the fire isolated stair.

3.4.4 Fire Rating

The structure to Platforms 11 to 12 should be fire rated based on compliance with BCA (prescriptive provisions) and NSW building regulations.

If applying BCA DtS Provisions (the prescriptive provisions of the BCA) to this area, as a new build station, we would need to have 2 hours fire rating. RailCorp's own code would require 4 hours fire rating.

NSW regulations do not force existing buildings to be upgraded, if impracticable; however it is likely to be considered that a fire rating solution is practicable.

There is scope for omitting fire rating to the beams, if it can be demonstrated in a severe fire the structural effects would be localised. That can involve complex analysis, and the beams may not have much spare load capacity for this to work. It may be possible to get agreement for 2 hours fire rating though.

3.5 Summary, Issues and Risks

3.5.1 Existing Station

The existing station has the following key fire safety issues:

1. Long single direction of escape from Platform 11 / 12 (Eastern Suburbs Line).
2. No smoke control from the Platform 11 / 12.
3. Non-fire rated beams above sections of Platform 11/12.
4. Long single direction of escape from the platforms and inadequate exit width from Platforms 1 to 9.

3.5.2 Station Redevelopment

The new concourse will improve safety in relation to Item 4, by reducing the travel distances on Platforms 1 to 9 and increasing the exit width capacity; however, there will still be a long single direction of travel and on some platforms inadequate width.

3.5.3 Codes and Regulations

Platforms 11 / 12 can be addressed by the Building Code of Australia and the RailCorp standard for underground stations. Codes and regulations in NSW do not adequately address above ground rail stations (Platforms 1 to 10 and the concourse); however interpretations of their requirements can be made.

As an existing station, there is a limit to what can implemented at the station to improve fire safety. This is recognised in legislation. The key principle is that fire safety should be improved as much as practicable.

3.5.4 Fire Safety Upgrade

The following fire safety measures should be implemented, in addition to the construction of the new concourse and underground station entrance:

- New fire isolated stair to be built at the southern end of Platforms 11 and 12 (Eastern Suburbs Line).
- Provide smoke control from the Platforms 11 /12. The preliminary proposal has adopted natural ventilation.

The proposals will be subject to further design development. In addition to these measures, the following active systems are required throughout the station as per the BCA, Australian Standards and RailCorp Standards:

- Occupant warning and public address system to all areas;
- Smoke detection at Platform 11 /12 and in enclosed areas;
- Sprinklers to back of house areas in the ESL underground station section, and to risk areas, such as escalator pits;
- Emergency lighting and exit signage; and
- Fire fighting systems (hydrants, hose reels and extinguishers) per code.

The following can be subject to further review to determine the effectiveness of adopting these measures, as follows:

- **Fire rate all the beams above Platforms 11/12**

  Undertake fire engineering assessment to determine the risk associated with having non-fire protected beams.

- **Retain the northern stair to Platforms 1 to 9**

  RailCorp should carry out a risk review by to compare the overall risk associated with retaining or removing the existing northern stairs. The risk assessment will need to address emergency evacuation, slips trips and falls, and operational management in an emergency.

3.5.5 Outstanding Issues and Risks

Outstanding fire and life safety issues and risks are as follows:

1. RailCorp's brief statements are to be consolidated as part of a FLS.
2. Confirm the FLS design requirements.
3. Clarify the project brief for Platform 11 & 12 and in particular, determine whether RailCorp require full upgrade at this stage.

4. Agree the acceptable level of risk (qualitatively) for fire safety on open platforms, particularly in relation to the risk of falls. There is a conflict in requirements for the fire safety and falls, due to the narrow platform width.
5. Ascertain staffing and security levels at the station. This could affect the design solution, and could preclude some exit locations and design options.
6. Ascertain how soon can trains be stopped from running through the station, in the event of major evacuation in a peak period. If prolonged running periods after an incident, then there is a greater need to avoid excessive queuing periods, so leading to a need for larger stair widths.

4 Rail Systems Engineering

4.1 Design Criteria, Data and Assumptions

The traction overhead wiring in this area is a regulated tension system comprising a single 270mm^2 catenary and twin 137mm^2 contact wires. The system constant is 588 and the system is designated by RailCorp as "System 2". (See EP 08 00 00 16 SP)

The contact wire is generally ramping up from low points (4.75m) at Lawson St bridge through the station towards the standard design height of 5.0m. Ideally the ramp rate should not be greater than 1:500. However, with approval this can be increased to 1:300 – see RailCorp standard EP 08 00 00 01 SP.

The catenary heights are generally in the range 6.3 – 6.6m. With the bay lengths in this area this gives a minimum dropper length of around 950mm. This is significantly greater than the minimum of 450mm or 150mm for a restricted dropper as used under a structure.

The maximum allowable bay length for this system is 67m. There is some curvature on most of the tracks and the bay lengths in these areas are further constrained by the versine.

Analysis of the options has revealed that it is not feasible to construct the new concourse completely above the existing OHW structures. It will therefore be necessary to alter the OHW.

In developing the proposed design account has been taken of the following:

- The need to stage the OHW modifications to coordinate with the progressive construction of the new concourse.
- The need to minimise the amount of modification required, particularly minimising re-work and also ensuring that only a manageable amount of work is required at each stage.
- Minimising the number of structures on the platforms to reduce impediments to free pedestrian movement and improve aesthetics.

4.2 OHW Modifications

The proposed modifications to the OHW system and possible staging are described in the following sections.

4.2.1 Concept Design for OHW Modifications

The concept design for modifications to the OHW system to accommodate construction of the paid concourse structure is described in the following sections. The proposed works are described by line and platform and summarised in Figure 18.

For Option 1, additional OHW support may be required on the underside of the unpaid bridge, depending on the design of the bridge and OHW profiles. The requirements would be determined at the next stage of design.

Up / Down Main (P1 / P2)

- Provide alternate anchor for crossover wire on No.1 Platform.
- Support the OHW from the signal gantry at ~SW1+337 and Sydney face beam of new concourse. The span to Signal gantry will be approximately 38m and from the new concourse to SW1+233 will be approximately 55m.

Up / Down Suburban (P3 / P4)

- Disconnect Down & Up Suburbans OHW from SW1+304 and attach to the country face of the new concourse. There is some curvature of the track but it seems likely

that the geometry will work. The span from the country face of the new concourse to SW1+340 would be approximately 35m.

- Disconnect Down & Up Suburbans OHW from SW1+267 and attach to the Sydney face of the new concourse. There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 47m.
- If the geometry will not work it will be necessary to provide a new portal over the Down & Up Suburbans between Sydney face of the new concourse and SW1+233 clear of the platform 4 / 5 Sydney side stair. Alternately, on a cost / benefit basis it may be acceptable to provide hand-rails around the leg of SW1+267 and leave it just at the foot of the stair - the stair is quite wide - architects to confirm if this is an acceptable option.

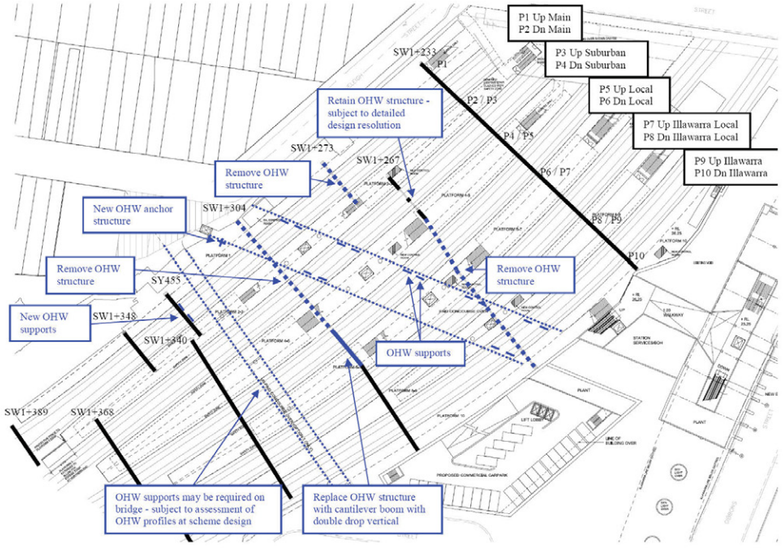


Figure 18 - Proposed OHW modifications

Up / Down Local (P5 / P6)

- Disconnect Down & Up Locals OHW from SW1+267 and attach to the Sydney face of the new concourse. There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 40m.
- Replace the span of SW1+304 over the down & up Locals with a cantilevered boom and double drop vertical nose. Assumes that the foundation and leg on platform 6 / 7 is suitable for the greater loads and that the structure can reasonably be modified. Also assumes that the clearance from the foot of the country side stair on platform 6 / 7 to the existing leg is acceptable.

Up / Down Illawarra Local (P7 / P8)

- Disconnect OHW from SW1+267 and attach to the Sydney face of the new concourse. There is some curvature of the track but it seems likely that the

geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 33m.

Up / Down Illawarra (P9 / P10)

- Disconnect OHW from SW1+267 and attach to the new concourse. The spans would be essentially unchanged.

4.2.2 Possible OHW Staging

The following approaches should be appropriate for coordinating the construction of the concourse with the alterations required to the OHW:

Up Main (P1)

- Installation of concourse
  - Provide alternate anchor for crossover wire on No.1 Platform.
  - Support the OHW from the SY455 signal gantry at ~SW1+337 and detach from SW1+304 - span from SW1+273 will be approximately 60m. Track appears straight so intermediate support or registration will likely not be required.
  - Remove SW1+304 over Down & Up Main

Down Main (P2)

- Installation of concourse
  - Support the OHW from the SY455 signal gantry at ~SW1+337 and detach from SW1+304 - span from SW1+273 will be approximately 60m. The track appears straight so intermediate support or registration will likely not be required.
  - Remove SW1+304 over Down & Up Main

Platform 2 / 3

- Installation of headstock
  - No OHW issues
- Installation of Sydney side stair
  - Detach Down & UP Main OHW from SW1+273 & attach to Sydney face beam of new concourse - Span to Signal gantry will be approximately 38m and from the new concourse to SW1+233 will be approximately 55m.
  - Remove SW1+273
- Installation of country side stair
  - Disconnect Down & Up Suburbans OHW from SW1+304 and attach to the country face of the new concourse (must follow the installation of the concourse over the Down & Up Suburbans). There is some curvature of the track but it seems likely that the geometry will work. The span from the country face of the new concourse to SW1+340 would be approximately 35m.
  - Remove SW1+304 over Down & Up Main, Down & Up Suburbans, and the leg of SW1+304 on Platform 2 / 3.

Up Suburban (P3)

- Installation of concourse
  - Lower OHW between SW1+267 and SW1+304. If necessary, attach to the Sydney face of the new concourse.

Down Suburban (P4)

- Installation of concourse
  - Lower OHW between SW1+267 and SW1+304. If necessary, attach to the Sydney face of the new concourse.

Platforms 4 / 5

- Installation of headstock
  - No OHW issues
- Installation of Sydney side stair
  - Disconnect Down & Up Suburbans OHW from SW1+267 and attach to the Sydney face of the new concourse (must follow the installation of the concourse over the Down & Up Suburbans). There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 47m. If the geometry will not work it will be necessary to provide a new portal over the Down & Up Suburbans between Sydney face of the new concourse and SW1+233 clear of the platform 4 / 5 Sydney side stair. Alternately, on a cost / benefit basis it may be acceptable to provide hand-rails around the leg of SW1+267 and leave it just at the foot of the stair - the stair is quite wide - architects to confirm if this is an acceptable option.
  - Disconnect Down & Up Locals OHW from SW1+267 and attach to the Sydney face of the new concourse (must follow the installation of the concourse over the Down & Up Locals). There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 40m.
  - If the leg of SW1+267 must be removed, remove SW1+267 over the Down & Up Suburbans, and Down & Up Locals, and the leg of SW1+267 on Platform 4 / 5.
- Installation of country side stair
  - Disconnect Down & Up Suburbans OHW from SW1+304 and attach to the country face of the new concourse (must follow the installation of the concourse over the Down & Up Suburbans). There is some curvature of the track but it seems likely that the geometry will work. The span from the country face of the new concourse to SW1+340 would be approximately 35m.
  - Replace the span of SW1+304 over the down & up Locals with a cantilevered boom and double drop vertical nose. Assumes that the foundation and leg on platform 6 / 7 is suitable for the greater loads and that the structure can reasonably be modified. Also assumes that the clearance from the foot of the country side stair on platform 6 / 7 to the existing leg is acceptable.
  - Remove the leg of SW1+304 on Platform 4 / 5.

Up Local (P5)

- Installation of concourse
  - Lower OHW between SW1+267 and SW1+304

Down Local (P6)

- Installation of concourse

- Lower OHW between SW1+267 and SW1+304

Platforms 6 / 7

- Installation of headstock
  - No OHW issues
- Installation of Sydney side stair
  - Disconnect Down & Up Locals OHW from SW1+267 and attach to the Sydney face of the new concourse (must follow the installation of the concourse over the Down & Up Locals). There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 40m.
  - Disconnect Down & Up Illawarra Locals OHW from SW1+267 and attach to the Sydney face of the new concourse (must follow the installation of the concourse over the Down & Up Illawarra Locals). There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 33m.
  - Remove SW1+267 over Down & Up Local, Down & Up Illawarra Local, and the leg of SW1+267 on Platform 6 / 7.
- Installation of country side stair
  - No OHW issues provided that the clearance from the foot of stair to the existing leg of SW1+304 is acceptable.

Up Illawarra Local (P7)

- Installation of concourse
  - Disconnect OHW from SW1+267 and attach to the Sydney face of the new concourse. There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 33m.
  - Remove SW1+267 over the Down & Up Illawarra Locals.

Down Illawarra Local (P8)

- Installation of concourse
  - Disconnect OHW from SW1+267 and attach to the Sydney face of the new concourse. There is some curvature of the track but it seems likely that the geometry will work. The span from the Sydney face of the new concourse to SW1+233 would be approximately 33m.
  - Remove SW1+267 over the Down & Up Illawarra Locals.

Platforms 8 / 9

- Installation of headstock
  - Construct headstock around the leg of SW1+267. If necessary remove knee braces and stabilise leg from headstock. Provide plywood shuttering to live equipment.
- Installation of Sydney side stair
  - No OHW issues

Up Illawarra (P9)

- Installation of concourse

- Disconnect OHW from SW1+267 and attach to the new concourse. The spans would be essentially unchanged.
- Remove SW1+267 over the Down & Up Illawarra lines.

Down Illawarra (P10)

- Installation of concourse
  - Disconnect OHW from SW1+267 and attach to the new concourse. The spans would be essentially unchanged.
  - Remove SW1+267 over the Down & Up Illawarra lines.

Profiles should be produced to check the vertical clearances before any staging arrangement is finalised. There is significant system depth (distance between catenary and contact wires) in the existing arrangement and this will likely need to be reduced in the vicinity of the new concourse. It will also likely be necessary to reduce the contact wire height in the vicinity of the new concourse.

4.2.3 Summary of Issues and Risks

The OHW systems issues and risks for are as follows:

1. The supports of the OHW from the new concourse must be insulated from the concrete with secondary insulation. The design of the secondary insulation system requires care and attention to detail to ensure the long term integrity of the insulation.
2. A full OHW design will be required to assess vertical clearances and pantograph security / stagger.
3. OHW field resources are scarce and it will be essential to ensure that a stage is not attempted with inadequate resources on site if time overruns are to be avoided.
4. Careful survey and measurement will be essential to ensure that as much pre-assembly as possible can be done successfully.

4.3 Signalling

4.3.1 Design Criteria, Data and Assumptions

Signal SY455 is fitted to a gantry structure over the Down and Up Main lines on the "country" side of the proposed new concourse.

SY455 is provided to allow trains to leave Sydney Yard travelling 'wrong-road' along the Up Main. i.e. Southbound through platform 1. RailCorp have indicated that this signal is critical to the operation of Sydney Yard and as such must remain in service throughout the works at the station.

The signal itself does not conflict with the proposed concourse. However, it is likely that the new concourse will unacceptably reduce the sighting distance.

If the separate un-paid link option is adopted this would likely represent an even greater impediment to sighting of this signal.

4.3.2 Proposed Design Solution

The preferred design solution is to leave the signal at its present location and lower the signal head to restore the sighting distance. To this end a detailed survey should be made to establish the relative positions of the kinematic envelopes for the Down and Up main lines to the signal gantry and the underside of the proposed concourse.

Gatsometer BV of the Netherlands is one company known to manufacture systems allowing signal heads to be raised or lowered. Raising the signal to gantry level for maintenance rather than accessing from within a cage (as currently) should allow a narrower assembly that could be positioned lower (closer to the kinematic envelopes) to achieve better sighting under the concourse. Such an arrangement would also eliminate the longstanding personnel safety issues with accessing the signal via the cage. The photos in Figures 19 and 20 show systems manufactured by Gatsometer BV.

Figure 19 - Height adjustable signs by Gatsometer

Figure 20 - Close up of Gatsometer BV height adjustment system

Provided that the signal head was well constrained on a track, the lateral electrical clearance required to the OHW and pantograph would be quite modest (~200mm). Provided that the new arrangement mounted a standard signalling head the type approval

issues may not be too onerous. Once the minimum practical height for the signal head between the Down and Up Main lines has been determined a long section should be developed to determine the likely sighting distance.

Should the first option not prove feasible then moving the signal to the Sydney side of the proposed concourse will be necessary. Given the constraints of the heritage building on platform 1 and the new stair on platforms 2 / 3, it seems likely that the signal would have to be supported from the Sydney face of the new concourse, potentially with maintenance access from the concourse. It may be possible to reduce construction time by having the signal pre-mounted on the edge plank before the plank is lifted into position. However, maintenance access to the signal would be required throughout the period while the concourse is under construction.

4.3.3 Summary of Issues and Risks

The signalling systems issues and risks for are as follows:

1. Unavailability of signalling resources, which are known to be heavily in demand..
2. Type approval will be required for any slide-down signal arrangement. This may not be straightforward. However, RailCorp are likely to have other uses for such a configuration and may welcome a catalyst to trigger its adoption.
3. If the two level combined paid concourse and un-paid link makes the first option practical, then the cost and resource issues associated with relocating the signal may be the deciding factor in relation to the configuration of the un-paid link.

Appendices

A1 Vertical Clearance to the Soffit of the Concourse

This is a clarification summary of the RailCorp Standards and requirements in regards to determining the minimum vertical clearances to the soffit of the concourse structure for the Concept Design of Redfern Station.

The requirements for minimum vertical clearances to structures, above an electrified rail track, are stated in the following Standards and documents, as follows:

1. Redfern Station Redevelopment Project, User Requirements Version 1.2, March 2007
2. RailCorp Standard ESC 320 Overbridges and Footbridges, July 2007
3. RailCorp Standard ESC 215 Transit Space, December 2008
4. RailCorp Standard EP 08000001SP Overhead Wiring Standards for the Electrification of New Routes, July 2008
5. RailCorp, Station Design Guide, July 2006

User Requirements Version 1.2
With reference to Clause 3.3.9 the requirements are noted as follows:

3.3.9 1500v Overhead Wiring system

3.3.9.1 Concept designs proposals shall consider the impact of a new concourse structure on the existing 1500V Overhead Wiring (OHW) system. It is likely that the catenary height for the OHW on all tracks will need to be re-designed and re-profiled.

Consultation with RailCorp's Engineering (Electrical Systems) and the Region have indicated that the minimum clearance from the top of mean rail level to the soffit of the overbridge (or services) is to be:

- *OHW unattached to overbridge (preferred) 5500mm*
- *OHW attached to the overbridge 5300mm*

Note that the above clearances are provided as working figures and will require the approval of a waiver of the requirements detailed in RailCorp's Civil Standard ESC215 Section 6;

3.3.9.2 Reprofiling and or reconstruction of the OHW system shall as a minimum comply with the relevant RailCorp and Australian Standards, however the design shall also consider maintenance issues, such as minimising the number of contact and catenary splices.

In summary the User Requirements states that the minimum vertical clearance to the soffit of the new concourse structure is **5500 mm** for OHW unattached, and **5300 mm** for OHW attached.

ESC 320 Overbridges and Footbridges
Clause 4.5 of this Standard states:

…… 'vertical clearances for new overbridges and footbridges ….are to comply with ESC 215 Transit Space'.

ESC 215 Transit Space

Clause 7.2 states:

'For all track in electrified areas the minimum vertical dimension between the underside face of non-energised equipment and the design maximum height of the low rail shall be;

5 900mm - Wiring Attached

6 500mm - Wiring Not Attached'

Clause 8.1.1.1 states:

Electrified areas:

In electrified areas the vertical distance from the rail to an item of infrastructure is governed by the height of the contact wire. The contact wire and associated energised electrical equipment are an approved physical interface.

The minimum vertical height (Dimension 'B') of non-energised equipment and other infrastructure above the design height of the low rail shall be 200mm above the highest contact wire position.

The design of overhead wiring shall be in accordance with the requirements of RailCorp Electrical Engineering Standard EP 08 00 00 01 SP.

The minimum value for the vertical dimension from the lowest contact wire position to the maximum height of the low rail shall be as detailed as follows;

5 400mm Public Level Crossings

*5 000*mm Other Areas (Including Private Level Crossings)

In summary, ESC215 states that a clearance of **6500 mm** is required for all structures where wiring is unattached, but allows reduction of this clearance by considering the kinematic structure gauge, contact wire heights and the EP 08000001SP Overhead Wiring Standard.

EP 08000001SP Overhead Wiring Standards for the Electrification of New Routes

Clause 6.4 states:

'Minimum Clearance to Underside of OLB – OHW Attached : 5.50m from mean rail level

Minimum Clearance to Underside of OLB – OHW Not Attached: 5.65m from mean rail level.'

Summary

Allowing for a standard contact wire height of 4.75 m (which currently exists at Redfern station), a dropper height of 300 mm, cantenary sag of 150 mm for wiring attached to the structure, 300 mm clearance to the soffit, then the minimum vertical clearance is calculated to be 5.5 m. This is consistent with the requirements of the EP Standard. It also exceeds the required minimum vertical clearance noted in the RailCorp User Requirements

In summary, a minimum vertical clearance of 5.5 m can be considered above the low track level up to the soffit of the concourse structure. This assumes that OHW is attached to the soffit of the structure. Careful detailing of the OHW fixing details will be required. In addition, a Transit Space Waiver may be required for RailCorp approval but this is considered to be a formality, since it complies with the OHW Wiring Standards and RailCorp User Requirements for Redfern Station.

A2 Assessment of Electrical Supply Demand

A high level review was undertaken of the impact of the refurbishment works at Redfern Station on the existing electrical supply. The review was carried out by an Arup Electrical Engineer based on the following:

1. The information contained in the Connell Wagner report "Redfern Station Upgrade – Preliminary Services Recommendations – Rev. 3" dated 15/03/07
2. The refurbishment will consist of 6 new Machine-Room-Less Lifts (MRL) and approximately 3000m² additional concourse area
3. The possible inclusion of escalators providing access from the Concourse to the platforms – equates to 12 new escalators.

Existing Loads

From Connell Wagner's report, the station is supplied by 2 off 500kVA transformers, one loaded at 46% of design capacity and the other 84% of design capacity. The design capacity for the transformers is that the maximum load per transformer is to be 50% of the transformer rating, such that if one transformer fails, the entire station load can be supplied from the remaining transformer. The following table summarises the existing demand:

Transformer	Rating	Design Capacity	Existing Transformer Demand (@ March '07)		Spare Capacity
	kVA	kVA	% Design Cap.	kVA	kVA
1	500	250	46%	115	135
2	500	250	84%	210	40

Additional Lift and Light Load

To determine the additional demand due to the lift installation, the demand of each lift was based on demands for similar size of lifts as advised on recent projects. From this information, the demand of each lift is approximately 30Amps. Maximum demand was calculated based on Table C2 of AS/NZS3000 – 2007.

- The additional maximum demand due to the lifts was calculated as 86kVA.
- For additional Concourse lighting load, a basis of 10VA/m² has been used.
- The additional maximum demand due to the new Concourse lighting was calculated as 30kVA.

Additional Escalator Load

To determine the additional demand due to the escalators, the demand of each escalator was based on demands for similar size escalators as advised on recent projects. From this information, the demand of each escalator is approximately 36Amps (10 total), with the 2 escalators serving the Illawarra platforms having a demand of approximately 50Amps (2 total). Maximum demand was calculated based on Table C2 of AS/NZS3000 – 2007.

- The additional maximum demand due to the additional escalators was calculated as 201kVA.

Revised Loads & Impacts

Based on the information outlined above, the loading on the existing transformers with lifts and lighting changes only is summarised as per the following table.

Without Escalators – Lifts and Lighting Only

Transformer	Existing Load	Spare Design Capacity (existing)	Additional Load	New Transformer Load	Spare Capacity
	kVA	kVA	kVA	kVA	kVA

1	115	135	116	231	19
2	210	40	0	210	40

Based on the information in Connell Wagner's report and the details as stated above, the existing transformers would have sufficient capacity for the additional load based on our assessment of the additional lift and lighting demand. Should there have been any upgrades or changes in the 2 years since Connell's report, this has not been captured in this analysis. Clarification on any additional loads on the transformers at the station over the last 2 years should be obtained.

Should escalators be installed to Platforms 1 to 10, the existing capacity of the transformers will be exceeded, requiring an upgrade as per Connell Wagner's report. The preferred option in this report was for the upgrade of the existing 500kVA transformers with 750kVA transformers, which from preliminary review would appear the most satisfactory option.

A3 Revised Concept Design – Engineering Drawings

Refer to the following structural concept drawings, produced for the purpose of estimating the construction cost and assessing constructability:

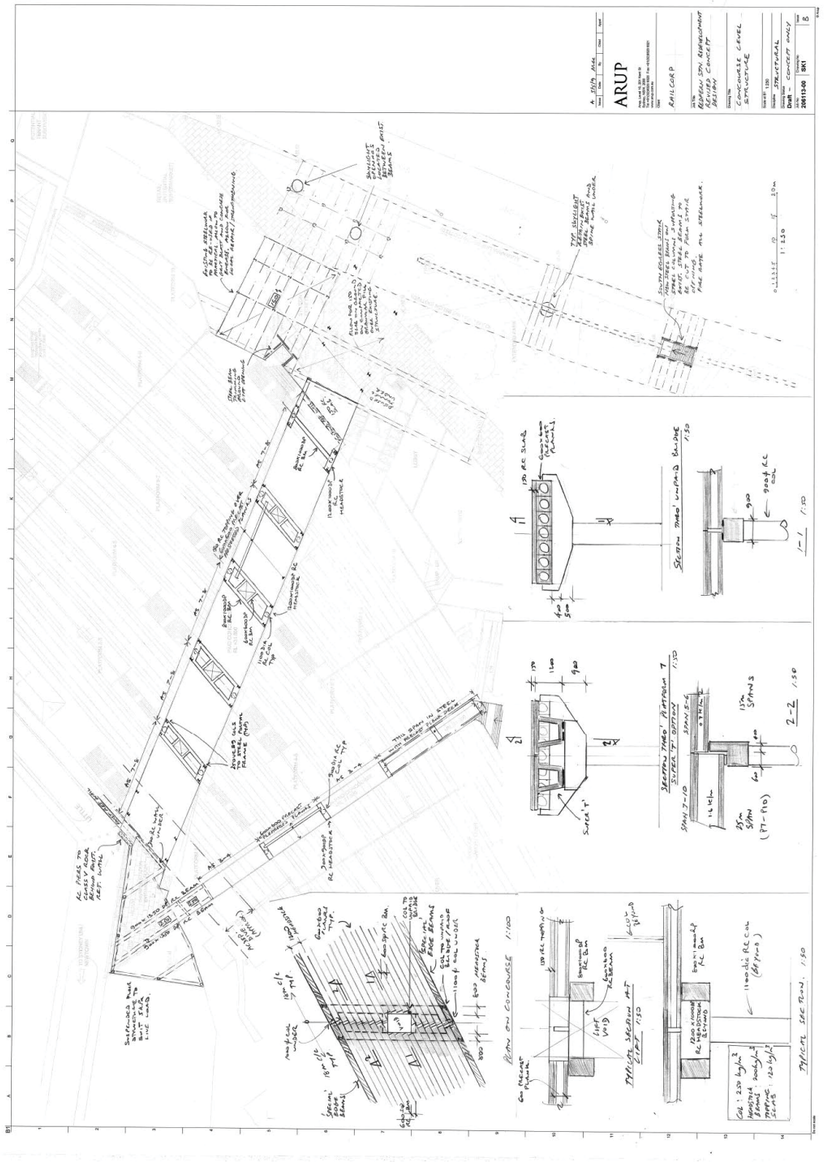
Drawing SK1B Concourse Level Structure

Drawing SK2A Platform / Intermediate Concourse Level Structure

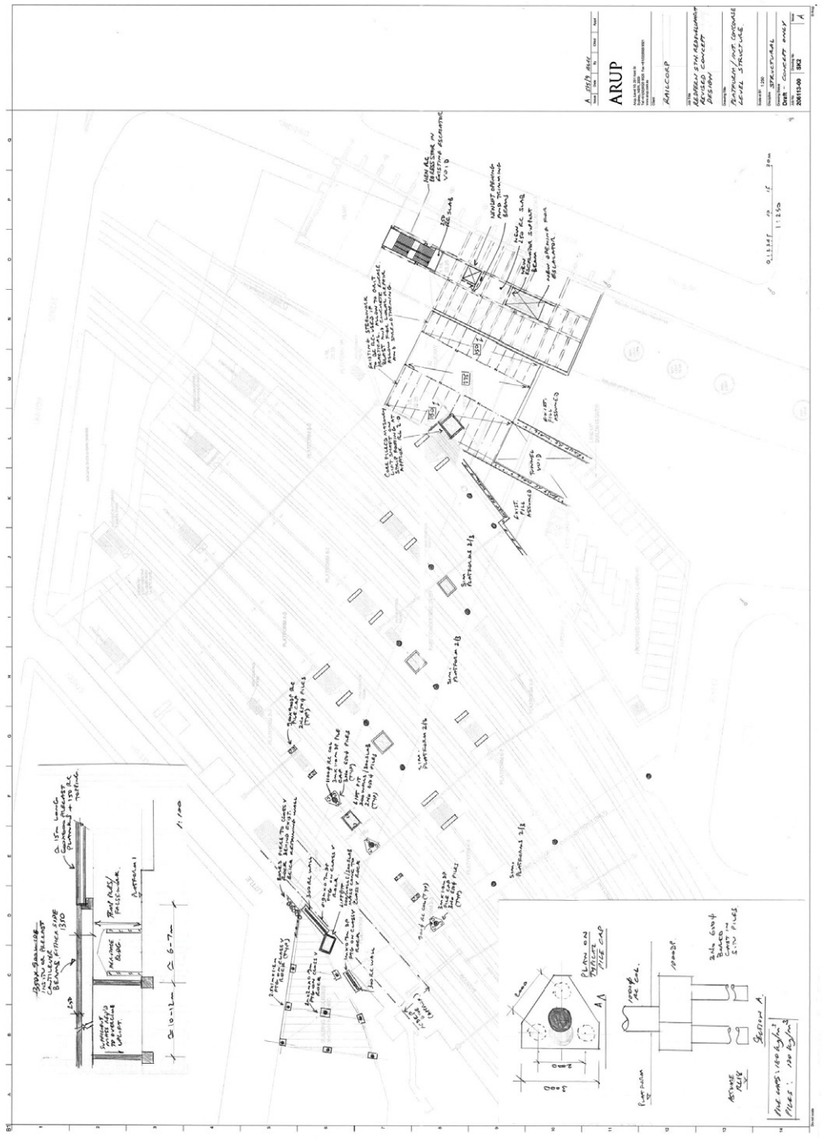
Drawing SK3B Illawarra platform Level structure

Drawing SK4A Concourse Roof Structure

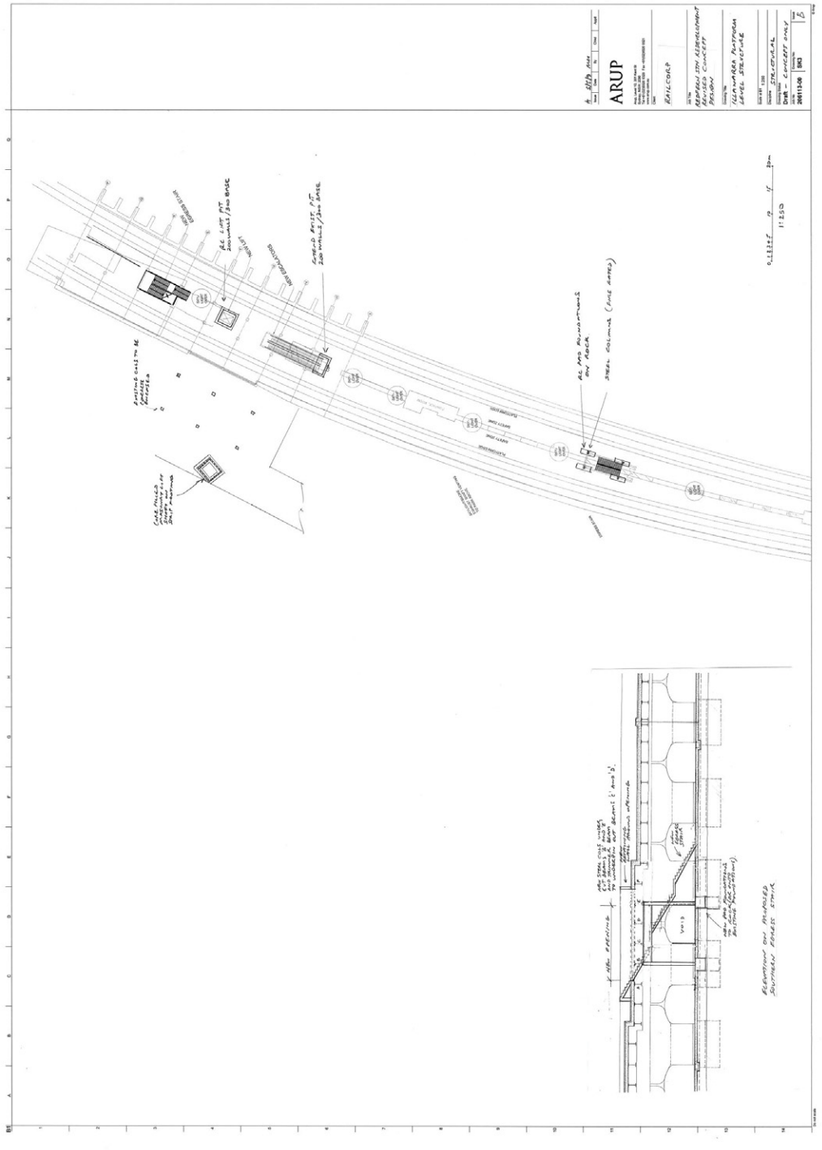
Drawing SK1B Concourse Level Structure



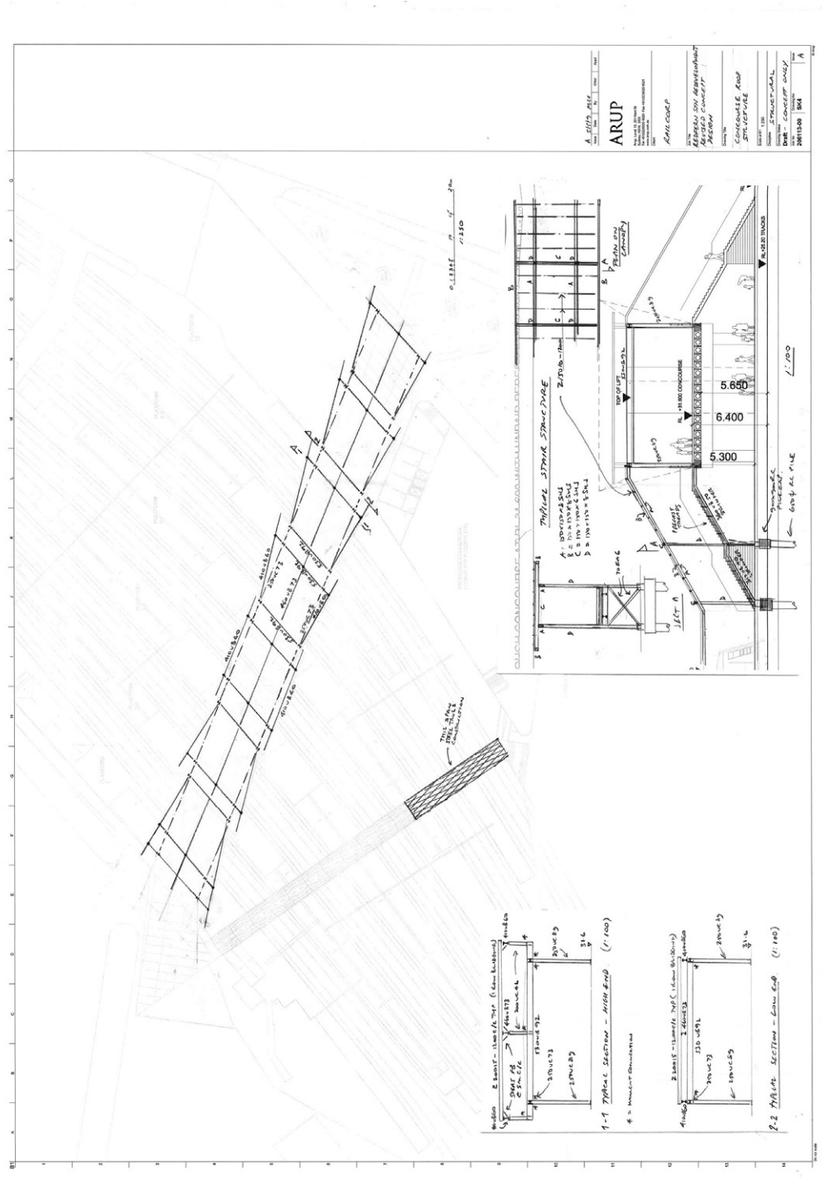
Drawing SK2A Platform / Intermediate Concourse Level Structure



Drawing SK3B Illawarra Platform Level Structure



Drawing SK4A Concourse Roof Structure



A4 Photographs

The following photographs were taken during an inspection of the disused tunnels and void on 18 March 2009.

1. Lawson St Overbridge - Sydney Face showing portal of Down Southern Suburbs Railway dive adjacent to the Down Illawarra Line. Note that the cable troughs on the wall are marked High Voltage and probably contain RailCorp 11kV feeders 539 and 620/2

2. Down side of rail corridor looking towards Central from the Sydney side of Lawson St Overline bridge

3. Within the void looking at the western wall of the mezzanine level above platforms 11&12

4. Within the void looking away from Sydney from the "country" portal of the Down Southern Suburbs Dive.

5. Within the void looking away from Sydney from the "country" portal of the Down Southern Suburbs Dive.

6. From the car-park looking towards Sydney. The entrance building for platforms 11 & 12 is on the right. The country portal of the Down Southern Suburbs Dive can be seen in the middle and the stairs from the concourse to platform 10 can be seen top left.

7. Space between the country portal of the Down Southern Suburbs Dive (left) and the entrance building for platforms 11 & 12 (right)

8. "Country" Portal of Down Southern Suburbs Dive

9. Sheet steel wall between void and platform 11

10. "Country" Portal of Up Southern Suburbs Dive (foreground). Country portal of the Down Southern Suburbs Dive is distant to the right and at the upper level.

11. Up Southern Suburbs "tunnel" looking from the void away from Sydney. Note that a considerable quantity of spoil from track reconditioning has been placed in the tunnel.

12. Portable building positioned on steel beams in the void at mezzanine level.

13. Steel beams within the void.

14. Exposed shale at base of excavation adjacent to Platform 11.

15. Steel beams within the void looking from the Southern Suburbs "tunnel" towards Sydney.

16. Looking from the Southern Suburbs "tunnel" towards Sydney. the country portal of the Up Southern Suburbs Dive is visible immediately below the steel beams.

17. Up Southern Suburbs "tunnel" looking away from Sydney. The spoil is stacked quite high in the far section of the tunnel.

18. Looking from the window of the former signals depot on the mezzanine level over the void towards Sydney. The Down southern Suburbs Dive is visible in the distance left of the portable building.

19. From the car park looking towards Sydney at the top of the brick and concrete wall between platform 10 and the void. The roof of the heritage building on platform is visible to the left.

20. From the car park looking towards Sydney at the entrance building for platforms 11&12.

21. From the car park looking towards Sydney across the void. the concourse is visible over the brick and concrete retaining wall. The "country" portal of the Down Southern Suburbs Dive is also visible.

22. From the car park looking over the steel beams above the void. The "country" Portal of Up Southern Suburbs Dive is visible below the beams.

23. From the car park looking towards the start of the Up Southern Suburbs tunnel.

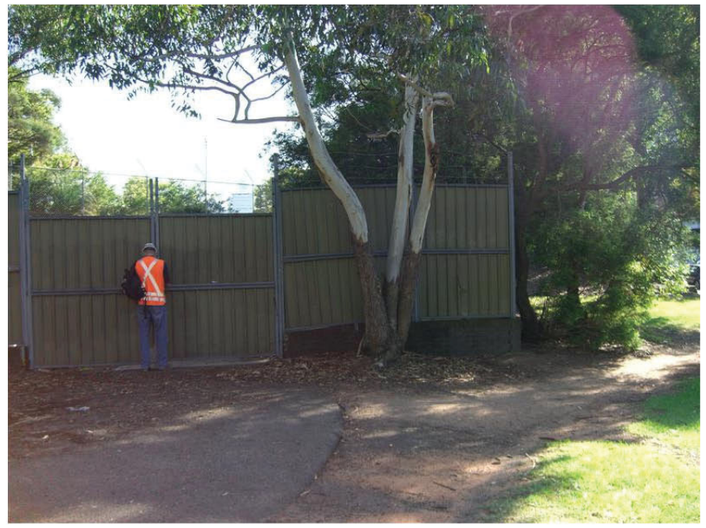
24. From the car park looking across to void towards platform 10.

25. Looking towards Sydney from the driveway leading from the park to the former signals depot (inside the fence).

26. Looking towards Sydney from the driveway leading from the park to the former signals depot (inside the fence). Roller door is at Mezzanine level.

27. Looking towards Sydney from the driveway leading from the park to the former signals depot (inside the fence).

28. Looking towards Sydney from the park. The sheet piling at the end of the Up Southern Suburbs Tunnel is ~ 6m beyond the chain wire fence.



29. Looking towards Sydney from the park. The ramp down to the former signals depot is beyond the fence.

30. Car park looking away from Sydney.