Connell Wagner Pty Ltd
ABN 54 005 139 873
116 Military Road
Neutral Bay
New South Wales 2089 Australia

Telephone: +61 2 9465 5599
Facsimile: +61 2 9465 5598
Email: cwsyd@conwag.com
www.conwag.com

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1. Introduction

1.1 Background

The Australian Rail Track Corporation (ARTC) is planning to improve rail freight services in NSW, by constructing a new single rail line from east of Sefton station to south of Macarthur station along the existing rail corridor. Freight trains currently share rail lines with the passenger trains for this section.

Location of the proposed works is shown below in Figure 1.

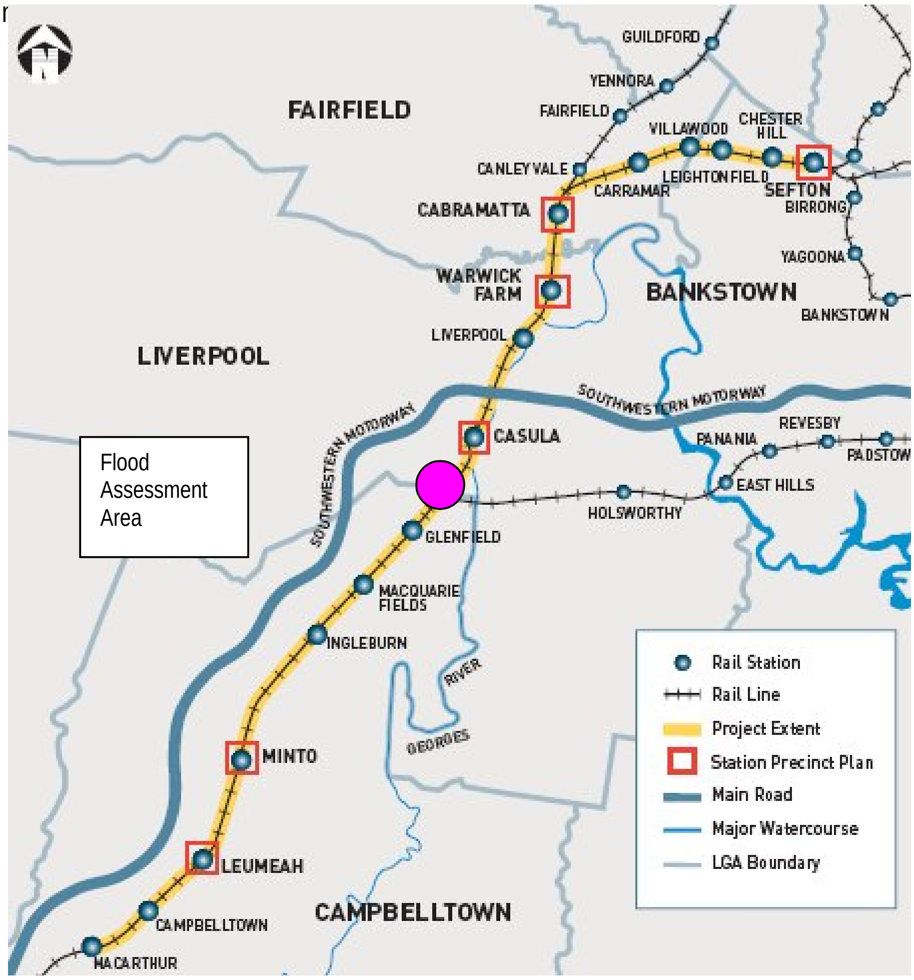

Figure 1 - Location Plan

1.2 Conditions of Approval

The purpose of the Flood Management study is to "achieve the objective in design of not worsening existing flooding that is outside the corridor or which affects rail track, either upstream or downstream, of the sections of the project past which stormwater flows". The Minister's Conditions of Approval are as follows:

62. The Proponent must undertake a Flood Management Study in consultation with Relevant Government Departments, Councils and the CLG(s), and CoA 63 prior to construction. The Project will be designed to not worsen existing flooding characteristics upstream or downstream of the Project's elements. Not worsen is defined as:

> *(a) a maximum increase in inundation levels upstream of the Project of 50 mm in a 1 in 100 year ARI rainfall event; and*
>
> *(b) a maximum increase in inundation time of one hour in a 1 in 100 year ARI rainfall event.*

63. The Flood Management Study must:

> *(a) investigate lower return period (more frequent) events, including quantifying inundation levels and times likely to result from the project during a 1 in 5, 10, 20 and 100 year flood event;*
>
> *(b) identify design and compensatory measures that would be implemented as part of the Project to not worsen existing flooding characteristics including:*
>
> > *i an assessment of the hydraulic capacity of existing drainage structures, identifying where provision for upgrade would be made on the SSFL side of the corridor;*
> >
> > *ii temporary structures required to maintain water flow across the rail line during Construction;*
> >
> > *iii measures in relation to local flooding and ponding impacts (including the location and design of noise barriers, embankments etc); and*
>
> *(c) consider the requirements, principles and objectives of the Greater Metropolitan Environmental Management Plan No. 2 – Georges River Catchment (REP 2) and the Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, 2005).*

The SSFL has a potential to effect the watercourses that it crosses, as well as the watercourses that it runs along and nearby and in some cases re-direction of watercourses that run along the corridor is required to accommodate construction. The design of the railway has been carried out to ensure that the construction of the SSFL will not increase the risk of flooding, and the design and construction features that achieve this are described in this report.

1.3 Other relevant Documentation

1.3.1 Greater Metropolitan Regional Environmental Plan No. 2 – Georges River Catchment

This plan details the wider regional objectives and planning principles for the Georges River catchment with no specific mention of tributaries or flood related criteria.

These objectives and planning principles pertain to:
- river flows
- flood regime

- construction of flood control works, and
- piping or channelisation of the river or tributaries associated with developments.

The REP applies to the Georges River Catchment, which is part of the region declared under the Act and known as the Greater Metropolitan Region. The Catchment consists of parts of Bankstown City, Blacktown City, Campbelltown City, Camden, Canterbury City, Fairfield City, Holroyd City, Hurstville City, Kogarah, Liverpool City, Rockdale City, Sutherland, Wollondilly and Wollongong City local government areas that are within the Georges River Catchment.

Clause 7 of the Greater Metropolitan Regional Environmental Plan (REP) requires a consent authority to apply the planning principles of this REP when it determines a development application. The specific planning principles that apply to the development of the SSFL are:

1. Disturbance of the bank or foreshore along the Georges River and its tributaries is to be avoided and those areas and any adjoining open space or vegetated buffer area must be protected from degradation.
2. The following are to be recognised:
   a) the benefits of periodic flooding to wetland and other riverine ecosystems,
   b) the pollution hazard posed by development on flood liable land in the event of a flood,
   c) the cumulative environmental effect of development on the behaviour of flood water and the importance of not filling flood prone land.
3. The environment within the Catchment is to be protected by ensuring that new or expanding urban development areas are developed in accordance with the Urban Development Program and the Metropolitan Strategy and that the requirements of the *NSW Floodplain Development Policy and Manual* (prepared by and available from the Department of Land and Water Conservation) are also satisfied. It is important to ensure that the level of nutrients entering the waterways and creeks is not increased by the development.

These considerations were included in the Ministers Consent Approval for the project under part 3A of the EP&A Act.

With respect to the SSFL the following comments address the GMREP No. 2 objectives and principles:

- No flow path will be completely blocked by the project and therefore river flows will be maintained. The additional hardstand areas may have an impact on groundwater recharge which can influence river flows but this is likely to be insignificant as new hardstand will be minor in scope and mostly near Minto and Leumeah stations.
- The flooding regime for the tributaries is not likely to change significantly with the proposed extension of culverts and bridges and there will be no impact on mainstream flooding of the Georges River.
- Proposed flood control works associated with the project have been designed to ensure that the local flood behaviour is not adversely affected. This includes changes to peak flood level and flood velocities. There is unlikely to be any change in the timing of the design flood events because no works are proposed outside of the rail corridor and no floodplain storages are proposed.
- The proposed works include the extension of culverts and bridges which involves further channelisation of the watercourses that intersect the SSFL. These works will be aligned to existing crossings to minimise the impact and energy dissipaters will be landscaped into the crossings as required preventing changes to the geomorphology of the watercourses.

1.3.2 Georges River Floodplain Risk Management Study & Plan, Bewsher Consulting Pty Ltd, 2004

The Georges River Floodplain Risk Management Study and Plan (FRMSP) is the third and fourth steps in the NSW Government floodplain management process. The FRMSP document summarises the flooding situation for the Georges River and its main tributaries and proposes measures to manage flooding and flood liability within the Georges River catchment.

The SSFL intersects Bunbury Curran Creek, a tributary of the Georges River catchment. Bunbury Curran Creek is located in the upper catchment area and is not directly affected by flooding from the Georges River according to the FRMSP.

The recommended management measures relate to land use planning which involves graded planning controls for different levels of flood risk. While the SSFL is not directly impacted by flooding from the Georges River, the recommended floodplain risk management measures should still be considered. With respect to the SSFL, this would mean that the project should manage flooding such that it does not change the flood risk of land outside the SSFL corridor. In terms of flood risk, this means no change to the area of inundation, the timing of inundation and the flood hazard for land outside the SSFL or critical infrastructure or property adjacent to the SSFL.

The design of the SSFL has taken these requirements into account and review of the engineering details has indicated that these objectives have been satisfactorily achieved in the design.

1.3.3 Other relevant Documentation

*Why do Fish Need to Cross the Road? – Fish Passage Requirements for Crossing Waterways (*DPI)
The guideline aims to minimise impacts on fish passage and general aquatic wildlife. The extension of drainage structures may have an impact on the crossing of aquatic wildlife. The design of all Culverts and Culvert extension has taken into account the design Guidelines to allow the passage of fish when water levels are high enough.

2. Consultation with Stakeholders

ARTC have consulted on flood issues with the local Councils whose jurisdiction the SSFL passes through. ARTC particularly values the contribution of flood data to this Study that has been made by local councils from their detailed modelling of stormwater flow in their area.

ARTC have also consulted with RailCorp over the details of the track drainage and flood management works. RailCorp have reviewed the detailed drawings and discussed the design with the designers. There are no outstanding comments from RailCorp on flood management that have not been resolved.

ARTC are also in the process of consulting with a number of other stakeholders in the NSW State Government over the development of the Flood Management Study for the South Sydney Freight Line. At the time of issuing of the report no comments had been received from NSW State Government Departments other then the DoP. Comments from the following NSW Departments would be welcomed, and will be incorporated into this report, if received: DPI, DWE and DECC. The DoP's comments have already been incorporated into this report.

3. The Scope and Methodology of the Study

3.1 Study scope

The scope of the study covers the length of the SSFL from Sefton to McArthur.

The local drainage within the rail corridor was assessed using standard methods for small catchments, and the design of the drainage within the corridor has followed the RailCorp standards for track and local drainage.

The construction of the SSFL across the existing cross corridor drainage has been considered as both a general and a particular issue. The general approach has been to allow for the extension of the full flow area of the existing cross corridor drainage. The second part of the procedure is then to consider each cross corridor drainage for particular issues that may be raised by the construction of the SSFL. The issues that have been identified have been discussed in this report.

There are three locations where district drainage runs either diagonally across the corridor or runs along the length of part of the corridor, and where this occurs the drainage has to be relocated to accommodate the SSFL track. These locations are at Sefton Dive, Glenfield Flyover and Narrellan Road. At each of these locations the effect of the proposed works on the district drainage has been modelled in a detailed study. The scope of this study has included the following elements of hydrological and hydraulic analysis:

- Site assessment
- Hydrological analysis of the catchments relevant to the study area
- DRAINS modeling of channels and culverts
- Water levels for the 2, 5,10,20, 50 and 100 year ARI along the creek deviation
- Assessment of culvert and channel capacity and potential impacts to the surrounding areas and;
- Identification of flood prone areas

Australian Rainfall and Runoff (AR&R) procedures have been used to determine the peak flows in the analysed system.

3.2 Methodology for Detailed Studies

For each detailed study the assessment and analysis has adopted the approach and scope that is scheduled below:

- Site visit and field observations
- Review existing available data
- Assess current catchments from existing recent photo maps, cadastral information and any previous studies that have been carried out either by the local Council or RailCorp
- Calculate catchment areas
- Create a DRAINS model from design information and analyse flows
- Compare 100 year ARI model results with previous studies that have been carried out either by the local Council or RailCorp
- Analyse impacts on existing conditions and identify flood prone areas
- Complete review, provide figures and report

The results of modelling require interpretation, and are also subject to the limitations imposed by the existing data on field parameters. Some of the main issues that could influence the outcomes of this assessment and analysis include:

- The interpretation of the catchments areas
- Inaccuracies with the photogrammetry survey
- Assessment of general terrain rainfall infiltration parameters and runoff coefficients
- Limited available information on existing flood data and studies to calibrate results
- Blockage due to debris at the culverts entry point
- Limitations of the DRAINS modelling program

4. Local Drainage

4.1 Track Drainage with the Formation on an Embankment

Most of the length of the SSFL alignment is on a widening of the existing embankment, with the formation constructed on a 3% cross slope to achieve the continuation of the existing track drainage to the edge of the embankment. The longitudinal grades are generally flat to very flat (almost never more that 1 in 100), and so there will be negligible drainage along the formation. Much of the existing embankment has been constructed to raise the formation above the surrounding flood plain.

Once it has drained off the embankment, run-off will continue to drain as it does at present, with surface levels typically unaffected by the proposed construction. The district drainage runs along existing stream courses, and south of Glenfield these have been straightened, excavated and in places lined with concrete

One embankment that requires particular comment is the alignment through Leightonfield Yard. This is on a low embankment over what used to be a marsh. The natural gradients are very flat, and the area will flood with backwater from the major drains that cross it flowing in a south to north direction. The only track drainage that can therefore be carried out is laterally over the capping layer and into the yard formation. There is nothing to be achieved by adding to the drainage along the length of the yard.

4.2 Track Drainage with the Formation in a Cutting

Over a total length of about 10% of the SSFL route the alignment is in cutting instead of embankment and in these locations where the cutting is being made wider the track drainage will require construction of a new cess drain.

These are the locations where specific track drainage design is required. They are scheduled below:

- Sefton Dive. The cess drainage and pump design for the dive has been separately documented and the recurrence period for the flooding of the dive is being verified by the Hydraulics Group at present
- The alignment through Chester Hill. The existing formation drains west towards lower ground at Leightonfield, and the alignment of the SSFL will drain in the same way. The cess drain has to be constructed outside the 5V/1H slope of the excavated rock face. The cess will have to be made wide enough to walk in as the space between the excavated cutting slope and the track is at a minimum.
- The alignment under Miller St. The existing formation also drains west towards Leightonfield (Miller St is just to the west of Chester Hill). As at Chester Hill, the SSFL has to be lower than the existing tracks, and so the alignment is very flat on the west side of the bridge, with a correspondingly deepening cess drain being required. There is a conveniently sited cross corridor culvert just west of Miller Road
- The alignment under Bareena St. The existing formation drains east towards the southern side of the corridor. As at Chester Hill and Miller St, the SSFL has to be lower than the existing tracks, and so the alignment is very flat on the east side of the bridge. The cess will be graded to drain to a nearby cross corridor culvert just west of Bareena St.

All of these locations are close to Sefton Dive, which is flooded by storms with a recurrence of about 7 years, and so there is no value in spending scarce money on a better level of flood protection for the cess drains in any of these locations. Once a flood of greater recurrence occurs the stormwater will complete an electrical circuit between the rails, and the signals will go red until the stormwater subsides. Then the trains will run again after a short and possibly un-remarkable delay. The design flood recurrence for the SSFL track formation is therefore 10 years as a desirable period and 5 years as an absolute minimum.

It is worth noting that at Sefton Dive and Chester Hill the formation in the cutting is on rock, and so regular inundation of the formation is not expected to be a long term problem. At Miller Road and Bareena St the formation is on stiff to very stiff alluvial clay. Accordingly the flood water level at the design recurrence may be up to 400mm above formation level [i.e. 300 below top of rail] at Sefton Dive and Chester Hill. The flood level at the design recurrence may then be limited to up to 200 above formation level at Miller Road and Bareena St to reduce the frequency with which the formation is flooded at these two locations.

4.3 Drainage during Construction

Cross corridor drainage should not be affected during construction. The only places where structures or embankments are required to be constructed in drainage channels are at Sefton Dive, Glenfield Flyover and Narrellan Road, where the works require construction of a new drainage channel to carry the flow. At all of these locations the new channel will be constructed before any works that obstruct the present channel.

The drainage design for each of these precincts is discussed in further detail in this report.

The maintenance of local drainage inside the rail corridor and the control of sediment transport by storm water during construction are the subject of a separate CEMP plan, and the implementation of this plan is shown on the drainage drawings that are within the Construction Documentation. These drawings detail the sediment traps and the surface and piped drains that the design requires.

4.4 Drainage Details at Built Elements

The built elements of the scheme consist of cuttings, embankments, noise walls, bridge structures and station modifications.

There are only two cuttings of significance, being the cutting at Sefton Dive and the widening of the existing cutting through Chester Hill.

The cutting at Sefton Dive is a pumped excavation: the pumps are located at the deepest section and pump out to the cess on the southern side of the freight line at the junction with the Bankstown Line. This system has been designed as part of the overall drainage at Sefton Junction.

The cutting at Chester Hill will drain away from Chester Hill Station as it does at present, with added pipe and dish drains being constructed to suit the wider cutting. The total flow is not increased however, as the scheme does not widen the cutting at the top of its existing slope, and achieves the clearance for the SSFL by replacing the existing cutting slope with a narrow one that is that steeper.

The only change of surface drainage at existing embankments is that the embankment slope is moved towards the corridor boundary to allow for the width of the formation for the SSFL, any longitudinal cess drains that this fills in are relocated, and any cross corridor drainage conduits extended. The embankments typically drain laterally to the cess drain at the foot of the embankment slope, and then drain along the corridor to the nearest cross corridor drainage course.

Noise barrier walls that are on an embankment are to be constructed over a gabion wall that is filled with large size stone and through which the surface runoff can readily pass. These gabions are required to avoid a gap under the noise barriers through which there would otherwise be acoustic break-out.

The modifications at stations involve only small areas of roof and have rainwater drainage that is either to the SSFL track drainage system or to the existing stormwater drainage at the station. The modifications to kerbside parking in the existing streets at Cabramatta and Sefton will not require changes to the existing street drainage other than the relocation of side entry pits.

There are also extensions to off –street parking at Minto and Leumeah. The extension to the car park at Leumeah drains into the adjacent Bow Bowing canal, as does the existing car park. However this drainage will be through new pipes and will be fed through a filtration and detention system to control water quality. The extension to the car park at Minto will drain into the existing street drainage as an extension to the system for the existing car park.

4.5 District Drainage across the Rail Corridor

Local catchment drains that cross the alignment will all be extended to cross under the SSFL. The new culvert construction will typically extend from the end of the existing one to a new headwall that is 4.25m clear of the centreline of the SSFL where there is no Maintenance Access Track, and 6.2m clear of the centreline of the SSFL where there is a maintenance track

The design flow for this drainage has been reviewed as part of the issue of district drainage that has been discussed with the local council's engineering officers. The smaller culverts are generally only part of the district drainage, with paths of overland flow commonly being the main drainage under the larger flood events. The extension of these culverts will therefore be typically carried out on a matching basis with what is presently provided under the existing rail corridor.

The design issue with the larger stormwater channels varies along the rail corridor.

The significant issues with district drainage in the Bankstown City Council area are with the drainage over the Sefton Dive cutting, and the drainage across the alignment at Leightonfield Freight Yard. Both are discussed in individual detail in this report. Bankstown City Council's area extends to Prospect Creek

The SSFL proceeds down chainage from Prospect Creek, through the area of Fairfield City Council, down to Cabramatta Creek. In this section of the line most of the district drainage is parallel to the railway, with few drainage courses crossing the rail corridor

The section between Cabramatta Creek and Glenfield Road is under the Jurisdiction of Liverpool City Council (LCC). This length is made up of the following sections:

a) Cabramatta Creek to Elizabeth St at Liverpool Hospital. This is a section of flat terrain in which the district drainage is parallel to the railway corridor. The significant district drainage construction is the re-location of a large cess drain on the down side of the corridor between Warwick Farm and Cabramatta Ck. This drain also receives flow from the land adjacent to the railway

b) Elizabeth St to Casula Station. In this section the railway runs along the west bank of the Georges River, and so the alignment is crossed by a number of existing major district drainage channels, and these will include a new large size culvert that LCC is arranging to pipe jack under the rail corridor near the southern boundary of Liverpool Hospital, as well as a number of overland drainage flow paths in streets that are crossed by the railway with an underbridge. There are no known plans to upgrade this drainage system at the railway corridor other than the pipe jack noted above, for which the development is independent of the SSFL.

c) Casula Station to Glenfield Road. In this section the railway runs parallel to Glenfield Creek, and there is no district drainage across the existing railway tracks except two small open channels near Glenfield Road. However, the southern approach embankment to the Glenfield Freight Flyover has several crossings of a tributary channel to the head of Glenfield Creek. This channel is discussed in separate detail.

South of Glenfield the existing railway formation is almost entirely on a low embankment that serves to raise it above the surrounding floodplain of the tributaries to the Georges River. This section of the railway crosses the area for which Campbelltown City Council is responsible. The flow capacity of the district drainage across the rail corridor is limited by the width of the existing channel. In this area, all of these channels are engineered storm drainage features, most of which have a lining of concrete or cobbles. The culverts or bridges on the SSFL always at least match the hydraulic opening of those that exist under the existing railway

In summary, the design of the SSFL has been reviewed and found to have no impact upon district drainage except at three precincts where re-direction of the cross corridor drainage has been proposed:

- Sefton Dive
- Glenfield Flyover
- Narellan Road

The design for each of these precincts has included a separate hydraulic study to ensure that the design does not involve an unacceptable increase in inundation levels or inundation period.

Outside of these precincts, the extension of existing large culverts across the SSFL will not increase the resistance to flow because it replaces a short section of irregular grassed channel with a concrete conduit. The construction of underbridges over existing channels will not have a significant effect upon flow because the existing channel is not made narrow or constricted, and the piers always line up with the piers of the existing bridge.

5. Large Waterway Crossings

The drainage of large catchments across the existing railway line is accommodated with bridge structures. Some of these channels have a concrete lining that has been constructed in more recent time to achieve a standard of drainage that is required for urban development that has occurred after the original construction of the Main South Railway. The lining of an existing drainage channel greatly increases the flow that can be carried with a given flood level, and this approach has been extensively used by Campbelltown City Council on Bow Bowing Canal and its extension into Bunbury Curran Creek. Typically, the existing approach embankments to the bridge structure for the existing rail tracks are in the extent of the floodplain that has already been developed, and so drainage design has to make best use of the existing bridge opening.

Accordingly, the typical approach to the design for large drainage catchments has been to match the flow area to that of the bridge under existing railway line, and leave the issues of any improvement in upstream flood control as a matter of local government engineering.

The construction of bridge structures for the SSFL does not involve any reduction in the flow area of the drainage under the railway and any changes to the form of the drainage channel see an increase in the length of lined channel with a corresponding reduction in the existing length of rough ground over which the flood flow has to pass once it has breached the dry weather channel length. This pattern of work in fact serves to make a small reduction in the resistance to flow across the corridor.

In the consideration of the larger drainage crossings it is noted that over the half of the SSFL that is north of Glenfield, the larger streams that the SSFL crosses are not associated with a major flooding risk, and have generally been left in a natural state. Two of these are significantly larger than the others, and these are Prospect Creek and Cabramatta Creek. Both have been modelled in flood studies carried out for Liverpool City Council. Prospect creek is in Fairfield Council where the railway crosses it and Cabramatta Creek is on the boundary between Liverpool and Fairfield Councils.

Prospect Creek is affected by backwater flooding from the Georges River. The 100 year flood level is reported as RL6.6m AHD. At the SSFL bridge, the top of rail level is RL8.54, so the bridge superstructure is above the 100 year flood level. The Creek bed level is at about RL1.31.

Cabramatta Creek has a creek bed level of RL1.23, with a top of rail level of RL8.48 and a 100 year flood level of approximately RL6.80

The SSFL crosses both streams well upstream of their confluence with the Georges River. The approach embankments for both bridges involve an insignificant decrease in the volume of backwater storage. To illustrate this point it is noted that the railway embankments of Cabramatta Creek are the larger of the two, being about 400m long, with a volume below the 100 year flood level of approximately 8000 cum. The total backwater volume of Cabramatta Creek is over 3,000,000 cum, so that the reduction involved with the construction of the SSFL is less than 0.5%. It should also be noted that both of these crossing involve the widening of the embankment for the SSFL on the down-stream side of the existing crossings and hence will not contribute to any reduction in backwater capacity on the up-stream side of these structures.

South of Glenfield the terrain is flatter and more prone to flooding. The railway runs along the flood plain of Bunbury Curran/Bow Bowing Creek, with crossings of tributaries to this creek, and just south of Glenfield it crosses Bunbury Curran Creek itself. All of this area is under the jurisdiction of Campbelltown City Council, which has been active in a range of major flood control works over many years. Most of the creeks in this system have been heavily improved, with major engineering work straightening the course of the stream, and also with concrete lining added to much of its length. The waterway crossings of the SSFL will have no effect on any of these watercourses. The crossing of Bunbury Curran Creek is on an existing bridge on a section of the freight line that was constructed some years ago. The tributary watercourses are minor and are all accommodated with appropriately sized culverts as noted above.

6. The Culvert Overpass at Sefton Dive

The drainage from the area around the Birrong Girls High School runs along an open drain next to the cess on the south arm of the Sefton triangle.

The area around Sefton Junction drains from Potts Hill on the south side of the junction towards the north.

Under low recurrence period rainfall patterns the drainage of the area presently runs along a channel that is within the rail corridor next to the Bankstown line , crosses under the existing freight line and then flows north and west in a pipe culvert that goes under the adjacent streets.

Under major floods the main part of the drainage of this area is understood to presently be by overland flow westwards down the railway corridor, which is in a cutting below the adjacent existing ground , which is covered by suburban development of houses and small factories and warehouses. This means that rail services have to be halted under unusual flood conditions, and it is likely that there are other parts of the Bankstown line that are also affected by similar heritage drainage issues.

The overland flow path then joins the path of the existing municipal drainage scheme where it passes under the railway just north of Sefton Junction, and from which it flows in open drains to Duck River, which empties into the Parramatta River.

The proposed SSFL will not change any of these flow paths.

An existing 3m wide x 1.4m high culvert located near Dana Parade Birrong is to be extended as part of the works for the Sefton Dive Structure along the proposed South Sydney Freight Line. The culvert conveys water from a channel in the upstream part of the catchments, under the railway line to two 900mm diameter culverts at the downstream end under a unit development at 57Auburn Road.
As part of the rail upgrades the proposed freight line will be constructed within a dive structure beside the existing rail in this area. In order to accommodate the required track geometry the channel invert level will have to be raised by about 1m where it crosses over the SSFL. Analysis has shown that when this is done the channel flow crossing of the freight rail corridor will have inlet control. Basically, the channel bridge over the SSFL will function as a broad crested weir.

The design of the culvert bridge over on the south fork of the junction has limited the rise in channel invert level to ensure that the SSFL does not lead to more frequent flooding of the Bankstown line.

As the Bankstown Line is in a shallow cutting, there is no increased risk of flooding outside the rail corridor. The upstream pond cannot reach private property because well before that level is reached the water will flow north along the alignment of the Bankstown line.

6.1 Background

Drainage studies by Bankstown Council have indicated that flooding already occurs within the railway corridor both upstream and downstream of the culvert.

A HEC-RAS model was created to determine whether the culvert upgrade would have an impact on existing flood levels within the area during the 5yr, 10yr, 20yr and 100yr ARI events.

The existing culvert is 3m wide x 1.4m high x 8m long. The culvert has an inlet invert of 31.71m AHD and an outlet invert of 31.68m AHD. Due to the dive structures proposed location the culvert will be extended over the top of the dive structure. The culvert will maintain the existing width and height but will have a new total length of 19.5m. The culvert will be extended over the roof of the dive structure with a new upstream invert level of 32.81m AHD. The existing and proposed culvert arrangement is shown on Figure 6.1.

The existing approach channel cross sections to the culvert crossing were obtained from a combination of surveyed cross sections taken by field survey and photogrammetry to enable input into the HEC-RAS model. The locations of the cross sections are shown in Figure 6.2.

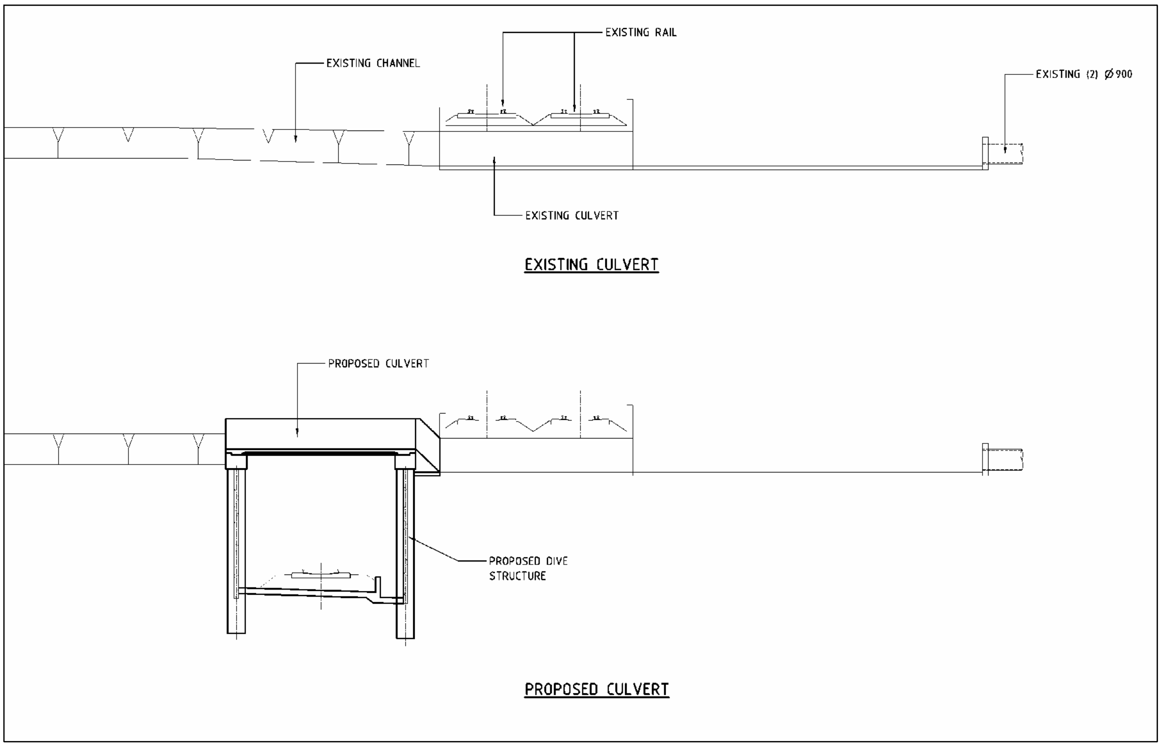

Figure 6.1 - Existing and Proposed Culvert Arrangements

6.2 Methodology

Bankstown City Council conducted a flood study for the locality near the culvert. In this study, DRAINS and TUFLOW modelling was used to obtain peak flows at the existing culvert inlet for a range of ARI events. These peak flows were used in the HEC-RAS hydraulic model to calculate water levels for the culvert and approach channel.

Table 6.1 shows the peak flows from DRAINS modelling, obtained from the Bankstown City Council Report, for a range of storm recurrence intervals.

Table 6.1 - Peak Flows for the Contributing upstream Catchments to the Culvert (Bankstown City Council, 2003)

Storm ARI (Years)	Flow (m^3/s)
5	3.8
10	7.2
20	11
100	14.5

Flooding maps produced by Bankstown City Council were used to obtain downstream flood level heights for the 5 to 100yr ARI to set the boundary conditions for the model.

Two separate HEC-RAS models were created, one with the existing culvert data and another with the design culvert data. A number of cross sections of the channel both upstream and downstream of the culvert were inserted into the model to find the water height and extent of flooding within the area. The model was then run under steady state conditions with the peak flows obtained from the Bankstown City Council drainage study. There was no blockage factor included in the modelling.

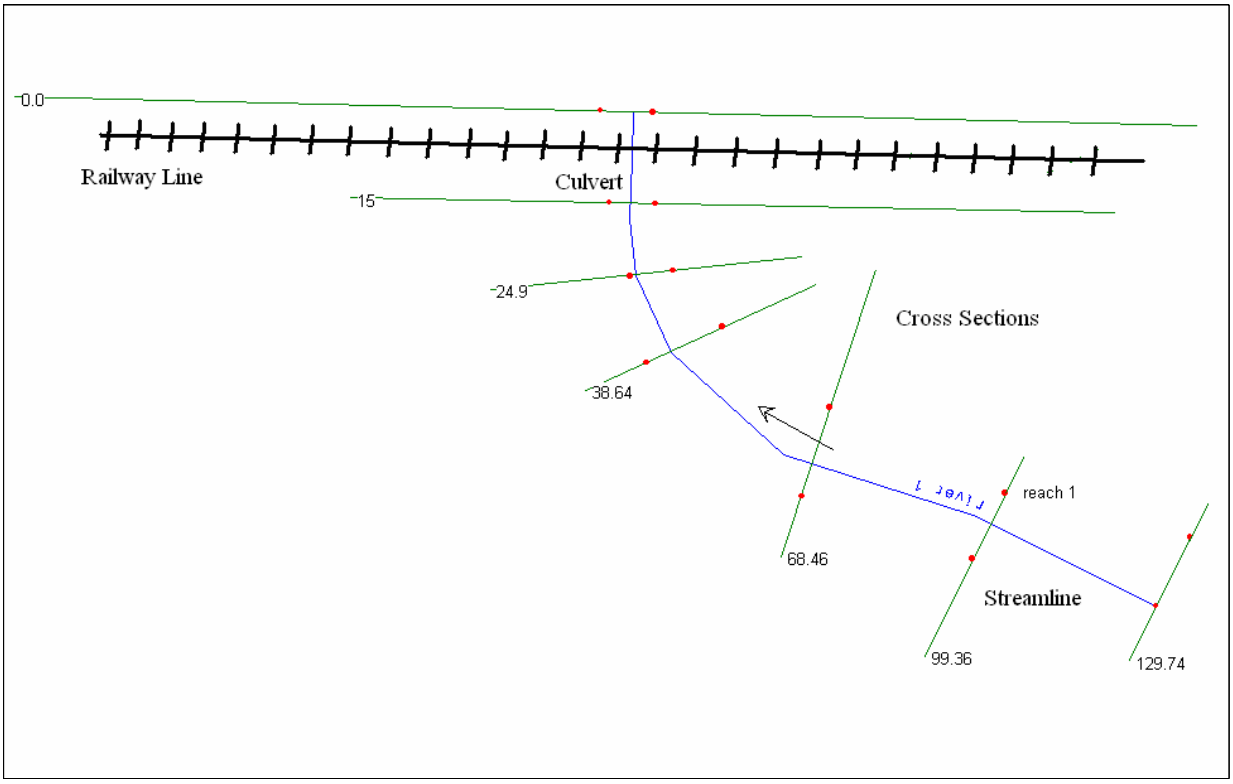

Figure 6.2 - Plan view of channel, culvert and railway line

6.3 Results

Table 2 gives a comparison between the upstream flood level for both the existing and proposed culverts over a range of storm recurrence intervals.

Table 6.2 - Upstream Water Level at the Existing and Design Culvert

Storm ARI (Years)	5yr	10yr	20yr	100yr
Existing Upstream Flood Level (m)	32.65	33.15	33.63	34.1
Proposed Upstream Flood Level (m)	33.9	34.33	34.4	34.43

The existing and design 5yr ARI storm water levels are represented schematically in Figures 6.3 and 6.4 respectively. The minimum required protection for the dive structure is the 5 year ARI event.

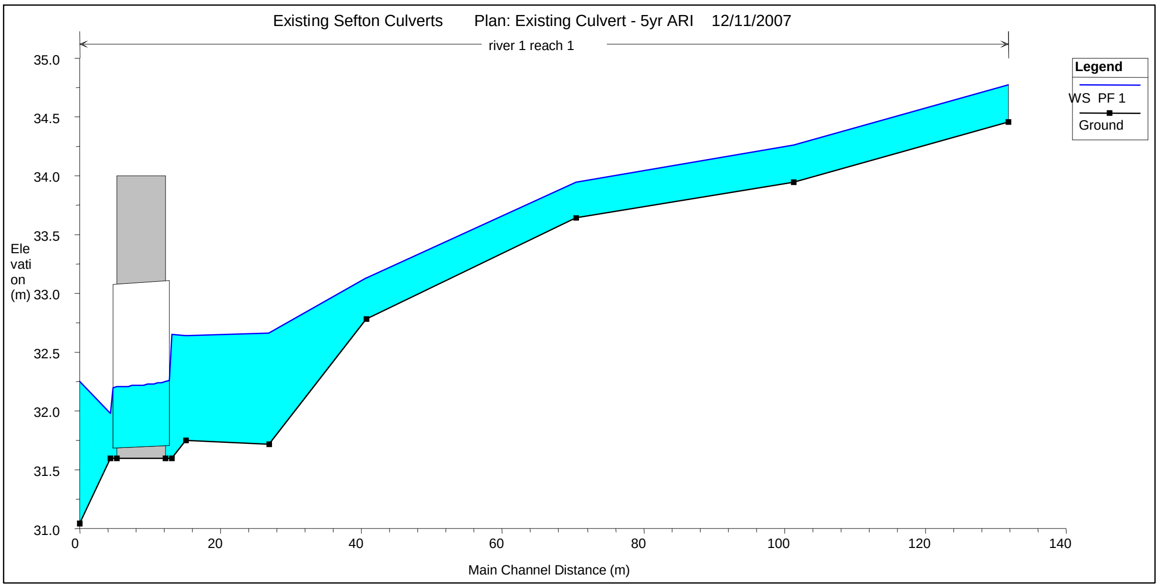

Figure 6.3 - Existing Water Course and Culvert Long section – 5 year ARI

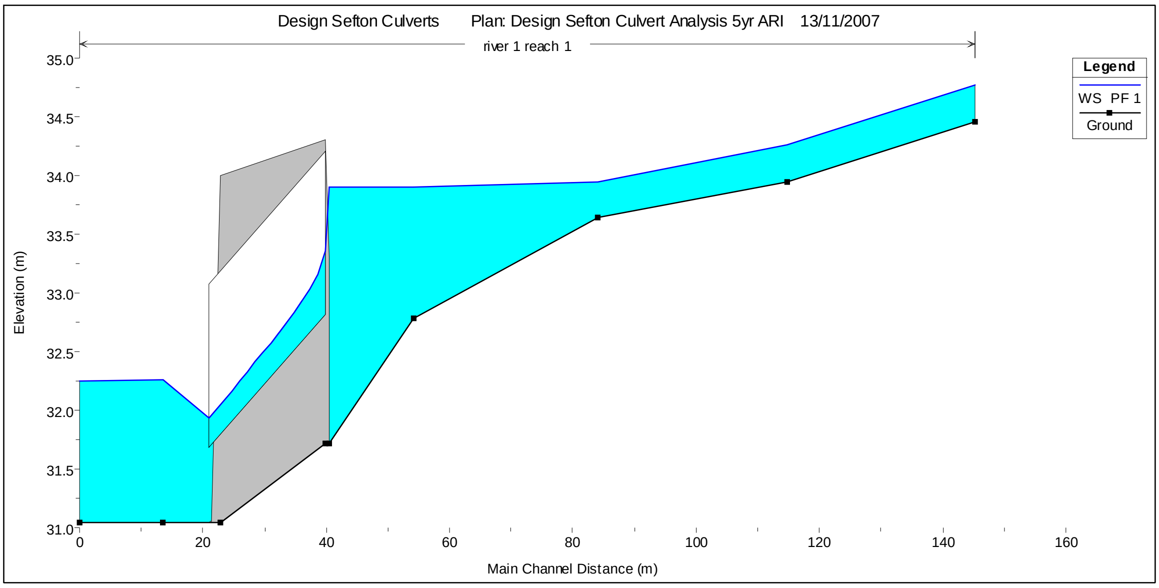

Figure 6.4 - Design Water Course and Culvert Long section – 5 year ARI

6.4 Discussion

The results indicate that the new culvert design will increase the 100yr level of flooding upstream of the culvert, but that this increase will be limited to a local ponding within the railway corridor next to the rail formation, where the flood level will increase by approximately 330mm. The results also indicate that the design culvert will have no impact on the downstream flood water levels. The rise in flood level that occurs with the new culvert arises from the construction of the culvert bridge over the SSFL having to be set at a higher level than the existing culvert invert, so that the culvert bridge over the SSFL acts as a broad crested weir in the culvert channel.

The flood level of 34.43m AHD during the 100yr event is well above the proposed dive structure wall height of 34.2m AHD. Protection from inundation to the dive structure is provided up to and slightly more than the 5 year ARI event with the current wall level at 34.2m AHD and the design of the freight line allows for its inundation with floods of greater recurrence.

6.5 Conclusion

The results show that local ponding inside the rail corridor will occur upstream of the new culvert bridge over the SSFL from a greater than the 5yr ARI event. The top of the side walls of the channel bridge are to be constructed to a level of 34.2m AHD to ensure flooding protection for the dive track in a 5 year ARI storm.

The proposed culvert will have no impact on the extent of flooding downstream, and the increase in the extent of upstream flooding inside the cess drain is contained within the rail corridor. The proposal will therefore comply with the Conditions of Approval for the project.

7. The Culvert drainage across the corridor at Leightonfield

The existing Leightonfield freight yard occupies the full extent of the flat and low lying land between Chester Hill and a shallow cutting at Villawood. The district drainage in this area is from the south to the north, where it meets a short tributary stream that flows into Prospect Creek. The catchment to the south of the railway has been extensively affected by recent industrial development, mainly for transport businesses. The land to the north of the rail corridor at Leightonfield is mainly an area of older light industrial development with some recent redevelopments.

There are two major culverts that cross the corridor between Christina Avenue and Llewellyn Avenue. They are shown on drawings UT-19 and UT-20, and are located at Km 23780 and Km 24400. There are also 4 smaller pipe culvert crossings.

The proposal for crossing the existing channel at Km24140 is with a single span. The crossing will span over the existing concrete channel with a new piled abutment on each side of the channel. This will exceed the hydraulic area that is available under the adjacent RailCorp tracks.

It is proposed to cross the larger of these two channels at Km 23780 with a box culvert crown section located in the existing channel. This structure matches the one that is under the RailCorp tracks. The walls of the crown culvert structure are within the drainage channel, but they present a minimal reduction in flow width, which remains substantially larger than that of the existing culverts under the RailCorp tracks.

In each case the proposed works will not reduce the flood capacity of the existing drainage across the rail corridor.

It is understood that Bankstown City Council do have plans to augment the district drainage across the railway corridor at Leightonfield. The need to carry out this work will be strongly related to the extensive recent development to the south of the corridor, and it is presumed that this development has not involved the construction of detention basins that are adequate to compensate for the increase in flood run-off and the decrease in the time of concentration that results from development of this type. As a corollary of this presumption, it would be expected that Council should have collected headwork's contributions from the development of this land.

The construction of the SSFL does not increase the flood volume, and so its development should not involve a commitment for the construction of additional flood drainage across the existing railway.

The way in which the construction of the SSFL can accommodate the construction of an additional floodway by Council is then related to the way in which Council plan to have this additional floodway is constructed. Council have a number of alternative ways of constructing the additional floodway under the existing rail tracks, and each of these options requires a different arrangement for the construction of the SSFL over the new floodway as described below.

Option	Future construction under existing RailCorp tracks by Bankstown City Council	Accommodation of Council's future construction by the SSFL scheme	Information that is required from Council for the documentation of the SSFL scheme
1	Construct with a crown culvert structure that is installed during a two week shutdown. A two week shutdown occurs in some but not all years	Construct matching culverts under the SSFL	Location and size of the culverts, and council commitment to these works in enough advance to insert the work into RailCorp's shutdown planning
2	Construct with a jacked box culvert that is installed from the northern side of the corridor , or from the southern side before the SSFL has been constructed	Construct matching culverts under the SSFL	Location and size of the culverts and commitment by council to meet the SSFL project timeframe
3	Construct with a jacked box culvert that is installed from the southern side of the corridor after the SSFL track has been constructed	The jacked box has to extend across the SSFL as the jacking pit has to be clear of the track	No information required, as for this option the SSFL would construct nothing more than to match existing so as to leave the existing ground un-obstructed

This choice of outcomes remains with Bankstown City Council. Council have not indicated an intention to proceed with drainage works of their own across the railway corridor, and unless they do make that choice the option that will have to be followed is the third one.

8. The SSFL and the Georges River

The route of the SSFL runs down the west side of the Georges River. The Georges River is one of two major watercourses that have the railway running down its flood plain rather than crossing it as is the case with Cabramatta Creek and Prospect Creek.

The existing railway embankment next to the Georges River is of low height, generally varying between 1-3m, with locally higher sections of up to about 6m high at minor creeks. At the M5, for example, the top of the formation is at RL10.85, and the level of the river bank is at RL7.5 at the base of the embankment. The level of the 100 year flood is RL9.25. The embankment has to be widened by between 6.4m and 8.35m (depending on whether there is maintenance track at the position involved). The decrease in flood flow area of the river that results from the construction of the SSFL is therefore an average of 17 sq.m out of a floodway area of over 500 sq.m under the 100m year flood. The flood velocity of the river is low, so that an increase in velocity of 3.4% over a length of just under 4km will involve an increase in velocity head that is much less than the 50mm allowable increase in afflux.

The effect of the railway embankment on the backwater volume of the Georges river is a even smaller because its embankment is only in the 100 year floodway between Mill Road and the Glenfield Creek (i.e. less than 4km), which is a small portion of the total length of the rivers floodplain.

9. Watercourse Redirection at Glenfield

9.1 The Scope of the Proposed Works

The western section between Casula and Glenfield stations will incorporate a new rail flyover which will impact on Glenfield Creek. Realignment of the creek will be required to allow construction of this section.
An assessment of the new creek alignment, hydraulic capacity of the proposed channels and culverts has been undertaken to ensure that existing flow conditions in the area are maintained.

The general nearby areas are currently undeveloped with the exception of Glenfield substation and consist of rural land, open space and some road infrastructure. A portion of Leacock Regional Park and two playing fields are impacted by the flyover.

There is a formed drainage gully on the west side of the rail corridor that starts just north of Cambridge Avenue over-bridge at Glenfield, and then runs north on the west side of the existing rail corridor, passing on the eastern side of the Glenfield substation (between the substation and the running lines) and running on the west side of the existing rail corridor until it joins with the other streams to become Glenfield Creek.

The SSFL will join onto the existing freight line near the southern end of this formed feature, and the SSFL will displace the gully, so that it will have to be re-formed on the western side of the SSFL, with a new route on the western side of the substation that then connects to a new culvert under the SSFL that will join onto the existing watercourse north of the substation

The existing channel was mainly formed by informal earthworks associated with the construction of the existing railway and the original route of Glenfield Road crossing the railway to Cambridge Avenue, which had a level crossing of the railway just south of the substation. The new channel will be of regular profile, and will have a lower invert than the existing one at Cambridge Avenue overbridge. The width of the channel is typically lower, but the improvement in outlet drainage and effective roughness will allow a flow capacity that matches that of the existing channel. The channel will be lined with cobbles rather than concrete lined throughout so that plant growth between the stones can facilitate the movement of small wildlife.

The storm drainage north of Cambridge Avenue flows north between the Railway and Glenfield Road, then flows around the RailCorp substation and from there flows into Leacock Regional Reserve. It then flows north across the reserve in the existing formed channel. The flow in dry weather, and also high peak events follow an existing channel that will be crossed twice by the SSFL. Both crossings will therefore require culverts under the SSFL embankment and also re-alignment over part of its length. A major part of the flow in high peak events is by overland flow across the playing fields at the southern end of Leacock reserve , which provide significant flood storage, and then around the two ponds to flow into the head of Glenfield Creek. Under floods of approximately annual recurrence the flow presently floods the playing field that is in the park, then passes through the two existing ponds that are next to the railway line, before reverting to the dominant overland flow path described above. The nearest dwellings are on higher ground to the west of this drainage system. The two existing ponds are understood to be flooded gravel pits that would have been excavated around the time that the original rail corridor was constructed. The SSFL will not change this regime of extensive flood detention. The flow data are summarised in this report.

The southern approach embankment to the flyover crosses the watercourse twice as both share the narrow strip of land between the existing railway tracks and the ponds at Leacock Park. A gulley that drains the area on the north side of Glenfield Road joins the watercourse just upstream of the southern crossing, and a second gulley that drains the area to the west of playing fields joins the watercourse between the two ponds. Large twin cell box culverts are proposed to take the flow across the embankment at both locations, with a 1500 diameter reinforced concrete pipe proposed for the inflow from the area to the west of the park, which enters the channel between the two ponds. The existing drainage pipes are 600 dia., so that the new construction will be of substantially greater flow capacity.

The design of this watercourse re-formation follows the conclusions of the flood study for this development that was carried out by Cardno Willing in April 2002.

Under floods of greater than annual recurrence a major part of the total flow will continue to be across the playing fields at the southern end of the embankment and then across the two Leacock Ponds, joining the main channel north of the embankment as it does at present.

The box culverts have been selected and detailed to allow access for an excavator to "de-silt" them if that proves to be necessary. A larger flow area has no advantage, and will only promote silting under normal flow conditions because of the flat grades in this system.

An existing feature of the drainage is that Glenfield substation has been constructed on a raised platform embankment to keep the electrical equipment above flood level, but this embankment is close enough to the railway formation to severely constrict the flow of the creek that passes between the two embankments. This contributes to the flooding of Glenfield Road on an approximately 5 year recurrence. The proposed scheme will replace the constricted channel between the substation and the railway with a larger channel to the west of the substation, which will allow some improvement to this, though the frequency of flooding in Glenfield Road will not be reduced.

No likely risk to habitable dwellings or structures is involved with the proposed works.

9.2 Glenfield Flood Study - Data Acquisition

9.2.1 Previous studies

A previous study completed by Cardno Willing (NSW) Pty Ltd – *Glenfield Grade Separated Junction Hydrology and Hydraulic Study – April 2002* was used for comparing the 100 year ARI flows and contributing catchments for the extent of works.

9.2.2 General Mapping Information

Mapping information was sourced using:

- Google Earth Pro
- Land and Property Information NSW mapping resources
- Photogrammetry survey
- Some detailed survey
- Department of Lands 2.0 metre digital contours and;
- Connell Wagner field survey

(Refer to - figure 9.2 below for a recent photo map of the area).

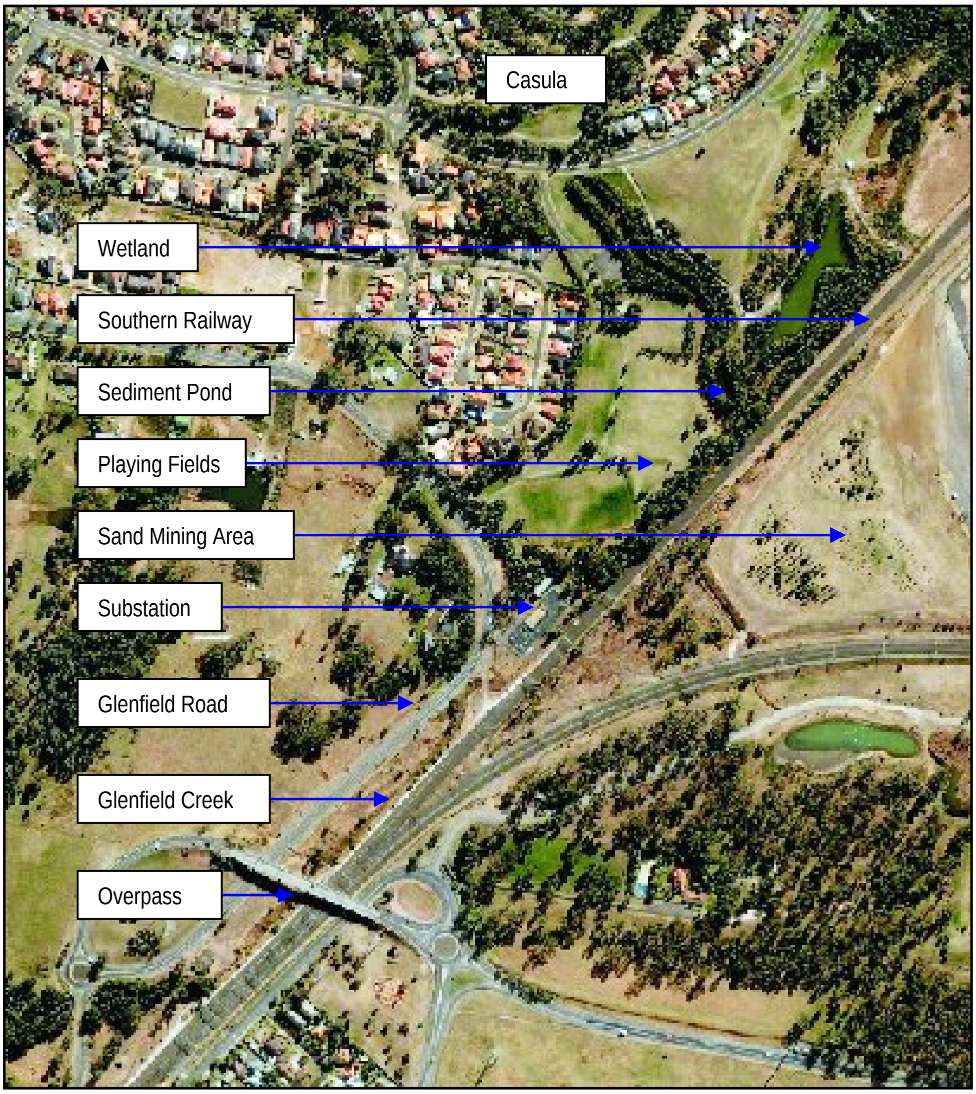

Figure 9.2 – Photo Map of Study Area

9.2.3 Site inspection

A site inspection was carried out by CW representatives on 15th November 2007 at Glenfield to ascertain the extents of the works, catchments, existing creek characteristics, flood prone areas and any additional survey that may be required to complete the flood assessment.

9.3 Drainage Conditions

9.3.1 Existing Drainage Conditions

Currently Glenfield Creek meanders north east alongside the city bound railway line between Glenfield Road and Leacock Regional Park. The creek is mostly overgrown with weeds and tree species. Existing drainage pipes and watercourses enter the creek from the northwest and southeast at various locations

A pair of pipe culverts (culvert 3) is located approximately at rail chainage 41,140km (Main South) and will require extending under the proposed South West Rail Link (SWRL) Glenfield Junction and SSFL tracks to the proposed realigned Glenfield Creek. This culvert captures flows entering two sag gully pits along Railway Parade near Foreman Street.

A pipe culvert (culvert 2) that crosses under the railway from the south east adjacent to the sand mining area also connects into Glenfield Creek. Flows to this culvert are controlled by a wet detention basin upstream.

Leacock Regional Park has two playing fields adjacent to the creek with a sediment pond and wetland at its northern end. It is observed that the northern playing field may act as a detention basin during larger rainfall events storing creek high flows. Glenfield Creek skirts around the wetland and eventually empties into the Georges River before Casula station.

Observed flood prone areas are the northern parts of Leacock Regional Park alongside the existing watercourse and the low point of Glenfield Road just north of the Canterbury Road overpass bridge (Refer to Appendix A -figure 4 for the existing predevelopment flood levels and general arrangement plan).

9.3.2 Proposed Creek Works

The proposed works extents will be approximately between 41.2 km – 40.2km (rail kilometres) on the northwest side of the existing southern railway. Starting from the upstream end, near the Glenfield Road roundabout, a new open channel will be constructed up to the existing Glenfield substation between the proposed flyover and Glenfield Road.

A series of box culverts will be built along side the entrance to the substation and the creek diverted around through Leacock Regional Park. An open channel will continue until it meets the proposed flyover where a series of box culverts will take it under the railway. The creek will then almost resume its existing channel alignment located between the southern rail and the proposed flyover. It will then cross under the flyover again with box culverts, near the existing wetland and then resume as an open channel adjacent to the wetland. The channel will then connect into the existing creek near the northeast end of the wetland.

Critical areas along the creek deviation include the low point along Glenfield Road, Culvert 3 connection, Glenfield Substation and the interface between the playing field detention storage area and proposed low flow/backwater pipe connection to the realigned creek. (Refer to Appendix A -figure 4 for the general arrangement plan).

9.4 Hydrological Analysis

9.4.1 Catchments Definition

Glenfield Creek starts near Roy Watts Road west of the Southern railway and meanders north east alongside the city bound railway and eventually empties into the Georges River.

The topography of the general area is gently undulating with average valley slopes of 6.0% and creek slopes of 8.0%. The terrain consists of grassed rural slopes, urban development and railway corridor. The current overall land use is approximately 47% urban built and 53% rural grassland/remnant forest.

For the purpose of this report the catchments analysis was undertaken for the existing current conditions.

9.4.2 Model Development

The Glenfield Creek catchments were separated into sub-catchments by their local contribution to existing culvert outlets, minor creek outlets and railway corridor runoff. A 2.0m digital contour data base from the Department of lands and a photomap of the area was used to determine the sub-catchments (refer to Table 9.4.1). Impervious areas, pervious areas and average ground slopes were also calculated for these sub-catchments using this data (Refer to Appendix A -figure 3 for the catchments plan).

All data was entered into the DRAINS model.

Table 9.4.1 – Major Catchments Summary for Glenfield Creek for the Current Conditions

Contributing Catchments Number	Total Area (ha)	% Impervious (current condition)	Impervious Area (ha)	Pervious Area (ha)	%Slope
1	85.7	20	17.14	68.56	5.3
2	12.4	20	2.48	9.92	5.7
3	30.8	50	15.4	15.4	7.0
4	128.7	50	64.35	64.35	6.3
5	3.6	20	0.72	2.88	2.5

9.4.3 Catchments and Flow Comparisons

Catchments and peak flow comparisons was on the *Glenfield Grade Separated Junction Hydrology and Hydraulic Study – April 2002* summary of catchments and rainfall data results and a site assessment.
Design 100 year ARI 2 hour storm flows from the previous study were compared with the DRAINS model output (refer to Table 9.4.2 below).

Table 9.4.2 – Comparison of Calculated Catchments areas and 100 year ARI Peak Flows

Catchment Number	Connell Wagner Study Calculated Catchment Area (ha)	Cardno Willing Previous Study Catchment Area (ha)	Connell Wagner Study Calculated Peak 100 year ARI Flow (m3/s)	Cardno Willing Previous Study Area Peak 100 year ARI Flow (m3/s)
1	85.7	87.2	13.3	13.0
2	12.4	9.4	2.69	1.5
4	128.7	120.6	30.0	20.9

9.5 Hydraulic Analysis

9.5.1 Model Development

The DRAINS software package was used to model hydraulic performance along the Glenfield Creek Deviation. A combination of 3d digital survey data and manual input was used to produce cross sections and a network of channels and culverts for analysis. The creek channels and culverts were modelled using steady state flows to determine water levels for a range of storm events.

Separate modelling was also undertaken using CULVERT MASTER software to determine headwater levels for culvert 3 along Railway Parade.

9.5.2 Boundary Conditions

The 100 year ARI boundary conditions were adopted from the *Glenfield Grade Separated Junction Hydrology and Hydraulic Study – April 2002.* The Georges River at the confluence of Glenfield Creek has an estimated 100 year flood level of 11.0m AHD but the peak storms for each creek do not coincide. Instead a 20 year ARI level of 9.8m AHD has been adopted as the backwater level for the 100 year event for Glenfield Creek. A normal depth assumption has been applied for the tail water conditions downstream for the 2, 5, 10, 20 and 50 year ARI events.

The 100 year ARI flood level comparisons between the existing and proposed conditions are summarised in Table 9.5.3.

9.5.3 Model Parameters

The DRAINS modelling parameters used in this study are summarised in Tables 9.5.1 and 9.5.2.

Table 9.5.1 – Model Parameters

Model Parameter	Adopted Values
Paved(impervious) area depression storage(mm)	1
Supplementary area depression storage(mm)	5
Grassed (pervious) area depression storage(mm)	10
Soil type	2
Manning's 'n' for concrete conduits	0.013
Manning's 'n' for grassed channels	0.045
Manning's 'n' for reno mattress channels	0.04
Manning's 'n' for gabion channels	0.04
Inlet loss coefficients for culverts	0.5

Modelling of culverts was undertaken without blockage factors.

Table 9.5.2 – IFD Data Parameters

	2 Year	50 year	
1 Hour Rainfall Intensity(mm/hr)	32.5	62.5	G=0
12 Hour Rainfall Intensity(mm/hr)	6.0	12.0	F2=4.29
72 Hour Rainfall Intensity(mm/hr)	1.9	4.0	F50=15.9

9.5.4 Modelling Results

Table 9.5.3 – Comparison of the Existing and Proposed Design Conditions 100 years ARI Flood Levels along Glenfield Creek

Track Chainage (km)	Existing Condition - Approx 100 year ARI Flood Level (m AHD)	Proposed Design Condition 100 year ARI Flood Level (m AHD)	Difference in Level (m AHD)
41.16	15.82	16.06	0.24
41.06	15.20	15.47	0.27
40.90	14.70	14.67	-0.03
40.78	14.20	14.27	0.07
40.29	12.01	11.38	-0.63

Table 9.5.4 – Comparison of the Proposed Design Conditions Range of ARI Flood Events Levels along Glenfield Creek with the Flyover Track Level

Track Chainage (km)	2 Year ARI Flood level (m AHD)	5 Year ARI Flood level (m AHD)	10 Year ARI Flood level (m AHD)	20 Year ARI Flood level (m AHD)	50 Year ARI Flood level (m AHD)	Design Track Level for Flyover (m AHD)
41.16	15.27	15.43	15.57	15.78	15.93	18.92
41.06	14.71	14.88	15.01	15.21	15.35	17.74
40.90	13.91	14.03	14.13	14.39	14.57	16.14
40.78	13.33	13.50	13.65	13.9	14.09	15.27
40.46	11.58	11.81	12.01	12.33	12.54	18.24
40.29	10.37	10.56	10.74	10.98	11.18	19.93

Table 9.5.5 – Culvert Crossing 3 Extended to Glenfield Creek Deviation (100 Year ARI DRAINS Analysis - no blockage)

Structure	100 year ARI Inflow (m3/s)	Length (m)	US Surface Level (m AHD)	US Invert (m AHD)	DS Invert (m AHD)	Slope (%)	Tailwater Elevation Along Creek (m AHD)	Calculated Headwater Elevation Railway Parade (m AHD)
Culvert 3 (2-1050 RCP)	7.5	64.0	16.67	14.84	14.58	0.40	16.06	17.42

Table 9.5.6 – Culvert Crossing 3 (10, 20 and 50 Year ARI DRAINS Analysis - no blockage)

ARI (Years)	Inflow (m3/s)	Tailwater Elevation Along Creek(m AHD)	Headwater Elevation Railway Parade (m AHD)	Water Depth Railway Parade (m)
10	4.39	15.57	16.8	0.13
20	5.49	15.78	17.14	0.47
50	6.57	15.93	17.26	0.59

Note: 1. Max water level at culvert 3 inlet before overtopping Railway Parade towards Cambridge Avenue for the existing condition is RL17.85 m AHD

2. Shaded area indicates surcharging

Table 9.5.6 – Peak Water Levels for the Northern Playing Field Detention Basin for Various Storm Events with the Proposed (1) 1.5m Diameter Pipe Connection and By-pass Channel

2 Year ARI Flood level (m AHD)	5 Year ARI Flood level (m AHD)	10 Year ARI Flood level (m AHD)	20 Year ARI Flood level (m AHD)	50 Year ARI Flood level (m AHD)	100 Year ARI Flood level (m AHD)
11.18	11.37	11.51	11.71	11.87	12.04

9.6 Impacts from the Proposed Works

9.6.1 Glenfield Road

Glenfield Road grades towards a low point midway between the railway overpass and the substation which is approximately track chainage 40.90km, 14.03m AHD. This level is 670mm lower than the 100 year ARI sourced level from the *Glenfield Grade Separated Junction Hydrology and Hydraulic Study – April 2000* of approximately 14.7m AHD.

The proposed creek deviation modelling results indicate that the level of local flooding in Glenfield Road will not be increased, and the existing flood recurrence period for inundation of Glenfield Road of about 5 years will not be changed. The road will flood but there are no significant impacts to the nearby areas or habitable dwellings.

A section of the creek deviation between 41.2km – 40.9km has an existing vital rail signal cable running alongside the Glenfield Road fence boundary and the new creek profile has been designed to fit into the space between the signal cable and the railway embankment. The new formation widths of the railway have been set at the minimum acceptable levels for the two SSFL tracks and for the two proposed RailCorp tracks for the Glenfield North flyover which is proposed to join the Up tracks at Glenfield to the East Hills track. The channel cross section is typically trapezoidal, with a base of 3m wide, and a sloping face on each side of that.

However, opposite the low section of Glenfield Road between Cambridge Avenue overbridge and the substation, the width of the channel base is increased to 4.5m to provide the required hydraulic area with the limited depth that is available below the road level in this section. This requires a near vertical side for the railway embankment. Over this section the railway formation right across the new works in the corridor has been set with the spacing between tracks and the shoulder widths at the absolute minimum acceptable values so as to maximise the width of the channel.

The new channel will replace an informal one that has an irregular profile, and for the downstream connection to Glenfield Creek a large culvert and a following section of deep channel on the west side of the substation will replace the existing constricted channel in the cess between the existing railway and the substation. The drainage that is achieved with these works will be at least as good and is likely to be a small improvement on the existing drainage for flood control on Glenfield Road. Modelling results for the 2, 5, 10, 20 and 50 year ARI events indicate that Glenfield Road would be trafficable up to a 5 year peak ARI event.

9.6.2 Culvert 3 Railway Parade

The drainage across the corridor at culvert 3 will be maintained with the extension of the existing twin concrete pipe across the proposed formation using a box culvert of larger cross section. With the construction of the proposed works tailwater levels will be no greater than the existing conditions for the connecting culvert 3, from Railway Parade, for various storm events.

Modelling results for culvert 3 using Culvert Master indicate a required headwater elevation of RL 18.66 AHD for the 100 year downstream tailwater condition. This is significantly higher than the road level of RL16.67 along Railway Parade at the culvert location. Existing ground survey levels and site observation indicated the maximum level that can be attained before overtopping occurs towards Cambridge Avenue along Railway Parade is approximately RL17.85 AHD (1.18m).

Modelling shows that surcharging will continue to occur from Glenfield Creek for events greater than the 1 in 10 Year ARI at the culvert 3 inlet locations, but that the resulting flooding is restricted to the road and does not present a likely risk to habitable dwellings or structures.

9.6.3 Glenfield Substation

The Glenfield Substation is located on the Glenfield Road bend and is built on a platform level of approximately 15.1m AHD. For the current condition it is not subject to the nearest 100 year ARI flood level of 14.2m AHD sourced from the *Glenfield Grade Separated Junction Hydrology and Hydraulic Study – April 2002.*

The proposed creek deviation modelling results indicates a 100 year ARI flood level of 13.9m AHD which is significantly lower than the existing modelled flood condition.

9.6.4 Playing Fields – Leacock Regional Park

Leacock Regional Park consists of two playing fields, a sediment /trash collection pond and a wetland.

The lower northern field acts as a detention basin during large peak storm events. Currently during low flow Glenfield Creek and a watercourse from the Casula urban development empties into the parks sediment pond and then gradually drains into the adjacent wetland through a pit and connecting pipe. A high embankment separates the pond from the wetland. During high peak flows the water backs up into the playing field and in larger events drains back up into Glenfield Creek and around the south east perimeter of the wetland or overtops the embankment.

The proposed deviation will replace the connecting channel branch to the park with a 1.5m diameter pipe which will maintain the existing low flows to the pond and also a by-pass channel 5.0m wide x 1.5m high (base

RL10.4m AHD) will be constructed to control flood levels within the park. High overtopping flows will be diverted to Glenfield Creek along the existing wetland.

The western side of the park is bordered by urban development with property levels ranging from RL16.80m AHD to RL 12.40m AHD. Modelling results indicate there will be no flood impacts for the 100 year ARI.

The existing terrain contours indicate that the current basin level may reach a maximum RL 11.9m before it overtops to Glenfield Creek. The maximum water level form the proposed works for a 100 year ARI storm in the detention basin would reach RL 12.04m AHD.

9.6.5 The Proposed Flyover

There are no flood impacts to the proposed track works for up to the 100 year ARI event along the Glenfield Creek deviation works.

9.7 Glenfield Flood Study -Summary and Conclusions

The Glenfield Creek deviation will consist of an open channel lined with cobbles, culverts and pipes located along the northwest side of the southern railway between track chainages 40.2km – 41.2km.

The creek alignment will follow Glenfield Road and then relocate around the Glenfield Substation along Leacock Regional Park. It will then go under the proposed flyover and follow the existing creek line until it crosses under the flyover again and connects back into the existing creek near the existing park wetland.

The realignment of Glenfield Creek will have minimal influence on increasing the existing upstream water level conditions for the culvert 3 crossing from Railway Parade.

Modelling results indicate that the existing occurrence of flooding along Glenfield Road will continue for events greater than the 10 year ARI . However, the frequency of this flooding will not be made worse, and the time of inundation will be reduced because there will be no tail-water restriction from the area once the existing narrow channel between the railway and Glenfield Substation has been bypassed.

Glenfield substation is protected from the 100 year ARI event and existing conditions are improved by the works at this location.

Low flows to the existing wetland and backwater conditions are maintained with the proposed 1.5m diameter pipe connection between the playing fields and Glenfield Creek. The 5.0m wide x 1.5m high (base RL10.4m AHD) by-pass channel provides 100 years ARI flood immunity to properties adjacent to the park.

All culverts have been modelled assuming no blockage.

Construction will be carried out in a sequence that does not involve any blockage to flow being put in place prior to the permanent works being constructed that provides the by-pass around the new construction.

In conclusion there seem to be no significant flood impacts to the surrounding existing areas due to the proposed creek deviation works for the predicted 100 year ARI flood levels and slight improvements have been made to events up to the 10 year ARI. Nuisance flooding may occur, as it does now, preventing street access but there is no likely risk to habitable dwellings or structures. The Conditions of Consent for the SSFL project for flood management will therefore be complied with.

9.8 Appendix to Glenfield Flood Study

Figure 9.3 – Catchments Plan
Figure 9.4 – General Arrangement Plan
Figure 9.5 – Drains Output Plan

10. Watercourse redirection of Bow Bowing Creek at Campbelltown

10.1 Introduction

At Narellan Road overbridge the construction of the SSFL will require a local redirection of Bow Bowing Creek where it passes under Narellan Road Bridge.

The design of the watercourse re-direction of Bow Bowing Creek at Narellan Road, Campbelltown follows the conclusions of the flood study for this development that was carried out by Cardno Willing in July 2002. The modelling in this study was benchmarked against existing flood records, and the hydraulic parameters that were derived from this analysis were then used in the design of the proposed works.

Narellan Road Bridge is a three span structure with the middle span over Bow Bowing Creek and the eastern span over the adjacent railway. Construction of the SSFL and an adjacent planned additional RailCorp track in the centre span will require the relocation of the creek to the western span. The RailCorp track is for a planned back entry into the Campbelltown stabling yard, and is an enhancement that is likely to proceed in a few years.

At this point Bow Bowing Creek is a formed drainage canal. The redirection is over less than 50m in length. It is an adjustment to an existing canal to accommodate a new construction feature.

A feature of the scheme is that Burunji Creek joins Bow Bowing Creek just upstream of the bridge. The junction of this creek with Bow Bowing Creek must then be located on the new channel of Bow Bowing Creek. Two options exist for this junction:

1) With Burunji Creek joining Bow Bowing Creek through a channel on the upstream side of the bridge at a right angled junction, which is the present layout.

2) With Burunji Creek joining Bow Bowing Creek at about 45 degrees through an approach channel that crosses diagonally under the middle span

Both options were studied.

There is also an access track to Gilchrist Oval that has a small single span bridge over Bow Bowing Creek under the Narrellan Road Bridge. This bridge has to be demolished, and access along the rail corridor maintained on a road that will be provided next to the freight line. Access across Bow Bowing Creek will be maintained if required for public access, and the crossing of the creek by a water pipe replaced.

The flood capacity will not be reduced, and flood levels not increased, and so the proposed works will comply with the Conditions of Consent..

10.2Features of the Design

The re-alignment works were based on the following considerations:

(i) Minimization of the length of any re-alignment within the identified hydraulic constraints;
(ii) Maintain as far as possible the same channel and floodplain conveyance in the 100 yr. ARI flood;
(iii) Maintain similar invert levels to the invert levels of the existing channel;
(iv) Maintain similar or flatter side slopes than the existing channel;
(v) Maintain a minimum 2 m buffer around any piers supporting the existing Narellan Road bridge;
(vi) Maintain access along the rail corridor for access to Gilchrist Oval.
(vii) Ensure that earthworks do not reduce the stability of the piers and abutments of Narellan Road bridge.

The drainage channel and the front batter of the bridge approach embankment fill the length of the west span under the bridge, and so the access road has to fit into the centre span along with the two new rail tracks.

The details of the accessway and the options for its connection to Glichrist Oval are a separate issue from the hydraulic design of the creek re-alignment. Because the accessway has to be in the centre span of the bridge the options for its design are essentially separate from the issues that are involved with the creek re-alignment, and so are not covered by this report. They will be separately resolved with Campbelltown City Council along with other issues of local access and amenity that arise at the station precincts.

The rail formation has an accessway on the west side of the freight line. North of the bridge where flow width is constricted by the rail embankment, the accessway is set on a terrace at a lower level than the rail formation so that under major flood events its width is available for flood flow. Analysis has shown that this is important to keep flow velocities within the limits that allow the use of random rock for the floor and sides of the main part of the channel.

The limited space for the connecting channel for Burunji Creek between the existing culverts and the junction with Bow Bowing Creek require the use of gabions and Terramesh retaining wall construction for the channel sides. The new two span culvert under the SSFL provides a larger area for flow than the existing 3 span culvert.

The future RailCorp track will cross Burunji Creek with a single span bridge

Upstream of the junction with Burunji Creek, the channel for Bow Bowing Creek has base width of 3m, which matches that of the existing channel. Downstream of the junction the channel is wider, with a base width of at least 5m and additional flow area once the water level exceeds that of the accessway next to the rail formation.

10.3Hydraulic Modelling

Campbelltown City Council have been carrying out a program of flood mitigation in the area over many years, and have modelled the hydraulics of the Burunji Creek and Bow Bowing Creek in detail. Both creeks have detention basins along their length. Gilchrist Oval, which is immediately adjacent to the site has been constructed to act as a detention basin for Bow Bowing Creek and the control outlet from the basin is about 100 m upstream from Narellan Road. The creek flows through the basin with an outlet adjacent to Narrellan Road. The outlet has a low flow pipe 900 dia., and a main outlet comprised of a large corrugated steel arch culvert.. The inlet hydrographs to this detention basin and the outlet hydrograph from Burunji Creek that were provided by Council formed the basis of the previous study that was carried out by Cardno Willing.

This study calibrated the model for this section of Bow Bowing creek against flood levels that had been established by Council, and found good correlation. The study concluded that the re-alignment works would lead to a slight lowering of 100 yr ARI flood levels in the vicinity of Narellan Road. This was associated with changes to roughness values. At the same time it was estimated that the peak 100 yr ARI flood level in Gilchrist Basin would rise by up to 0.02 m.

It was also concluded that the proposed works would also increase 10 yr ARI flood levels upstream of the extended Birunji Creek crossing.. These increases were estimated to be 0.06 m (under Option 1) reducing to 0.03 m (under Option 2).

Connell Wagner have repeated the analysis of this drainage using a DRAINS model. The purpose of Connell Wagner's analysis was to extend the model to incorporate the layout changes that arose from the detailed design of the SSFL. The proposed works for the SSRFL have the two new tracks for the railway in the centre span of Narrellan Road bridge, and the creek diverted to the western span, as anticipated in the earlier study. However, the geometry of the new channel for Bow Bowing creek differs in cross section profile because of the track alignment north of the Narrellan Road Bridge, and in addition the scope of detail at the confluence of the two creeks is better defined by the detail design process than the details that would have been available before the proposed railway works had been considered in their present detail. The hydraulic parameters that were derived in this way by Cardno Willing have been used in the model.

The results from this study on the 100 year flood are summarised below. The levels and flow velocity values are similar to those that were provided by the previous study.

DRAINS results prepared 08 August, 2008 from Version 2007.02

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)
Gil Cul	37.626	4.2	67.491	67.32

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Chainage (m)	Max HGL (m)
RC Inlet	25	1	0	66.079
		1.2	18	66.065
RailCul	25	2.4	0	66.065
		2.7	16	66.052
Chnl4	25	2		
5m channel	49.478	1.8	0	66.044
		2.4	30	65.52
Dummy Channel	44	0.6		
3m channel	37.626	1.5	0	66.933
		2	90	66.044

OVERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV
OF4	0	0	7.665	0	0

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level
Gilchrist	68.5	56456.5	37.626	37.626	0

10.4 Discussion on Alternative Layouts for Burunji Creek

Two options exist for the junction of Burunji Creek and Bow Bowing Creek:

1) With Burunji Creek joining Bow Bowing Creek through a channel on the upstream side of the bridge at a right angled junction, which is the present layout.

2) With Burunji Creek joining Bow Bowing Creek at about 45 degrees through an approach channel that crosses diagonally under the middle span

The hydraulic modelling has shown that the flow velocity in Burunji Creek is not sufficient to present a risk of erosion of the west bank of Bow Bowing Creek into which this creek flows. A major part of this assessment is the realisation that the two creeks will flood at the same time, so that flood flow from Burunji Creek will enter the channel for Bow Bowing Creek with it also full of water. The width of the basin that is proposed for the confluence has been detailed to maintain the scour of the channel bed to be within the scour resistance provided by the chosen channel lining of 200mm cobbles. In the previous study the potential for erosion with the right angled junction had been raised as a concern.

The angled junction has less turbulence at the junction and it is hydraulically more efficient, but the head loss at the confluence is not major and so there does not appear to be a concern over available head in the system that would predicate the selection of this option for that reason.

The right angled option is easier to construct because the new culverts over Burunji Creek are clear of the existing access track bridge. With the angled culvert access through the site would be cut during construction.

For these reasons ARTC have adopted the right angled option as the scour is expected to be controlled by the proposed channel lining, and as the hydraulic loss from turbulence is acceptable.

10.4.1 Hydrological Data

Campbelltown City Council (CCC) supplied the following hydrological information to Cardno Willing, and this data has been used in Connell Wagner's analysis:

- The stage - storage curve for Gilchrist Basin , scheduled below:

Gilchrist Basin Stage-Storage Curve

Stage (m)	Storage (ML)
0.5	0.0
1.0	1.5
1.5	5.1
2.0	12.9
2.5	24.7
3.5	55.3
4.0	75.0
4.5	94.2

- Plan No. 84/82 Sheets 1, 2, 3, 4 and 7 of Outlet/spillway details for Gilchrist Basin; 100
- 100 yr ARI critical duration hydrographs at:
  - Gilchrist Drive (the inlet to the Gilchrist on-line retarding basin) (refer Figure 2),

- the outlet of the Birunji Creek catchment that joins Bow Bowing Creek at Narellan Road (refer Figure 2
- Fishers Ghost Creek just upstream of the confluence with Bow Bowing Creek; and

- Available 100 yr ARI flood levels in the study area and downstream at the confluence with Fishers Ghost Creek (refer-Figure 3).

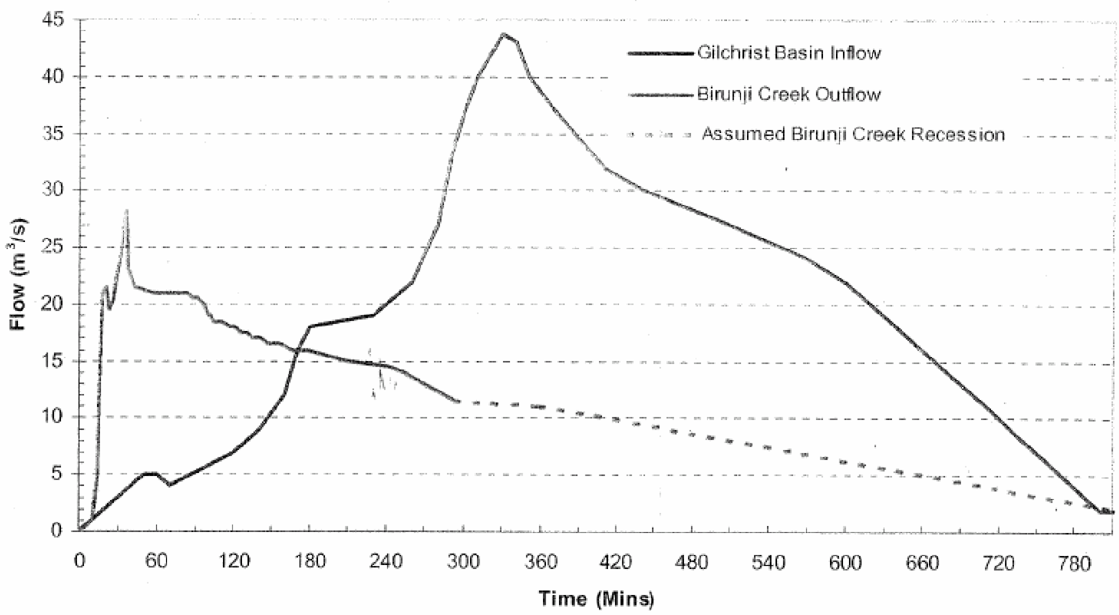

Figure 2 Adopted Inflow Hydrographs for XP-SWMM Model

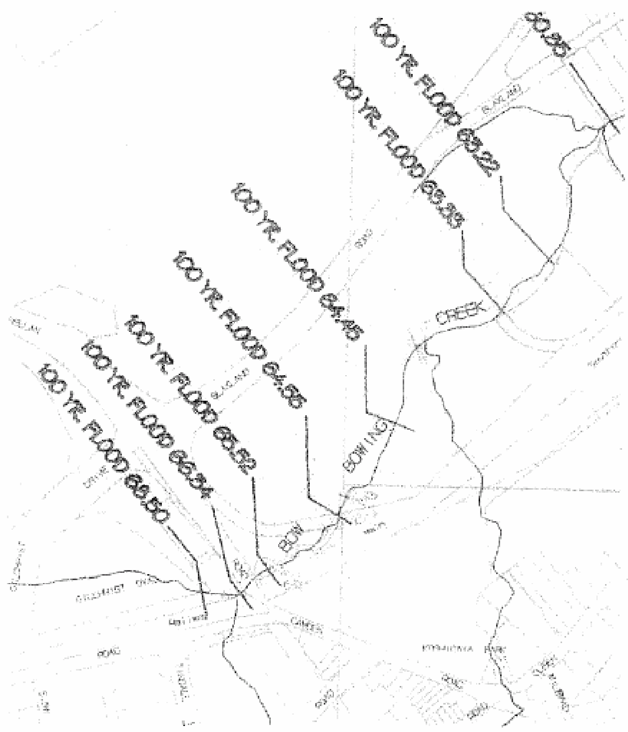

Figure 3 100 yr ARI Flood Levels supplied by Campbelltown City Council

11. Schedule of stormwater crossings

The stormwater crossings of the SSFL are scheduled below, with notes added on detailed considerations where useful.

Cross corridor culvert drainage structure [station and road positions also noted for reference]	Existing structure	Construction for SSFL	Note on location	Drg.No	Chainage (km)
Cooper Road					19.600
Culvert under existing Freight line	1500X3000 box culvert	Matching channel section bridging over the Sefton Dive	Culvert crosses SSFL in overbridge	Cl215	19.930
Auburn Road					20.7
Woods Road					20.75
Sefton Station					21.15
Culvert	Stormwater Pipe	extend existing culvert	On west side of Hector St	UT-014	21.73
Culvert	Culvert	extend existing culvert	East side of Miller Rd	UT-017	22.86
Miller Road					22.88
Culvert	Culvert - (Approx 1200H x 1000W)	extend existing culvert	East end of Leightonfield Yard	UT-017	22.96
Leightonfield Station					23.67
Llewellyn Avenue Culvert	3 x 2400 x 1840 cell RCBC, max height 1.85, width 2.45, roof 0.77 thick, inv. RL 13.02-13.07	RCBC 3.0 wide 3.0 min. height with side spans across existing concrete channel	Leightonfield Yard	UT-019	23.77
Culvert	Culvert	extend existing culvert	Leightonfield Yard	UT-019	23.92
Culvert	2400 x 1840 cell RCBC	Bridge over existing concrete channel	Leightonfield Yard	UT-020	24.19
Woodville Road					24.32
Villawood Station					24.37
Culvert	750 diameter pipe	extend existing culvert	On east side of Horsley Dv	UT-022	25.15
Horsley Drive					25.28
Culvert	Culvert - (Approx 2000W)	extend existing culvert	East end of Carramar Stn	UT-024	25.73
Caramar Station					25.97
Culvert	Culvert	extend existing culvert	Next to Prospect Ck	UT-025	26.01
4th Ave. Pedestrian bridge					27.25
Bareena Street					27.7
Culvert	Structure under Main South is a single 4.25m span depth varies 1.22 max, 0.86th roof slab	extend existing culvert as 3 cell 1200X1200	On west side of Bareena St	UT-029	27.86
Cabramatta Station					32
Culvert	Stormwater Pipe Diameter 375 mm	extend existing culvert		UT-035	33.77
Hume Highway					33.97
Warwick Farm Station					34.05
Culvert	1500 x 1000 RCBC	extend existing culvert	On west side of Warwick Farm Stn	UT-037	34.397
Culvert	460mm Culvert	extend existing culvert	Culverts under corridor with outlet to	UT-039	35.161
Culvert	460mm Culvert	extend existing culvert		UT-039	35.244

Cross corridor culvert drainage structure [station and road positions also noted for reference]	Existing structure	Construction for SSFL	Note on location	Drg.No	Chainage (km)
Culvert	610mm Culvert	extend existing culvert	Georges River at steep section of river bank	UT-039	35.354
Liverpool Station					35.6
Newbridge Rd					35.78
Culvert	910mm Culvert	extend existing culvert	Under Newbridge Rd bridge	UT-040	35.788
Culvert	525 diameter brick culvert	extend existing culvert	Under Newbridge Rd bridge	UT-040	35.8
Culvert	610mm Culvert	extend existing culvert	In Liverpool stabling yard	UT-041	35.844
Culvert	610mm Culvert	extend existing culvert	In Liverpool stabling yard	UT-041	35.898
Culvert	610mm Culvert	extend existing culvert	In Liverpool stabling yard	UT-041	35.97
Culvert	910mm Culvert	extend existing culvert	Culverts under railway embankment in Mill Park	UT-043	36.961
Culvert	910mm Culvert	extend existing culvert		UT-044	37.044
Culvert	610mm Culvert	extend existing culvert		UT-044	37.38
South-Western Motorway					37.39
Culvert	Possible Culvert	If culvert exists and is used, extend existing culvert	Culverts under railway embankment in River Park	UT-046	37.97
Culvert	1220mm Culvert	extend existing culvert	Culverts under railway embankment in River Park	UT-046	38.161
Culvert	610mm Culvert	extend existing culvert	On north end of Casula Stn	UT-047	38.309
Culvert	610mm Culvert	extend existing culvert		UT-047	38.431
Culvert	300mm Culvert	extend existing culvert		UT-047	38.548
Culvert	300mm Culvert	extend existing culvert		UT-049	38.775
Casula Station					38.7
SSFL Flyover					39.7
Cambridge Ave					41
Culvert on south side of Cambridge Avenue	2 X 1050 dia RCP	extend existing culvert with a twin cell RCBC 1200X1500			
Glenfield Stn					41.85
Henderson Rd					44.85
Ingleburn Station					45.65
Culvert	1800 x 750 mm conc box culvert	extend existing culvert		UT-068	46.359
Culvert	1800 x 700 mm conc box culvert	extend existing culvert		UT-068	46.447
Culvert	Disused Culvert	If culvert exists and is used, extend existing culvert		UT-069	46.688
Culvert	Culvert 2/900mm connecting to 2/1200mm pipes	extend existing culvert		UT-075	49.3
Minto Station					49.7
Culvert	2 No. 600 dia pipes	extend existing culvert		UT-076	49.825
Ben Lomond Road					49.95
Culvert	1350 mm Pipe connecting to Culvert	extend existing culvert		UT-077	50.015

Cross corridor culvert drainage structure [station and road positions also noted for reference]	Existing structure	Construction for SSFL	Note on location	Drg.No	Chainage (km)
	3300 mm x 900 mm and follow by connecting to 600 mm Pipe				
culvert	2 No. 900 dia pipes	extend existing culvert with RCBC 3m wide, 2.3m deep		UT-078	50.4
Culvert	Culvert 1200 mm connecting to 400 mm Pipe + 900 mm Pipe + 400 mm Pipe	extend existing culvert		UT-079	50.84
Culvert	Culvert 750 mm connecting to 600 mm pipe	extend existing culvert		UT-081	51.49
Culvert	Culvert 600 mm	extend existing culvert		UT-081	51.645
Culvert	Culvert 600 mm	extend existing culvert		UT-081	51.718
Rose Payten Drive					52.01
Underbridge [culvert]	Culvert 1200 mm	extend existing culvert		UT-082	52.15
Leumeah Station					52.53
Campbelltown Road					53.4
Culvert	500 mm RCP, 2 cell RCBC each cell 3.03 wide, depth varies 1.57m max, invert RL56.66	extend existing culvert with 2 cell RCBC 3.0m wide, min 2.1m high		UT-086	53.61
Culvert	Culvert	extend existing culvert		UT-086	53.811
Culvert	Culvert	extend existing culvert		UT-087	54.22
Campbelltown Station					54.6
Culvert	2 cell RCBC 1.2m high, widths 2.975 & 2.63	extend existing culvert as 4 cell RCBC 1.8 min height, 3.0m wide		UT - 089	54.88
Fishers Ghost Creek culvert	Box Culvert 500mm Wide x 1200mm, Trapezoidal channel 1.24m high, width 3.31m at top ,0.9 at base invert at RL7.62	extend existing culvert as 4 cell RCBC 3m wide , min. height 3		UT - 090	55.35
Burunji Creek at Narellan Road	Three cell box culvert	extend existing culvert with a 3 cell RCBC 2.1m wide , min. height 2.7m			55.83
Gilchrist Drive					56.23
Culvert	Culvert	extend existing culvert		UT - 093	56.4
Macarthur Station				UT - 094	56.52
Culvert	Culvert	extend existing culvert		UT - 095	57.015