Appendix B

Sydney Light Rail - Inner West Extension Options Study – GreenWay, Alternatives for Davis Street to Old Canterbury Road

CLIENTS | PEOPLE | PERFORMANCE

Sydney Light Rail - Inner West Extension

Options Study - GreenWay Alternatives for Davis Street to Old Canterbury Road

November 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Executive Summary

The current concept design for the Sydney Light Rail Inner West Extension and GreenWay provides that, between Davis Street and Old Canterbury Road, the GreenWay shared path departs from the rail corridor and diverts along Weston Street (the base case). This study considers a range of alternatives to the Weston Street GreenWay proposal and describes and assesses the issues associated with these alternatives, particularly with regards to constructability within the rail corridor.

A number of options were investigated and these are documented in this report. The options considered are:

Option 1 Western option with the GreenWay on the western side of the rail corridor and adjacent to the Hawthorne Canal, which includes three sub-options;

Option 2 Eastern option with the GreenWay on the eastern side of the rail corridor, which includes three sub-options;

Option 3 Adjustment of Light Rail to single track operation, which includes two sub-options; and

Option 4 Outside of rail corridor option where the GreenWay is taken to the east side of the rail corridor and utilises adjacent residential streets.

The merit of each option was assessed against a set of criteria comprising functionality (GreenWay and Light Rail), costs and impacts.

The Western Option (Option 1B), with the GreenWay shared path running adjacent to the existing Hawthorne Canal within the western side of the rail corridor, has been assessed by GHD as the Study Preferred Option out of the alternatives considered. In this study, it provides the best overall outcome of all the options in terms of functionality, cost and adverse impacts when assessed qualitatively. Indicative concept drawings are provided in Appendix C.

Option 1B provides an improvement in GreenWay functionality by maintaining the GreenWay within the western side of the rail corridor. Whilst technically feasible, this option nonetheless presents significant construction challenges and risks due to the existing terrain and the proximity of the Hawthorne Canal. There are also constriction points due to adjoining properties along the rail corridor. This option is estimated to cost in the order of $6.1m. This is significantly more than the current base case with the Greenway shared path directed along Weston Street between Davis Street and Old Canterbury Road.

It is not within the scope of this study to determine a preference between the current base case and the Study Preferred Option.

1. Purpose

The current concept design for the Sydney Light Rail Inner West Extension and GreenWay provides that, between Davis Street and Old Canterbury Road, the GreenWay departs from the rail corridor and diverts along Weston Street (the base case). The on-street deviation was adopted due to existing land use and corridor constraints at this section of the route.

The section of Light Rail Extension and the GreenWay from Dulwich Hill to Parramatta Road near Leichhardt is indicated in Figure 1, with the study area highlighted.

GHD has been advised that as part of the exhibition phase of the Environmental Assessment, a number of the residents of Weston Street have raised objections to the routing of the GreenWay along Weston Street.

The purpose of this study is to consider alternatives to the base case and to understand the issues associated with these alternatives, particularly with regards to constructability within the rail corridor. This study does not revisit the overall GreenWay strategy. The alternatives considered will need to integrate with the current GreenWay strategy as documented in the *Sydney Light Rail Extension - Stage 1 - Inner West Extension Environmental Assessment* prepared by Transport NSW.

It is not within the scope of this study to determine a preference between the current base case and the alternative options.

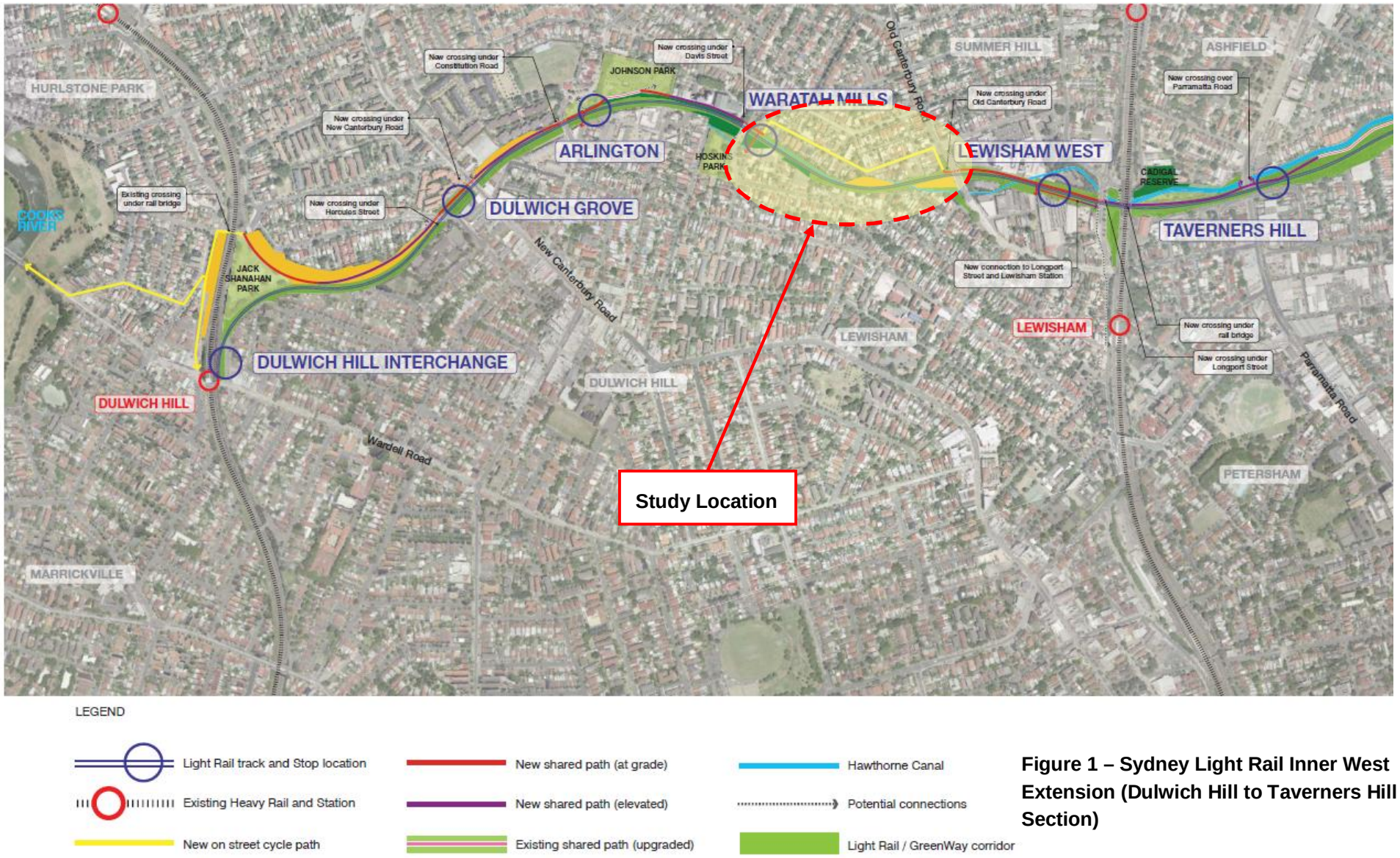


Figure 1 – Sydney Light Rail Inner West Extension (Dulwich Hill to Taverners Hill Section)

2. Background

The GreenWay Sustainability Project is a partnership between the four Inner West Councils of Ashfield, Leichhardt, Marrickville and Canterbury.

The GreenWay vision is to design and implement a best practice model for shared responsibility towards achieving a sustainable environmental, cultural and non-motorised corridor that links the sub-catchments of Cooks River and Iron Cove.

The section of the GreenWay associated with the Light Rail Inner West Extension is a shared movement and biodiversity corridor, incorporating a shared pathway (for pedestrians and bicycle users) predominantly located on the western side of the rail corridor.

The proposed GreenWay currently departs the rail corridor between Davis Street and Old Canterbury Road and diverts along Weston Street as a shared traffic zone. At the northern end of Weston Street, the GreenWay reconnects with the rail corridor prior to extending under Old Canterbury Road via a new underpass.

The Weston Street route was selected on account of the significant constraints within the rail corridor between Davis Street and Old Canterbury Road. These are discussed in Section 5.

Figure 2 – GreenWay between Waratah Mills and Lewisham West Light Rail Stops

3. Glossary

Term	Definition
Capping	Impermeable layer or fill located immediately above the main formation and designed to shed water to the sides of the track.
CSR	Combined Services Route.
Down Track	The rail track taking trains from Sydney. For the Light Rail, this track takes the vehicles away from Sydney's Central Station, and is the right track when looking towards Sydney along the rail alignment.
Formation	Ground immediately beneath the capping and track.
GHD	GHD Pty Ltd.
GreenWay	In the context of this report, the term "GreenWay" is the shared pathway associated with the shared movement and biodiversity corridor between Cooks River and Iron Cove.
HV	High Voltage.
Kinematic Envelope	A two dimensional cross-sectional representation of the swept path of a particular vehicle.
OHW	Overhead Wiring.
Six Foot (6 ft)	The space between the tracks. For the Light Rail, this is the space between the Up and Down tracks.
Structure Gauge	Envelope around the track within which no structure is permitted.
Study Preferred Option	The preferred option resulting from options assessed under this study.
SWC	Sydney Water Corporation.
TNSW	Transport NSW.
Up Track	The rail track taking trains towards Sydney. For the Light Rail, this track takes the vehicles towards Sydney's Central Station, and is the left track when looking towards Sydney along the rail alignment.

4. Study Methodology

The following study methodology has been adopted to explore possible alternatives for the GreenWay in lieu of the Weston Street base case.

- Review the available existing information. A list of background information is included in Appendix G. A visual inspection of the site was also undertaken on 9th November 2010.
- Develop constraints and design parameters. These establish the criteria for option development in subsequent stages.
- Develop options with input from the various engineering disciplines.
- "Options Development Workshop" to challenge the options developed and the constraints/parameters adopted, add-value and determine additional options.
- Develop Options Filter. The options filter provides a method to assist in the ranking and potential abandonment of the various options.
- After the options have been ranked, a short-list of options or a Study Preferred Option would be identified. From this, a conclusion is provided.

Only the Study Preferred Option(s) have been developed further to permit a high level costing to be undertaken.

5. Key Features and Constraints

There are a number of key features and constraints along the rail corridor between Davis Street and Old Canterbury Road. These include:

- Hawthorne Canal originally constructed in the late nineteenth century. The canal crosses under the rail tracks immediately north of Davis Street and continues northwards along the western edge of the rail corridor prior to returning to the eastern side under the rail tracks approximately 100m south of Old Canterbury Road. Refer to Figure 2 in Section 2.
- The concrete canal structure resists significant earth surcharge loads from the existing properties on its western side and the existing rail embankment on its eastern side. A portion of the canal also supports masonry (and other) walls retaining earth fill; these walls rise to over 2m in height. These walls have been constructed after the canal and the structural adequacy of these walls is unknown. An inspection of the canal and the masonry retaining walls has not been conducted as part of this study; we understand that the canal has performed adequately to date.
- Sections of the existing rail embankment batter are steep and the quality of the embankment fill is unknown. The stability of the embankment has not been assessed as part of this study. The performance of the embankment to date should be confirmed with RailCorp.
- Aerial high voltage power lines run on timber poles along the western side of the rail corridor from Davis Street prior to crossing to the eastern side of the rail corridor.
- Extensive vegetation along the western side of the rail corridor providing a high degree of visual screening for adjacent residents. There are a number of trees located on the rail embankment, including Camphor Laurels and Eucalypts.
- There are a number of pinch-points along the rail corridor (approximate horizontal offset from nearest track centreline to the property fence line given in parenthesis from measurements undertaken by RailCorp surveyors):

  <u>Western Side</u>

  – 69 Weston Street (6.5m);
  – 37-39 Weston Street (7.2m); and
  – 115 Old Canterbury Road (5.8m).

  <u>Eastern Side</u>

  – 3 Nelson Street (4.0m); and
  – 1 Short Street (4.9m).
- Existing Bushcare sites on the north-east corner of Davis Street, and on the east side of the rail corridor between Nelson Street and Short Street.

6. Key Design Criteria

6.1 Operation of the Light Rail

The operational functionality, current and future, of the Light Rail is not to be compromised. Operational requirements include:

- Service frequency and reliability;
- Safety of Light Rail operation;
- Maintenance (such as wheel wear, track wear and re-tamping of ballast);
- Ride comfort; and
- Environmental considerations (such as noise).

6.2 Track Centres

For heavy rail systems in NSW, the minimum track centres for design of new works is 4.0m for straight tracks or where curve radius > 1000m. Where curve radius is less than 1000m the track centres will need to be increased to allow for curve effects.

A previous study has recommended track centres for the Light Rail based on the existing Variotram (reference: GHD report *Central Sydney Light Rail Route Evaluation Study Dynamic Envelope and Clearances*, August 2004, document number 21/11911/00/100503). The study also considered the guidance for clearance provided by the UK Health and Safety Executive (HSE) document *Railway Safety Principles and Guidance* Section 2 Part G *Guideline on Tramways* (Doc HS(G) 153/8). It must be noted that his study was undertaken for on street running of the Light Rail through Central Sydney. The track centres indicated in the study are tabulated below.

Table 1 Track Separation from *Central Sydney Light Rail Route Evaluation Study Dynamic Envelope and Clearances*

Dimension	Structure
3,350mm	Original Light Rail system specification for straight track and no super-elevation.
3,086mm	For Variotram (with rear facing cameras) for straight track and no super-elevation.
3,136mm	For Variotram (with rear facing cameras) for straight track and no super-elevation, using recommended clearances from UK HSE *Railway Safety Principles and Guidance*.
3,340mm	For Variotram (with rear facing cameras) for 50m radius track and no super-elevation, using recommended clearances from UK HSE *Railway Safety Principles and Guidance*.

The above report suggests that a minimum track centre of approximately 4.0m would be required where overhead wiring structures are to be located within the six foot.

Track centres are subject to detailed design taking into account wheel wear, track condition, bounce through suspension, track alignment (curvature and super-elevation), etc. Where reduced centres are to be used, a risk based assessment and agreement with the asset owner and operator will be required.

Survey information for the recently re-laid tracks is not yet available. Spot measurements of the track separation between Davis Street and Old Canterbury Road show the track spacing to vary from approximately 3.60m to 4.31m.

6.3 Minimum Clearances

The study of railway clearances generally follows the principle that line-side infrastructure or equipment should not impede the operation of railway vehicles and maintenance of the rail infrastructure. In review of RailCorp Standard ESC 215 this is managed in the following way:

- Normal Structure Gauge is an envelope indicating the minimum outline for new structures or infrastructure. This is applicable to all tracks where clearance is available, provides for ease of use under most circumstances and includes appropriate infrastructure service requirements. No restrictions are placed on rolling stock operation and its use does not require determination of kinematic envelopes, nor consideration of waivers or approvals.
- Where the requirements of the Normal Structure Gauge cannot be met, more detailed consideration is required. For certain elements of infrastructure Minimum Infrastructure Service Requirements are defined. These include OHWS, signals, bridge piers and structure footings.

It is noted that the operation of the Light Rail does not fall within all the requirements specified by RailCorp for heavy rail.

6.3.1 RailCorp Engineering Standards

RailCorp Engineering Standard ESC215 *Transit Space* specifies the following horizontal dimension between the face of a structure and the closest track centreline:

Table 2 ESC215 Transit Space Clearances

Dimension	Structure
2,150mm	To structures and structure footings up to one metre below design rail level to allow for operation of ballast cleaners. No allowance is required for curve effects.
3,000mm	OHWS masts and signal bridge masts adjacent to a track.
3,500mm	Piers, columns, deflection walls between tracks.
4,300mm	- Bridge substructure and deflection walls (except between tracks). - Cuttings without road access. - Station buildings. - Columns, footbridges.
5,000mm	Other structures located adjacent to electrified tracks and where road access is not required.
6,200mm	- Other structures and cuttings located adjacent to electrified tracks and where road access is required between the structure and the track. - Bridges or air-space developments where an overhead wiring or signal mast is required within the structure limits.

6.3.2 Previous Light Rail Studies

A previous study has recommended clearances for the Light Rail based on the existing Variotram (reference: GHD report *Central Sydney Light Rail Route Evaluation Study Dynamic Envelope and Clearances*, August 2004, document number 21/11911/00/100503). The study also considered the guidance for clearance provided by the UK Health and Safety Executive (HSE) document *Railway Safety Principles and Guidance* Section 2 Part G *Guideline on Tramways* (Doc HS(G) 153/8). It must be noted that his study was undertaken for on street running of the Light Rail through Central Sydney. The clearances indicated in the study are tabulated below.

Table 3 Clearances from Central Sydney Light Rail Route Evaluation Study Dynamic Envelope and Clearances

Dimension	Structure
2,200mm	Original Light Rail system specification to continuous structures with 600mm zone to kinematic envelope, for straight track and no super-elevation.
2,068mm	To continuous structures with 600mm safety zone to kinematic envelope for Variotram (with rear facing cameras) for straight track and no super-elevation.
1,718mm	To centre of road marking (adjacent to road traffic) for Variotram (with rear facing cameras) for straight track and no super-elevation, using recommended clearances from UK HSE *Railway Safety Principles and Guidance*.
1,765mm	To centre of road marking (adjacent to road traffic) for Variotram (with rear facing cameras) for 50m radius track and no super-elevation, using recommended clearances from UK HSE *Railway Safety Principles and Guidance*.

The *Sydney Light Rail Extension - Stage 1 - Inner West Extension Environmental Assessment* provides for a "minimum clearance between the track centre line and GreenWay shared path [of] 3.5 metres subject to detailed design and operational clearance requirements" (page 120). We note that this is a preferred clearance where there are no spatial impediments.

6.3.3 Clearance adopted by this Study

The rail corridor between Davis Street and Old Canterbury Road has a number of pinch points that severely impact the ability to provide the preferred clearances between the GreenWay and the track centreline. To minimise constriction on the GreenWay and the impact on adjoining properties, an absolute minimum clearance equal to Kinematic Envelope + 200mm (Structure Gauge) has been adopted between the GreenWay and the closest track centreline. A minimum clearance of 2,100mm has been adopted based on the following preliminary assessment of Structure Gauge:

- Light Rail Vehicle = 1,765mm + 200mm = 1,965mm.
- Maintenance Vehicle = 1,840mm + 200mm = 2,040mm.

These are preliminary only and are subject to detailed design taking into account wheel wear, track condition, bounce through suspension, track alignment (curvature and super-elevation), etc. These clearances will require a risk based assessment and agreement with the asset owner and operator.

6.4 Level of GreenWay

Discussions between Transport NSW and Sydney Water Corporation (SWC) indicate that the GreenWay structure should be above the 1 in 100 years Average Recurrence Interval (ARI) flood level. Information on the 1 in 100 years ARI level is not available at this stage.

For the purpose of this study, the level of the GreenWay when adjacent to the tracks is preferred to be located approximately at the same level as the top of rail. This would provide the same flood clearance for the GreenWay as for the Light Rail.

6.5 Rail Systems Space Proofing

For twin tracks, overhead wiring supports could be placed on the outside of the tracks. Where portals are utilised, then the GreenWay will need to be offset sufficiently to enable the supports to be located clear of the Structural Gauge and protected from GreenWay users by a protection screen. Alternatively, given the spatial constraints, overhead wiring masts cantilevering over both tracks from the non-GreenWay side will need to be provided. The design of the overhead wiring system, including the location of the supports, is undertaken during detailed design to best cater for the constraints once these have been identified.

Rail systems and services could be located in a combined services route (CSR) positioned to suit the GreenWay.

6.6 GreenWay Width

Austroads' *Guide to Traffic Engineering Practice, Part 14 – Bicycles* (1999, page 83) recommends the following off-road shared path widths:

Table 4 GreenWay Width

	Path Width (m)		
	Local Access Path	**Commuter Path**	**Recreational Path**
Desirable	2.5m	3.0m	3.5m
Accepted Range	2.0 - 2.5m	2.0 – 3.5m	3.0 – 4.0m

The overall strategy has considered the GreenWay a recreational path as documented in the *Sydney Light Rail Extension - Stage 1 - Inner West Extension Environmental Assessment*. Given the spatial constraints within the rail corridor and consistent with the above environmental assessment, the preferred minimum width for the Greenway is 3.0m.

6.7 GreenWay Ramp Gradient

The *Sydney Light Rail Extension - Stage 1 - Inner West Extension Environmental Assessment* has noted AS 1428.1 *Design for access and mobility – General*

requirements for access - New building work typically requiring that the gradient of general paths of travel are not to exceed 1 in 14, with a gradient of 1 in 20 or shallower being preferred. It acknowledges that some portions of the GreenWay are unlikely to achieve this requirement due to the nature of the terrain in the corridor.

This study has adopted a maximum gradient of 1 in 14.

6.8 GreenWay Features

Reference should be made to the *Sydney Light Rail Extension - Stage 1 - Inner West Extension Environmental Assessment* for features such as handrails/safety rails, fencing, lighting, signage and crime prevention.

6.9 Geotechnical Conditions

The Light Rail Inner West Extension alignment occurs within the upper sedimentary strata of the Sydney Basin. The bedrock stratigraphy comprises sub-horizontal beds of middle to early Triassic age. This sequence includes the Hawkesbury Sandstone that is overlain by the Ashfield Shale of the Wianamatta Group. The transitional Mittagong Formation is present at the boundary of the Ashfield Shale and Hawkesbury Sandstone. The subject area is generally within the lower portions of the Ashfield Shale and Mittagong Formation. A natural soil profile of residual and transported (predominantly water borne) origin is present near the surface. The near surface conditions have been substantially modified by past excavation and fill placement.

The existing rail formation between Davis Street and Old Canterbury Road is generally formed by embankment filling. The rail alignment in this area is either substantially parallel to or coincident with the Hawthorne Canal. Within the subject portion of the alignment, the Hawthorne Canal is generally located near the western toe of the rail embankment. However, the canal crosses below the rail embankment twice between Davis St and Old Canterbury Road and the northern and southern ends of the study portion have the Hawthorne Canal situated to the east of the rail corridor. The two Hawthorne Canal crossings are near Weston St (near the southern end) and near Fred St to the north.

Hawthorne Canal was developed along a natural drainage feature (Long Cove Creek) that drains towards Iron Cove. The tributary of Long Cove Creek would contain deposits of natural sediments that have the potential to be of low strength and compressible. The extent and depth of remnant sediment deposits along (adjacent to or below) Hawthorne Canal is not currently established.

Reference to historical drawings (*Sydney 7 Suburbs Storm Water Drainage - Long Cove Creek Main Channel*) illustrates the alignment of Hawthorne Canal relative to the surface drainage feature prior to canalisation. The drawing indicates that the canalisation of Long Cove Creek broadly followed a "smoothed" approximation of the natural Long Cove Creek alignment. In portions the natural creek alignment was apparently to both the east (below the rail embankment) and west of the current canal alignment, as well as directly below the canal.

The rail embankment adjacent to the canal is steep, and along portions of the alignment there does not appear to be any bench between the embankment and the canal. The embankments are moderately high and surcharge the canal. The structure and condition of the canal has not been subject to assessment at this stage. Assessment of the canal would need to be undertaken as part of the design of any options interacting with the canal. In some locations, the canal structure has been extended upwards with partial brick construction and would be potentially sensitive to minor movements. While we are not aware of reports of structural distress in the canal liner, the potentially settlement-sensitive nature of the canal requires that an increase in surcharge loading to be canal should be avoided unless substantive investigation or testing can validate performance requirements.

The composition of the embankment fill material in this region has not been established. Rail embankment fill materials may be expected to include material sourced from local cuttings (including excavated shale and sandstone). Fill material derived from Hawkesbury Sandstone is generally of favourable engineering qualities for use as embankment fill. Conversely, the soils derived from Ashfield Shale are of medium to high plasticity, require greater effort to achieve compaction (and hence are more likely to have received poor compaction), are subject to volume change with varying moisture conditions, are subject to breakdown with time and have lower shear strength. Recycled railway earthworks materials (spent ballast and capping) and ash are commonly encountered in rail embankments. Considering the age of the embankment construction, highly variable earthworks conditions may be encountered. Waste railway materials (sleepers, track or similar) as well as boulders can be encountered in embankments of this age, adversely affecting various construction activities - particularly piling, pier or anchor (if required) construction.

Notwithstanding the above, the embankment has been in place for many decades. We are not aware of reports of significant failures or adverse effects upon the adjacent Hawthorne Canal. Significant construction on or adjacent to the embankment or canal will require further review of RailCorp and Sydney Water records to further establish the past performance of these assets at this location. It is noted that the existing vegetation is likely to have aided the performance of the surface zone of the embankment to date. The root system of the established trees should not be removed if the vegetation is required to be removed or alternate stabilisation measures undertaken.

If deep excavation/drilling is required (such as for bored pier construction) then consideration is required to the assessment of potential contaminants within spoil derived from either the embankment fill or any natural sediments. Similarly, water ingress is to be anticipated into deep excavations or drill holes adjacent to a drainage feature. Embankment fill material and sediments are likely to be subject to collapse and will require casing or alternate support systems.

7. Analysis and Filters

7.1 Ratings for Options

The assessment below was made using a range of modifiers from positive improvements to negative impacts. The ratings were assigned in terms of the following compared to the current proposal along Weston Street (base case):

+ + +	Substantial improvement
+ +	Moderate improvement
+	Minor improvement
0	Neutral / no change
-	Minor impact
- -	Moderate impact
- - -	Substantial impact

7.2 Criteria

The following section provides a definition for the following assessment criteria.

Directness – Directness concerns the extent to which the infrastructure provides the opportunity to cycle and walk/run between points of departure and destinations via a route as direct as possible.

Comfort – Comfort for cyclists and pedestrians includes traffic nuisance factor, the ease of finding the route and comprehensibility. Traffic nuisance relates to cyclists and pedestrians travelling next to roads where there are likely to be traffic fumes, while way-finding and comprehensibility relate to cyclists and pedestrians being able to easily navigate along the GreenWay route.

Safety – Safety relates to avoiding conflicts with crossing traffic, separating cyclists and pedestrians and general traffic, and reducing speeds where possible.

8. Options Assessment

8.1 Summary of Options

A number of options were investigated and these, including various sub-options, are documented in Appendix A *Options Considered*. These options are:

Option 1 Western option with the GreenWay on the western side of the rail corridor and adjacent to the Hawthorne Canal, which includes three sub-options;

Option 2 Eastern option with the GreenWay on the eastern side of the rail corridor, which includes three sub-options;

Option 3 Adjustment of Light Rail to single track operation, which includes two sub-options; and

Option 4 Outside of rail corridor option where the GreenWay is taken to the east side of the rail corridor and utilises adjacent residential streets.

8.2 Assessment of Options

8.2.1 Option 1 Western option with GreenWay adjacent to the Hawthorne Canal.

This option continues the GreenWay along the western side of the rail corridor. The GreenWay will need to be suspended where it is close to the Hawthorne Canal or where the existing rail embankment is overly steep. This option is documented in Appendix C.

The Option Filter has determined that Option 1B is the Study Preferred Option. Detailed discussion is provided in Section 8.3.

8.2.2 Option 2 Eastern option with the GreenWay on the eastern side of the rail corridor.

This option takes the GreenWay to the eastern side of the railway corridor. The GreenWay is required to be conveyed over the Light Rail via a suspended structure after Davis Street, and then return to the western side of the rail corridor either via a suspended structure or an underpass. This option is documented in Appendix D.

This option has no additional advantages, has significantly more impacts arising from elevated structures and subway construction and is also more costly than Option 1. As such, it is not the Study Preferred Option.

8.2.3 Option 3 Adjustment to Light Rail to single track operation.

Option 3 adjusts the Light Rail operation from twin tracks to a single track. This would maintain the GreenWay on the western side of the rail corridor and provide sufficient space on the existing rail formation for the GreenWay. This option is documented in Appendix E.

A single track option would compromise the operational functionality of the Light Rail and is not preferred.

8.2.4 Option 4 Outside of rail corridor option where the GreenWay is taken to the east side of the Light Rail corridor.

This option takes the GreenWay to the eastern side of the railway corridor. The GreenWay is required to be conveyed over the Light Rail via a suspended structure after Davis Street, then departs the rail corridor and travels along Short Street, Victoria Street and Fred Street before returning to the rail corridor and crossing to the western side of the rail corridor via an underpass. This option is documented in Appendix F.

This option has no advantages, has significantly more impacts arising from elevated structures and subway construction, includes an on-street section of the GreenWay and is more costly than Option 1. As such, it is not the Study Preferred Option.

8.3 Details of Study Preferred Option

In terms of engineering feasibility, functionality for the Greenway and Light Rail operations and costs, Option 1B is considered to be the Study Preferred Option of the various alternatives to the current GreenWay route along Weston Street (between Davis Street and Old Canterbury Road).

8.3.1 Description

The Study Preferred Option maintains the GreenWay within the western side of the railway corridor between Davis Street and Old Canterbury Road.

Moving north from the proposed Waratah Mills Light Rail Stop, details of the proposed scope of the Study Preferred Option are as follows:

- The GreenWay is at grade until the headwall of the Hawthorne Canal at the rear of 69 Weston Street.
- From the Hawthorne Canal headwall, the GreenWay is conveyed longitudinally over the canal and along the rail embankment on a suspended structure. The length of the suspended structure is approximately 200m. This study proposes a structure consisting of concrete slabs supported on steel girders. These girders are supported on precast concrete headstocks with cast insitu reinforced concrete piles. The nature of the structural form, material selection and frame spacing are to be determined during detailed design. Significant clearing of the existing vegetation will be required.
- Where the Hawthorne Canal deviates from the railway tracks and the existing embankment is not overly steep, the GreenWay can return to grade for an approximate length of 90m. Clearing of some vegetation for the GreenWay will be required, retaining the vegetation not impacted by the GreenWay.
- A suspended structure (approximately 40m in length) will then convey the GreenWay over the Hawthorne Canal as the canal passes under the railway tracks near Eltham Street (behind 17 and 19 Weston Street) prior to returning to grade.

- The Greenway runs at grade until it reaches Old Canterbury Road. If adopted as a solution, the horizontal and vertical alignment of the GreenWay would need to be developed during detailed design to eliminate or minimise the need for retaining structures.

Supporting the GreenWay directly on the Hawthorne Canal is not currently considered to be a practical solution. Detailed investigation of the existing structure and discussion with Sydney Water Corporation will be required before this solution can be considered. Initial discussions with Sydney Water Corporation have indicated that this is unlikely to be an acceptable solution.

A safety screen will be required along the eastern side of the GreenWay to protect users from Light Rail operations and vice versa. Safety fencing and privacy screens will be required as appropriate along the western side of the GreenWay.

There are two overhead high voltage power poles along the proposed GreenWay route. One pole has been identified as requiring relocation. Subject to detailed design, it may be possible to position the GreenWay to avoid the second pole.

There is one constriction point currently identified at the rear of 115 Old Canterbury Road. The width of the GreenWay could be narrowed to keep the GreenWay within the rail corridor. A possible constriction could also occur at the rear of 69 Weston Street. These constrictions will need to be confirmed during detailed design.

An opportunity exists to realign the existing twin rail tracks to the east. The position of the Down track will be constrained by Waratah Mills Light Rail Stop, and the rail corridor boundary at Nelson Street (adjacent to 10 Nelson Street) and at Short Street. The separation between the Up and Down tracks could also be reduced if required to provide further gains in clearances to the GreenWay and to the rail corridor boundary. These adjustments would enable the GreenWay to be moved eastward and away from the Hawthorne Canal and the existing rail embankment batter slope. This would result in the reduction in the length of the GreenWay that would be required to be elevated. Detailed survey and further design is required to confirm this opportunity.

8.3.2 Constructability

The Study Preferred Option (Option 1B) includes some 3 types of construction. Types 1A and 1B are cantilever construction with piles on each side of the Up track and precast bearers connecting the piles and laid between the sleepers of the Up track; Type 2 is a trestle structure with piles located on the embankment slope side of the Up track, and; Type 3 is construction on embankment fill. There are various construction issues and problems associated with each type of construction, which should be taken into account when assessing the overall costing and viability of the option. These construction types are shown in Appendix C.

Types 1A and 1B - Cantilever Construction

In some locations, the proximity of the Hawthorne Canal will preclude the placement of the outer pile for the trestle-type construction. In these instances, it will be necessary to construct a cantilever support, comprising an inner (tension pile) in the "6 ft", and an

outer bearing pile outside the Up Track. There will be a precast headstock connecting the tops of piles and cantilevering out to support the GreenWay. The pre-cast headstock will need to be laid deep in the Up track formation so as not to hinder future ballast cleaning operations. The construction issues associated with this type of design include:

- Material to be bored through is of unknown quality and could contain obstructions, ground water and contamination.
- The material to be bored through is likely to be poorly consolidated and would require temporary casing during construction.
- Piling will occur in very close proximity to the Hawthorne Canal (in particular the masonry retaining walls). The canal structure and the impacts of piling operation in such close proximity will need to be determined during detailed design. The canal structure will need to be monitoring during construction activities.
- The pre-cast headstock will be locally widened to fit over the piles, and this will preclude its being slid between sleepers. Therefore one or two sleepers will need to be removed at each location and the ballast, capping and formation excavated to sufficient depth to enable the pre-cast headstock to be installed. As the ballast material will naturally fall into the excavation, it will undermine adjacent sleepers, necessitating some temporary support for the track at each location. The precast headstocks will need to be slewed into position.
- Upon completion of headstock placement, the track will need to be re-ballasted at each site and hand tamped with pneumatic tools to provide track support. The small quantity and localised nature of this work will make machine ballasting and tamping uneconomic.
- In some locations, overhead HV power lines will provide some constraint to piling and crane operations. Relocation of the overhead HV power lines may be required prior to commencement of piling works.
- Removal and delivery of spoil and construction material (embankment fill) will be constrained to small vehicles and will require the use of relatively small excavation machinery. There will also be a requirement for larger construction equipment, such as piling rigs and cranes.

Type 2 - Construction on Trestles

Where the side slopes are too steep to permit formation construction, the option proposes a piled trestle solution, consisting of either a single bored pile with headstock (i.e. T-shape) or twin bored piles with connecting headstock with both piles on the embankment slope side of the Up track. The construction issues associated with this method include:

- In both cases, the piling will require piles to be bored at a significant offset from the shoulder of the embankment. In such locations, the removal of spoil and placement of reinforcement and concrete will be made difficult by the steep slope upon which the piles are to be bored.

- Piling for the trestle will be further away from the Hawthorne Canal than for Types 1A and 1B construction. As such, the impacts on the canal structure are expected to be less.
- Piling construction will be subject to similar constraints and difficulties as affect the cantilever construction (Types 1A and 1B).
- In some locations, overhead HV power lines will provide some constraint to piling and crane operations. Relocation of the overhead HV power lines may be required prior to commencement of piling works.
- Vegetation clearing and set out will be made difficult by the steepness of the slopes.
- As the GreenWay substructure is outside the track, there is no requirement to excavate between and remove sleepers to install elements of the substructure.
- Similar access constraints apply as for the Types 1A and 1B works.

Type 3 - Construction on Formation

In some lengths of the proposed GreenWay, the slope and available width of the land on the outside of the Up track is suitable for the placement of fill to form a formation upon which the GreenWay would be constructed. There no significant construction problems associated with this method, but the following issues should be considered:

- Land clearing and vegetation removal will be required.
- Removal of topsoil will be required to provide a reasonable foundation for the new embankment. In so doing, it is possible that areas of contamination could be uncovered, as it is possible that, over past decades, all manner of materials could have been dumped or disposed of in the rail corridor. The excavated material is unlikely to be classified as Virgin Excavated Natural Material (VENM).
- Removal and delivery of spoil and construction material (embankment fill) will be constrained to small vehicles and will require the use of relatively small excavation machinery.
- In areas where this form of construction is used, it will be necessary to construct a cess drain between the GreenWay formation and the Up track formation. Depending on the topography and longitudinal slope gradient (appears to be very flat), it could be necessary to construct culverts beneath the GreenWay formation for disposal of cess drainage.

General

Following completion of the various forms of substructure, the construction of the superstructure should be relatively straight forward. The repetitive nature of the work will lend itself to off-site prefabrication of decking units, with the need to make adequate allowances for construction tolerances associated with the construction of the substructure.

Lifting of the steel girders, precast headstocks and precast deck units will need to be carried out from the existing rail formation and will be constrained by the overhead HV

power lines and the required reach. The latter will determine the maximum weight of the girders and precast units.

Overhead HV power lines will continue to be an obstruction to construction, and indeed will need relocation to remove power poles directly in the path of the Greenway.

Noise, dust, contaminants in the excavated material (if any) and the general unsightliness of a construction site and the need to avoid oversighting of adjacent private properties during construction will add to the site impediments.

8.3.3 Cost Estimate

The indicative estimate of the cost for the Study Preferred Option is included in Appendix H and summarised below:

Table 5 Cost Estimate

Item	Cost (millions, exclusive of GST)
Contractors Direct Costs	$2.98m
Contractors Indirect Costs	$1.13m
Sub-Total #1	$4.11m
Client Cost	$0.58m
Sub-Total #2	$4.69m
Contingency (at 30%)	$1.41m
Total	$6.10m

The above cost estimate is based on the extent of elevated structure as shown in Appendix C Figures 1-2 and 1-3.

8.3.4 Options Filter

The table below provides a detailed option filter for the Study Preferred Option with GreenWay adjacent to Hawthorne Canal. This table describe the impacts on each of the listed criteria in the manner described in Section 7.

Table 6 Study Preferred Option Detailed Option Filter

Criteria	Description	Rating
Functionality:		
Directness	Relatively direct.	+++
	Integrated with the rest of the GreenWay by remaining within the western side of the rail corridor.	+++

Criteria	Description	Rating
Comfort	Few grade changes, with relatively straight sections.	++
Safety	GreenWay users would be much closer to the Light Rail than on Weston Street. This will require protection fencing.	-
	Additional fencing and privacy screens on the western side of the GreenWay will create a “tunnel” effect.	-
	This section of the GreenWay would also be remote from the access points and Old Canterbury Road.	-
	The above fencing/screens and limited access - with no alternative route of escape - can create a safety issue for users.	-
Pedestrians	Pedestrians and cyclists would be mixed under this option, as compared to being separated on Weston Street.	0
Traffic	Pedestrian and cyclists would be on the GreenWay rather than Weston Street, resulting in no conflict with vehicular traffic.	++
Costs:		
Capital Costs	Approximately $6.1 million	- - -
Lifecycle Costs	Inspection and periodic maintenance of the suspended structure will be required.	- -
Impacts:		
Construction impacts	Difficult to construct along steep rail embankments.	- -
	Need to relocate overhead high voltage pole.	- -
	Impacts on existing track drainage.	-
	Impact on the location and type of overhead wiring structures.	-
	Risk of damage to track formation and rail infrastructure during construction.	-
	There is a risk that construction of the GreenWay may detrimentally impact the Hawthorne Canal, particularly the masonry retaining walls.	-
Environmental impacts	Removal of vegetation along the western side of the railway corridor.	- -
	Screenings will be required along the GreenWay for safety and privacy.	-

Criteria	Description	Rating
	Elevated structure reduces the impact of the 1 in 100 years ARI flood event.	0
Planning risks	Constriction of the GreenWay at the rear 115 Old Canterbury Road.	-
	Maintenance access to the Hawthorne Canal is readily available.	+
Structural impacts	Maintenance of the tracks will be detrimentally affected if the headstocks are not placed 1m below the top of rail.	-
	There is a risk associated with constructing a suspended GreenWay along the existing steep rail embankment. Geotechnical information on the embankment is not currently known.	-

9. Conclusion

A number of alternatives were developed to the base case GreenWay route along Weston Street north of Davis Street. The merit of each option was assessed against the criteria of the Options Filter.

A summary of the assessment is provided in the table below.

Table 7 Summary

Option	Options Filter Criteria		
	Functionality	**Cost**	**Impacts**
Option 1- Western Option	Improvement over the base case. The GreenWay remains within the rail corridor and maintains a direct western route.	Significantly more expensive than the base case.	More adverse impacts than base case. Impact on existing vegetation, privacy of adjoining residents, and risks to the Hawthorne Canal.
Option 2 - Eastern Option	Have both benefits and short-comings over the base case. The GreenWay remains within the rail corridor but does not provide a direct route.	Significantly more expensive than Option 1 (Western Option)	Significantly more impacts than Option 1 (Western Option)
Option 3 - Single Track Option	Whilst this option will improve the functionality of the GreenWay over the base case, this option significantly compromises the functional requirements of the Light Rail.	More expensive than the base case. Expected to be less than Option 1.	Expected to have low impacts other than to Light Rail operation. Impacts compromising the functional requirements of the Light Rail are unacceptable.

Option	Options Filter Criteria		
	Functionality	Cost	Impacts
Option 4 - Eastern Option Outside of Rail Corridor	Poor functionality when compared to the base case as it takes the GreenWay out of the rail corridor to the east, via an indirect path.	More expensive than the base case due to requirement to cross the tracks.	Significantly more impacts than the base case.

The Western Option (Option 1B), with the GreenWay shared path running adjacent to the existing Hawthorne Canal within the western side of the rail corridor, has been assessed by GHD as the Study Preferred Option as it provides the best overall outcome of all the options in terms of functionality, cost and adverse impacts when assessed qualitatively. Whilst technically feasible, this option nonetheless presents significant construction challenges and risks due to the existing terrain and the proximity of the Hawthorne Canal. There are also constriction points due to adjoining properties along the rail corridor. This option is estimated to cost significantly more than the current base case, with the GreenWay directed along Weston Street between Davis Street and Old Canterbury Road.

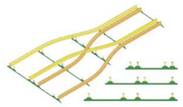
Appendix A

Options Considered

Option	Description	Advantages	Disadvantages	Risks	Opportunities	Mitigation	Functionality	Costs	Impacts
Base Case	Existing Option – GreenWay diverts to Weston Street								
Base	The GreenWay diverts to Weston Street between Davis Street and Old Canterbury Road.	Direct path. Network integrated as it keeps the GreenWay on the western side. Minimal costs.	Departs from the rail corridor. GreenWay is in a shared traffic zone. Objections from Weston Street residents.	GreenWay is in a shared traffic zone, increasing risk of potential incidents.		Delineate GreenWay from other traffic and provide additional signage.	0 (base)	0 (base)	0 (base)
1	Western Option – GreenWay adjacent to Hawthorne Canal								
1	General	Direct path. Network integrated as it keeps the GreenWay on the western side.	Costs Difficulty in construction. This will have a significant impact on the costs. Pinch points creating constriction at 115 Old Canterbury Road. Possible constriction at 69 Weston Street (South). Screenings and safety fence will create tunnel effect. Privacy for adjacent property owners.	Potential safety issue with proximity of GreenWay to tracks. Potential security issues for users with limited escape options. Risks associated with constructing in close proximity to the Hawthorne Canal and with clearing of vegetation on the existing embankment.	Push the GreenWay towards the western boundary to increase the clearances to the closest track. Narrow the GreenWay at pinch points to maximise the clearance from rail.	Provide fences/screens to separate GreenWay users from Light Rail. Provide privacy screens along the western side of the GreenWay.	See below.		
1A	Supported on Hawthorne Canal	Lower cost relative to sub-option 1B.	Reliance on existing structure for support. Require detailed investigation of existing structure. Likely to present problems in high rainfall noting that the canal is unlikely to be adequate for a 1 in 100 years ARI rainfall event. Difficult for SWC to access Hawthorne canal for maintenance. Poor construction access. Property boundary walls are already constructed on the Hawthorne Canal.	Existing structure may not be structurally adequate. The existing masonry walls are unlikely to be structurally adequate. Preliminary discussion with SWC has indicated that this is unlikely to be an acceptable solution for SWC. Impact on GreenWay in the event of localised failure of the existing structure.		Detailed investigation of the existing structure.	++	--	--
1B	Cantilever structure at pinch points. Portalised or cantilever structure generally.	Access to Hawthorne Canal is available for SWC maintenance. Minimise impact on the existing canal for the 1 in 100 years ARI rainfall event.	If level with sleepers, standard track maintenance can not be used. Relocation of over-head HV poles Difficulty in construction. This will significantly impact on the costs.	Interfacing with existing structures (Hawthorne Canal) Impact on track drainage system Location of overhead wiring structures Unknown geotechnical conditions for pile solution.	Opportunity to re-align the twin rail tracks (and to reduce track separation) to gain clearances and move the GreenWay further away from the Hawthorne Canal and the rail embankment. This may reduce the extent of the suspended GreenWay structure. There may be associated increase in maintenance cost, reduced ride comfort and localised speed reduction (note that Light Rail vehicles will be approaching or departing Waratah Mills stop). Detailed survey and further design development required.	Lower headstock to 1m below top of rail to keep standard maintenance. May require twin track cantilever OHWS.	++	---	-

Option	Description	Advantages	Disadvantages	Risks	Opportunities	Mitigation	Functionality	Costs	Impacts
1C	GreenWay structure supported on piles/piers along the western and eastern sides of Hawthorne Canal (independent of the Hawthorne Canal structure).	Expected to be similar in costs to Option 1B.	Due to the location of the existing property boundary relative to Hawthorne Canal, the new piers on the western side of the canal to support the GreenWay structure will need to beyond the existing rail corridor boundary. This will require property acquisition. Refer to disadvantages associated with Option 1A. Difficulty in gaining access for piling rigs to construct the new piles/piers to support the GreenWay structure along the eastern edge of the canal. Construction access will be required along the rear of the private properties adjoining the Hawthorne Canal to enable piling along the western edge of the canal. Difficulty in equipment access (and reach) for placement of prefabricated elements.	Refer to risks associated with Option 1A.		Detailed investigation of the existing structure.	++	---	--
2	Eastern Side of Corridor Option								
2	General		Indirect path with multiple changes over the Light Rail tracks. Existing overhead HV power lines will be impacted and will require substantial relocation works.				See below.		
2A	At grade crossings	Low costs relative to sub-options 2B and 2C.	High safety risk with GreenWay crossing the Light Rail tracks. Constriction due to pinch points at 3 Nelson Street and 1 Short Street.	High safety risks to users.			---	0	--
2B	Elevated crossing	Maintain the GreenWay within the Railway corridor.	Requires construction adjacent to Hawthorne Canal for significant part of or all of the length as for Option 1. Visibility of elevated structure. Elevated structure will need screens to protect privacy. Significant length of ramp seen as not user friendly. Significant costs due to the length of elevated structure required. Difficult to integrate with Lewisham West Stop if the GreenWay returns to the west via an elevated structure north of Old Canterbury Road.	Elevated structure may create environmental issues such as shadowing. Structure will have community impacts due to its visibility and will present privacy issues. Unknown geotechnical conditions for pile solution.		Create an aesthetic elevated structure with due allowance for privacy.	--	---	---

Option	Description	Advantages	Disadvantages	Risks	Opportunities	Mitigation	Functionality	Costs	Impacts
2C	Elevated and Underpass	Length of ramps for an underpass will be shorter than an elevated structure as the clearance required is expected to be marginally less under the rail than that required to clear overhead wiring.	User safety associated with an underpass. Water ingress into the underpass will require a sump at the low point and associated pumps. This will have an associated operating impact. The cost of an elevated structure and an underpass is expected to be significant. A longer construction time is expected for the underpass. Difficult to integrate with Lewisham West Stop.	Unknown geotechnical conditions for pile solution. Contamination may be an issue for disposal of excavated material. Security risk to users of the underpass.		Create an aesthetic elevated structure with due allowance for privacy.	--	---	---
3	Adjustment to Light Rail to single track operation								
3	General	The GreenWay can be kept on the western side of the Rail Corridor, generally constructed on the existing formation.	A preliminary assessment was undertaken by GHD in July 2010 (report titled *Sydney Light Rail Inner West Extension Study*) that indicated the need for two track light rail operations along the full length of the Inner West extension.						
3A	Single track section - points and signalling	Minimises width of track formation to ease the constraint upon the pinch points. Allows construction of the GreenWay on the current track formation, reducing the need for complex structural support of the GreenWay.	Single track operation has significant safety implications with risks of head on collisions of light rail vehicles. Although signalling systems do exist that would allow operation to occur they would not normally be considered viable for services operating at 12 minute headways in each direction . This would result in the need for speed restrictions to be enforced. (*Sydney Light Rail Inner West Extension Study* report by GHD dated July 2010). Requires signalling and interlocking arrangement. (more complex and expensive). Special trackwork will lead to an increased maintenance focus in the area. Reduction in future system efficiency and flexibility. There could be impact on operational reliability. Increased rail noise from rail cars crossing at cross-overs.	Passenger/employee injuries resulting from train collision.	Network modelling to determine impact of potential bottleneck.	Localised speed reduction.	++ (GreenWay) --- (Rail operation)	--	0 (GreenWay) - (Rail operation)

Option	Description	Advantages	Disadvantages	Risks	Opportunities	Mitigation	Functionality	Costs	Impacts
3B	Single track section - Gauntlet 	Minimises width of track formation to ease the constraint upon the pinch points. Allows construction of the GreenWay on the current track formation, reducing the need for complex structural support of the GreenWay. Does not require signalling arrangement. Avoids points	Single track operation has significant safety implications with risks of head on collisions of light rail vehicles. Although signalling systems do exist that would allow operation to occur they would not normally be considered viable for services operating at 12 minute headways in each direction . This would result in the need for speed restrictions to be enforced. (*Sydney Light Rail Inner West Extension Study* report by GHD dated July 2010). Safe use of the gauntlet is a function of the train driver/operational procedure. Special trackwork will lead to an increased maintenance focus in the area. Reduction in future system efficiency and flexibility. There could be impact on operational reliability.	Passenger/employee injuries resulting from train collision.	Network modelling to determine impact of potential bottleneck. More detailed risk assessment with all stakeholders to investigate safety issues.	Driver training/route awareness. Operational procedures, that is “give way” protocols. Localised speed reduction.	++ (GreenWay) --- (Rail operation)	-	0 (GreenWay) - (Rail operation)
4	Outside Rail Corridor on Eastern Side								
4	General	None.	Indirect path. Poor integration with the GreenWay network. Difficulty in conveying the GreenWay from the western side to the eastern side. This could be achieved by: ◗ Elevated structure south of Davis Street (costly, refer Options 2B/C). ◗ Elevated structure north of Davis Street (costly, refer Options 2B/C). ◗ At grade crossing at Waratah Mills Stop (safety issues, refer Option 2A)	Community impacts for residents on the eastern side.			---	--	---

Appendix B

Photographs

Photograph 1 – Looking north along the rail alignment near Davis Street

Photograph 2 – Looking north along the Hawthorne Canal

Photograph 3 – Looking north along the rail alignment

Photograph 4 – Looking north along the rail alignment towards Old Canterbury Road

Appendix C

Option 1B – Western Option: GreenWay Adjacent to Hawthorne Canal

Legend

- Constriction
- Powerpole
- approx Rail Centerline Drawn
- Greenway Alignment (Base Case)
- Hawthorne Canal
- Railway Boundary
- Light Rail Stop
- Greenway 1, At Grade
- Greenway 1, Elevated

1:1,250 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

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NSW Transport
Sydney Light Rail Inner West Extenstion

Option 1B
Greenway Adjacent to Hawthorne Canal

Job Number 21-19469
Revision A
Date 30 NOV 2010

Figure 1-1

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Project SYDNEY LIGHT RAIL INNER WEST EXTENSION
Title OPTION 1B - PLAN
GREENWAY ADJACENT TO HAWTHORNE CANAL

Original Size A1 Drawing No: Figure 1-2 Rev: A

Plot Date: 2 December 2010 - 8:10 AM Plotted by: Peter Boyan/Sydney/GHD/AU Cad File No: G:\21\19469\CADD\Drawings\21-19469-Fig1-2-3.dwg

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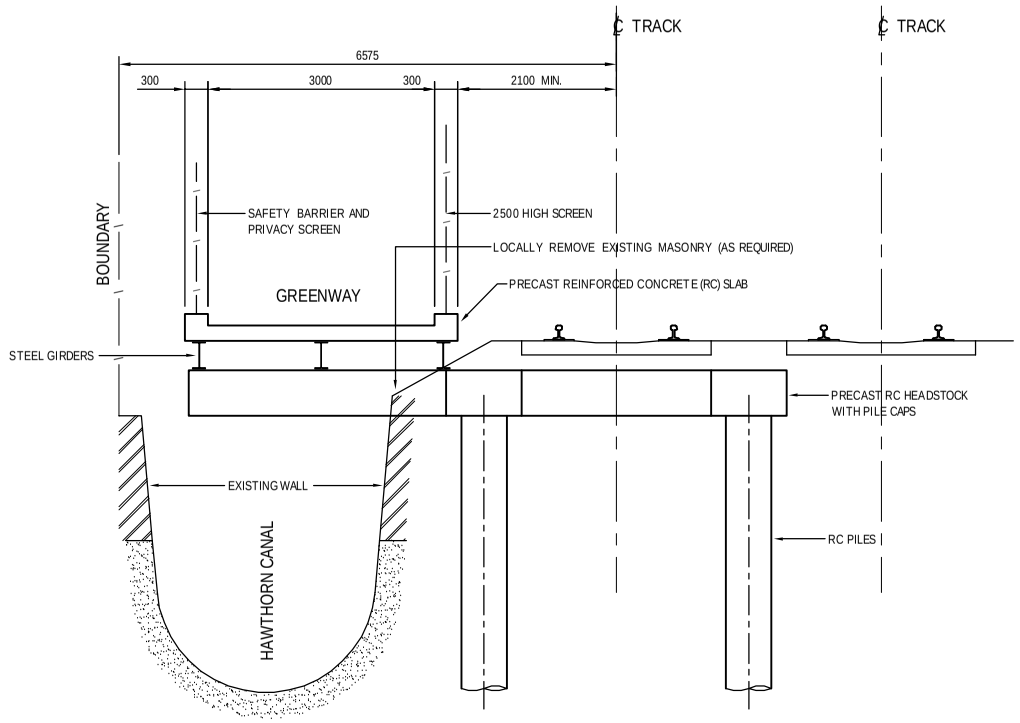

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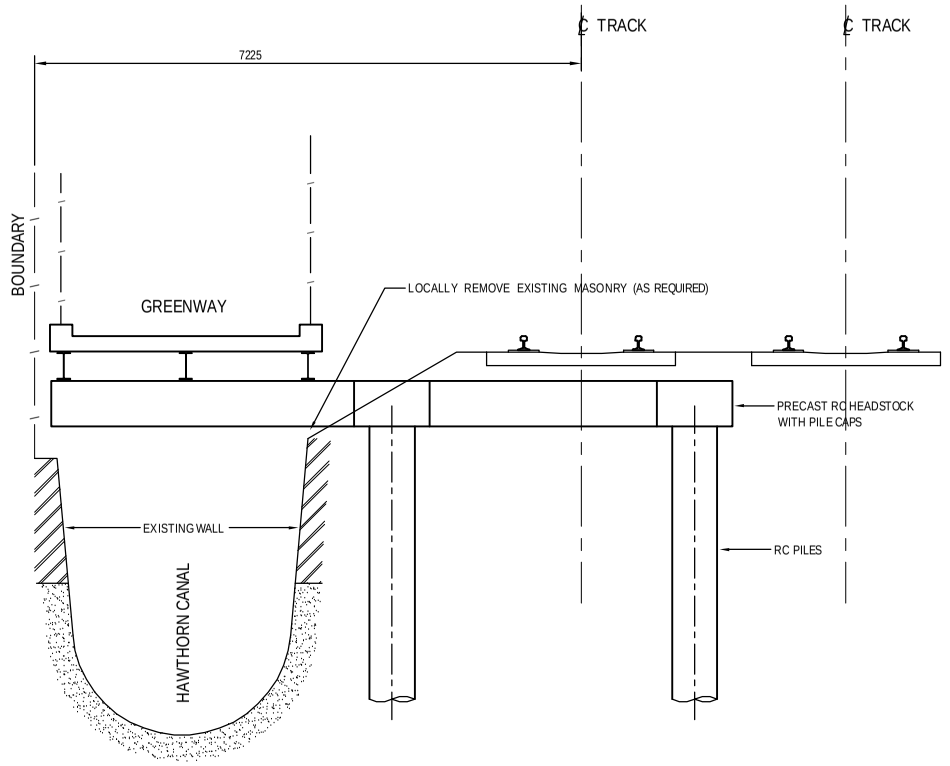

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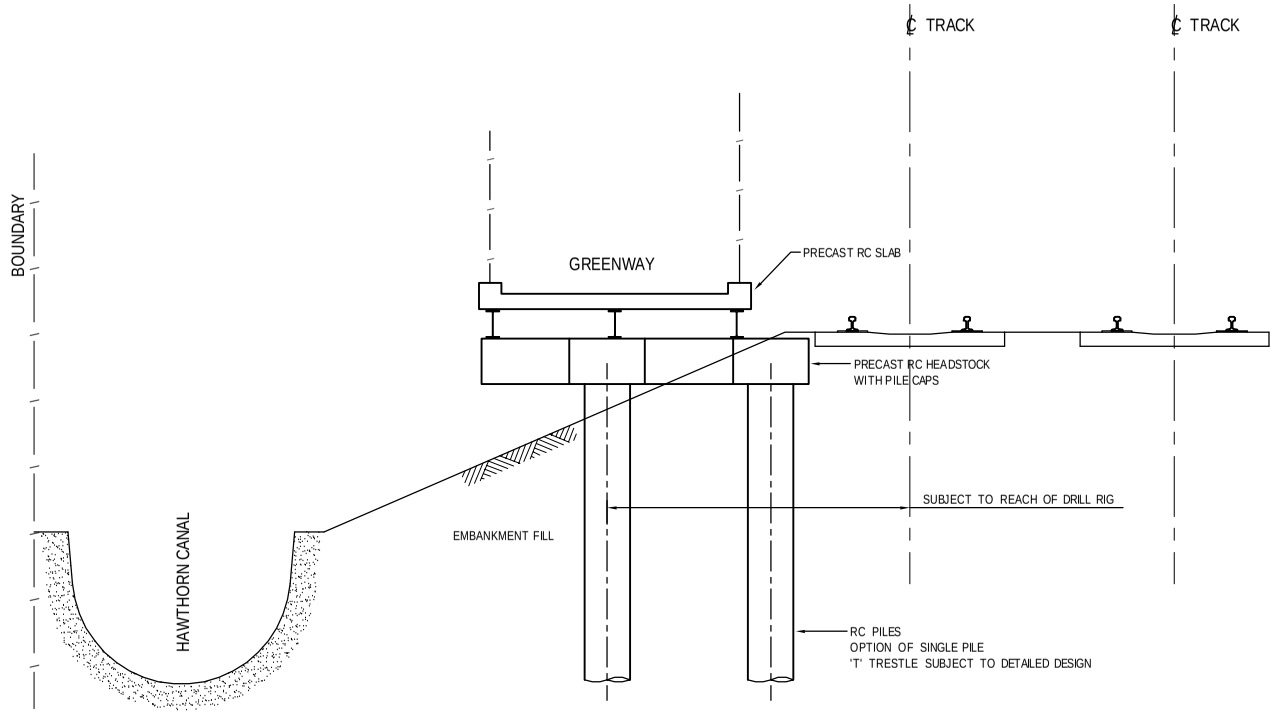

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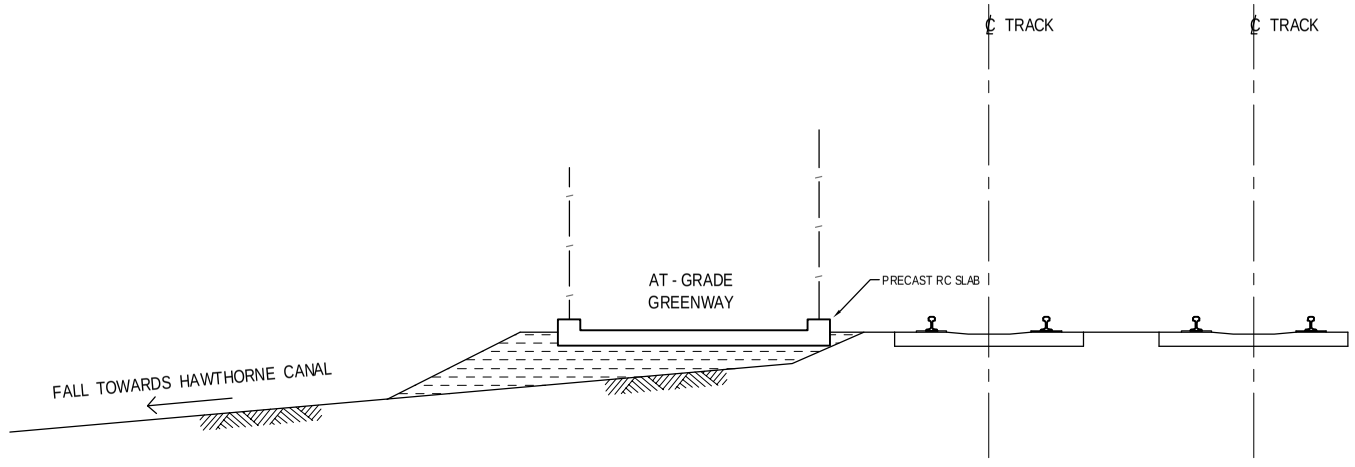
SCALE 1:50



TYPE '3' GREENWAY SECTION

SCALE 1:50

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GREENWAY ADJACENT TO HAWTHORNE CANAL

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