CITY OF
VANCOUVER

CITY CLERK'S DEPARTMENT
Access to Information & Privacy

File No.: 04-1000-20-2018-534

November 16, 2018

s.22(1) [redacted]

Dear s.22(1) [redacted]

Re: **Request for Access to Records under the Freedom of Information and Protection of Privacy Act (the "Act")**

I am responding to your request of September 28, 2018 for:

> **The final consultant report generated from *RFP PS07050 Consulting Services for Preliminary Engineering and Design for Phase Zero of the Downtown Streetcar Project*, from 2008.**

All responsive records are attached.

Under section 52 of the Act, and within 30 business days of receipt of this letter, you may ask the Information & Privacy Commissioner to review any matter related to the City's response to your FOI request by writing to: Office of the Information & Privacy Commissioner, info@oipc.bc.ca or by phoning 250-387-5629.

If you request a review, please provide the Commissioner's office with: 1) the request number (#04-1000-20-2018-534); 2) a copy of this letter; 3) a copy of your original request; and 4) detailed reasons why you are seeking the review.

Yours truly,

Barbara J. Van Fraassen, BA
Director, Access to Information & Privacy

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*If you have any questions, please email us at foi@vancouver.ca and we will respond to you as soon as possible. Or you can call the FOI Case Manager at 604.871.6584.

Encl.

:ag

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Downtown Streetcar Project

Preliminary Design Report

February 2008

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Downtown Streetcar Project

Preliminary Design Report

Issue and Revision Record

Rev	Date	Originator	Checker	Approver	Description
A	13 Nov 07	DSW/TS/ BW/SR	DSW/TS/SR	DH	Issued for CoV Comment
0	29 Feb 08	DSW/TS/B W/SR	DSW/TS/SR	DH	Final Issue

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Executive Summary

.1st Avenue in Vancouver is to be reconstructed between Wylie Street and Ontario Street as part of the redevelopment of South East False Creek (SEFC). As a consequence of this construction, the existing single track Downtown Historic Railway (DHR) alignment that runs along the north side of 1st Avenue will be relocated to a new central median. Hatch Mott MacDonald (HMM) was retained by the City of Vancouver (CoV) to assist in defining the reinstatement of the DHR between these points, including the tie-in to the existing DHR system. In doing so, HMM was to take into consideration the future implementation of a modern streetcar system from Granville Island to Science World with a spur line to a depot located at the junction of Pacific Boulevard and Quebec Street. This route was previously defined as Phase 0. The concept for Phase 0 was set out both in a report by IBI for CoV in September 2005, and by the CoV staff report of October 2006. These formed the basis upon which HMM's preliminary design for Phase 0 was developed.

A major function of HMM's preliminary engineering was the definition of a generic modern vehicle upon which the preliminary design could be based and to determine how this would interact with the existing DHR vehicles and infrastructure. It is intended that the two existing heritage vehicles operating on the DHR, cars 1207 and 1231, are to remain operating on the system in some capacity following any work undertaken. The Phase 0 preliminary design is based on a 2.46m wide vehicle which was somewhat defined by the previous 2005 IBI study. The IBI concept was based upon the Skoda Inekon T10 vehicle operating in Portland, Oregon; however the operation of other industry standard vehicles ranging in width from 2.44m to 2.65m were also considered within the preliminary design. The required rail right-of-way (ROW) was defined by these dimensions.

The preliminary engineering has confirmed that a modern streetcar with double track is practical within the width of the Granville Island and Wylie Street, albeit with the need for tree clearance, some re-grading and some short sections of retaining wall. In addition, the track alignment must be slewed to the north or south of its current position in order to provide sufficient corridor width. It was noted that the existing track is generally in a poor condition and should be replaced, although it may be possible to continue to operate the existing DHRs at a low speed along the current track with some track maintenance.

Taking both track condition and alignment into consideration, it is reasonable to propose that should track replacement be progressed for the DHR single track, then it should be aligned to accommodate a modern streetcar in the future, recognizing that this would also necessitate realignment and partial replacement of the Overhead Contact System (OCS). Overall, it is considered that this strategy would minimize future disruption if double tracking were to be installed at a later date. While an aspiration for grass track along the Granville corridor is reasonable, it has been assumed that that ballast track would continue to be used. This would be the most cost effective solution and not out of keeping with the current environment.

Along 1st Avenue between Wylie Street and Ontario Street, a 6.9m ROW was already being considered by the SEFC Project team based upon the findings of the 2005 IBI study. It was determined early in the preliminary engineering that the median design would have to be amended were it to accommodate a double track streetcar system. An absolute minimum median width of 7.1m is recommended for the 1st Avenue median, expanding to a maximum of 8.4m in some areas. Following discussions with the CoV and SEFC Project team it has been agreed to increase the median to reflect these minimum values.

The DHR and Streetcar alignments within the new median are heavily influenced by the SEFC Project schedule. Ideally, the preferred alignment for the DHR would run as a single track on one side of the median for the full length of 1st Avenue. This would allow the future implementation of a modern streetcar infrastructure by permitting the installation of a second track along the opposite side of the median with minimal disruption to the existing track. Constraints imposed by emergency services and related to the phasing of the SEFC Project necessitated a centre alignment for the DHR along the 1st Avenue median. This arrangement necessitates that the entire length of track be re-installed should a streetcar be implemented in the future.

The original DHR track along 1st Avenue was removed in late 2007 to allow for the reconstruction of 1st Avenue. A number of the rail components were salvaged and stockpiled. HMM was asked to evaluate the possibility of reusing these components for the reinstatement of the DHR. Based on the results of HMM's inspection, reuse of the stockpiled components for the reinstatement of the DHR is not recommended.

The DHR alignment from Ontario Street to Science World follows the existing track through a dedicated ROW. Expansion of the DHR alignment to the intersection of 1st Avenue and Quebec Street, in line with the final streetcar concept is not possible until further property is acquired along that block (Enterprise Car Rental Lot). The proposed Phase 0 alignment would extend the new 1st Avenue median through to Quebec Street then running in a dedicated ROW along the west curb of Quebec Street through to Science World.

Based on the CoV's aspiration for the Streetcar, a grass finish is recommended from Wylie Street intersection on 1st Avenue through to Quebec Street to Pacific Boulevard. A hard finish, concrete, asphalt or stone sets will be applied at road crossings, the approach into the yard along Quebec Street and in areas around stations.

In general, the proposed Phase 0 alignment could accommodate concurrent operation of DHR and modern vehicles, assuming restricted operations are implemented. Operational restrictions would include passing at stations only, lower speeds, and limiting DHR vehicles to one of the two tracks i.e. there is not enough space for two DHR vehicles to pass one another. Further design would be required to ensure that DHR vehicles could run on both tracks concurrently.

The IBI 2005 study identified a site for streetcar storage and maintenance at the junction of Pacific Boulevard and Quebec Street. The report confirmed a fleet size of six cars for Phase 1 and in principle laid out the yard to accommodate them. For the Phase 0 Preliminary Engineering a review of the proposed site layout was undertaken. An alternative preliminary layout design was developed for the site in order to accommodate the Phase 0 operations to and from Granville Island. The design incorporates requirements for security and operations, a maintenance building, material storage areas, limited staff parking and six modern streetcar vehicles (based on 25m long vehicles) in line with Phase 1 requirements.

In developing the cost estimates for this project three options developed:

- **DHR**: Basic *repair* of the existing system outside of the 1st Avenue corridor with new track along the new HMM alignment within the 1st Avenue corridor.
- **DHR Plus**: As DHR except with *replacement* and *realignment* of single track outside 1st Avenue corridor, following one of the new HMM full modern alignments to facilitate straightforward upgrade to the full modern in the future.
- **Full Modern**: Installation of twin track system with new trackwork, power, systems, stations, vehicles, and an Operations and Maintenance Centre

A detailed breakdown of the assumptions and exclusions that the cost estimates were based on can be found in Section 13.2. The following are the cost estimates for the three options:

Option	Cost Estimate
DHR	$9.8M*
DHR Plus	$13.7M*
Full Modern	$90.6M**

* OCS replacement is not included in these costs

**Operations and Maintenance Facility and Vehicle costs are included in this estimate.

1 Definitions

In this Chapter we define terminology used in this preliminary engineering design report.

Downtown Historic Railway (DHR)

The DHR is a single track rail system running from Granville Island to Science World along the south side of False Creek. Two heritage vehicles, restored and operated by the Transit Museum Society, are operated along the route on weekends and holidays over the summer. The route includes four stations: Granville Island station, Leg-In-Boot Square station, Ontario Street station, and Science World station. Service has been temporarily discontinued during the reconstruction of 1st Avenue.

South East False Creek (SEFC)

For the purposes of this report, SEFC refers to the block of land bounded by Cambie Street on the west, 1st Avenue on the south, Ontario Street on the east, and False Creek on the north. This area, including 1st Avenue, is currently being redeveloped.

Granville Corridor

Granville Corridor refers to the dedicated rail ROW running from Granville Island to Cambie Street, formerly owned by Canadian Pacific Railway. The predominantly single track DHR alignment currently occupies a portion of the corridor.

Heritage Vehicles

For the purpose of this report, the rail vehicles operated by the Transit Museum Society along the DHR alignment. The vehicles are understood to be restored St. Louis Car Co. 1200 series Interurbans, #1207 and #1231. The vehicles are similar to each other in overall design and dimension.

Streetcar

Streetcar is a modern form of rail transportation typically considered to operate on roads within urban environments, for the most part powered by an overhead electrical supply. The technology is similar to that used in Light Rail, although the capacity and speed of operation is often lower.

Developed Kinematic Envelope (DKE)

The DKE defines the space occupied by a vehicle when moving. It is based upon the static envelope and the dynamic envelope of a vehicle. The static envelope is the maximum cross-sectional dimensions of a given vehicle, essentially the space the vehicle occupies when at rest on level, straight track. The dynamic envelope is the static envelope enlarged to include additional space occupied by the vehicle when in motion on straight track. The developed kinematic envelope is the dynamic envelope enlarged to include permitted tolerances in track gauge and curvature and super elevation of the track.

Swept Path

The swept path describes a delineated zone of operation for the streetcar. It includes an additional clearance added to the DKE of the vehicle. The value of the additional clearance is based upon where the streetcar is operating or passing; for example, the clearance to a continuous solid feature (wall) or to adjacent road traffic.

Traction Power

Traction power is the electricity used to drive the motors of light rail vehicles and streetcars, delivered via a network of substations and wires including the OCS.

Overhead Contact System (OCS)

The OCS is an overhead wire used to transmit electrical energy to streetcars at a distance from the energy supply point. An electrical circuit is completed by returning current to the energy supply via the rail, in the case of a single wire arrangement, or via a second overhead wire in the double wire arrangement. Wires are typically suspended from poles either beside (side poles) or between (centre poles) the tracks. They can also be suspended from cross span wires, which are supporting wires spanning over the streetcar corridor connected to poles, buildings or other structures.

Stray Current

Stray current is an undesirable characteristic of DC powered transit systems that utilize the running rails as the electrical negative return. A certain portion of the electrical current required to run the vehicles returns to the substation other than on the intended path, the running rails. Often the unintended path is a parallel metallic gas, water or electrical utility or other buried infrastructure, resulting in potentially accelerated corrosion to that feature.

Trackwork

(i) Ballasted Track

Ballasted track is the traditional method of constructing track. The rail section, typically tee rail, is fixed to horizontal ties. The ties rest on and are embedded in ballast, which is essentially crushed rock.

(ii) Embedded Track

Embedded track refers to any track form in which the rails are surrounded up to and including the railhead. Typical finishes include concrete, block paving or asphalt.

(iii) Grass Track

A track form with a grass or similar plant species finish. The track is often supported on a structural slab similar to those used for embedded track. Some designs have used a modified version of ballasted track.

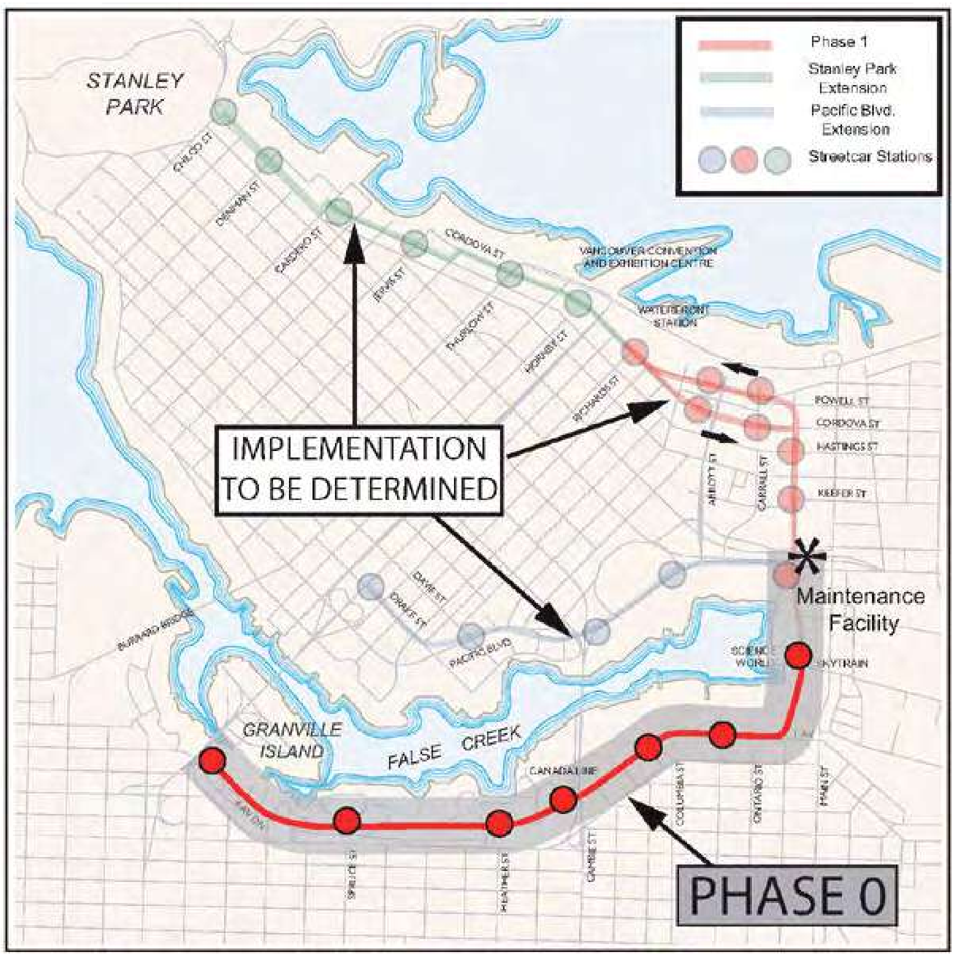
2 Introduction

The HMM team[1] was retained by the CoV to provide professional engineering services for the Vancouver Downtown Streetcar project. There are two distinct parts to the project for which advice has been provided:

- The reinstatement of the Downtown Historic Railway (DHR) service on 1st Avenue
- The Phase 0 Preliminary Engineering for a modern streetcar service

This introduction provides the context for the reinstatement of the DHR on 1st Avenue and the preliminary engineering for Phase 0, followed by a description of the report structure which documents the findings of the work to date.

Figure 1: Proposed Vancouver Downtown Streetcar (2007).



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[1] The HMM team includes Anthony Steadman and Associates, iTrans, PBA Consulting Engineers and VIA Architecture in association with ZGF LLP.

2.1 Reinstatement of the DHR

1st Avenue in Vancouver is to be reconstructed between Wylie Street and Ontario Street as part of the redevelopment of SEFC. As a consequence of this construction, the existing single track DHR alignment that runs along the north side of 1st Avenue will be relocated to a new central median. HMM has been retained by the CoV to assist in defining the reinstatement of the DHR between these points, including the tie-in to the existing DHR system. In doing so, HMM was to take into consideration the aspiration for a future a modern streetcar system along the same corridor, as defined by the Phase 0 Preliminary Engineering.

2.2 Phase 0 Preliminary Engineering

Phase 0 considers the introduction of a new modern Streetcar from Granville Island to Science World, with a spur line to a depot located at the junction of Pacific Boulevard and Quebec Street. The concept for Phase 0 was set out both in a report by IBI for the CoV in September 2005, and by the City staff report of October 2006. These form the basis upon which HMM's preliminary design for Phase 0 has been developed.

In summary, Phase 0 provides a double track streetcar between Granville Island and Pacific Boulevard, with associated infrastructure, including a maintenance yard at Quebec Street and Prior Street. A major function of HMM's preliminary engineering is the definition of generic vehicle for a modern streetcar and to determine how this would interact with the existing DHR vehicles and infrastructure.

2.3 Report Structure

The findings of the design carried out to date are presented in this report through a series of chapters covering the main engineering disciplines and key deliverables for the project, as outlined below. Appendices to the report contain the preliminary plans and supplementary reference material used in the design.

Report Chapters:

Chapter 3. Route Alignment

Chapter 4. Vehicle Selection

Chapter 5. Traction Power

Chapter 6. Track Form

Chapter 7. Traffic and LRT Signals

Chapter 8. Utility

Chapter 9. Stations and Urban Design

3 Route Alignment

3.1 Introduction

This chapter describes the key features of the route for both the DHR and the modern Streetcar proposals. It also discusses the impact of accommodating both the DHR and modern Streetcar on the same alignment, and where the design has been altered to achieve this fit.

3.2 Description of the Proposed DHR

The existing DHR alignment runs from Granville Island to Science World, primarily as a single track but with two sections of double track which operate as passing loops. On departing Granville Island, the alignment follows the Granville Corridor, a dedicated rail corridor just north of 6th Avenue. The rail converges with 6th Avenue west of Moberly St. and remains parallel until west of Ash Street, where it moves north before passing under Cambie Street Bridge. The current alignment continues along the north side of 1st Avenue until east of Ontario Street where it takes a diagonal route northeast to a dedicated ROW, before turning north along the west side of Quebec Street, ending in front of Science World. There are a total of four stations: one at each end of the route, one at Moberly Road (Leg-in-Boot station) and one at Ontario Street. The stations are low level platforms approximately 300mm high, of sufficient length to accommodate the 15m DHR vehicles and include a simple timber structure in a heritage style for shelter.

As noted in the Introduction, the existing DHR alignment along 1st Avenue is to be relocated to a new central median created as part of the redevelopment of SEFC. HMM's primary focus was this new replacement alignment along 1st Avenue from Cambie Street Bridge to Ontario Street. Outside of the 1st Avenue median, the HMM recommends either a repair and rehabilitation of the existing DHR equipment, including the required adjustments to complete the tie-ins to the new 1st Avenue section, or replacement of the track on a future modern alignment where practical. In areas where track is re-laid, provision for a future streetcar were considered in order to minimize future disruption during expansion to the modern streetcar. The majority of the alignment remains single line running with existing passing loops just east of Granville Island Station and west of Cambie Street Bridge. The following tables outline the key features of the alignment for the DHR:

Table 1: DHR alignment summary.

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	DHR Signals	Traffic Signals	Other DHR Systems
Granville Island to Ash St.	**Single and Double track sections existing or new HMM alignment.** (a) Option A involves repair of existing DHR on current alignment. (b) Option B includes new track on existing alignment (minimum recommended) (c) Option C includes replacement of track on new HMM alignment for Demonstration Line* and to permit double track for the future Streetcar. **Preferred option is C.**	Replacement or repair of existing track. Standard ballasted track similar to existing. Road crossing at Moberly Rd. requires reconstruction for option (a), (b) and (c).	Granville Island Station **(Existing - refurbished)** Leg-in-Boot Station **(Existing- refurbished)**	OCS as per existing; Single Wire Fixed Termination supported on cantilevers from side poles. Shift of alignment to new HMM alignment will require existing poles to be replaced and upgrade to Single Wire Auto Tensioned.	Only at Stations or existing	Existing Signals at Ash assumed to be satisfactory for DHR, no retrofit required.	Existing Signals at Ash assumed to be satisfactory for DHR, no retrofit required.	No additional systems required. Communications: As per existing arrangements.

* Refer to accompanying Demonstration Line Report for further discussion.

Table 1 (cont'd): DHR alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	DHR Signals	Traffic Signals	Other DHR Systems
Ash Street to 1st Avenue (at Wylie Street)	**Single track HMM alignment** Two options considered to provide tie-in between existing DHR and new alignment in the 1st Avenue median. (a) Option A ties back to the existing DHR within the shortest distance. This locates the DHR in a temporary alignment across Wylie intersection, and is the lower cost alternative (less construction at this time). (b) Option B realigns the DHR to the CoV proposals for a new road layout between 1st Avenue and Ash Street (based on the IBI streetcar concept report ref: Sept. 2005). **Preferred Option is B.**	Standard ballasted track as per existing. All options assume either replacement or repair of existing track. Road crossing at Wylie requires new slab track construction.	No existing stations.	Traction power substation as per existing at Ash Street. No modifications anticipated for two vehicle DHR operation. Single Wire Fixed Termination supported on cantilevers from side poles.	Only at stations or existing	DHR Signals required at Wylie provided by 1st Avenue work. Two LRT signal heads with pre-emption loops in track bed.	Extra traffic signal head required on Commodore Rd west of Wylie St. to station east bound traffic.	No additional systems required. Communications: As per existing arrangements.

Table 1 (cont'd): DHR alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	DHR Signals	Traffic Signals	Other DHR Systems
1st Avenue from Wylie St. to west of Ontario St.	**Single track within median, HMM alignment.** Two Options: (a) Option A is aligned to north side of street across Wylie, transferring to south side of median just after Wylie and remaining there until after Columbia. Between Columbia and Manitoba transfers back to north side of median to fit with Interim road layout at Manitoba. Remain on north side until Ontario. (b) Option B is aligned to the centre of the median for entire length of 1st Avenue. Option (a) ruled out by Emergency Services due to accessibility concerns. **Preferred Option is B.**	CoV preferred is Grass track. Lower cost solution is standard ballasted track with remainder of median finished in grass. Include for curb/boundary treatment between ballast and grass. Slab track with concrete or asphalt finish through intersections. Assume booted rail for stray current mitigation. Slab track with concrete or asphalt finish through stations. *Ballast does not permit trafficking of vehicles onto median if Option A is selected in previous column.*	Cook Street**(New)** Manitoba Street **(New)** Ontario Street – eliminated per SEFC work.	Single Wire Fixed Termination supported from cross span wires. Poles provided by 1st Avenue work.	Only on Stations. Elsewhere; as provided by 1st Avenue work.	No specific DHR signals provided at Crow, Cook, Columbia or Manitoba. DHR assumed to work with existing road traffic signals. To remove conflict with lefts turns at intersections it is assumed that DHR will approach the intersection 'at caution' – line of sight operation, and only cross when clear. Use of DHR bell/warning sound required	No specific DHR signals, but consideration will be given to additional signage/warning signals to road traffic. Left turns will have to give way/yield to DHR.	No additional systems required. Communications: As per existing arrangements.

Table 1 (cont'd): DHR alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	DHR Signals	Traffic Signals	Other DHR Systems
Ontario Intersection	**Single track HMM alignment:** Two options considered for connection to existing DHR ROW (a) Option A cuts diagonally across intersection from the median to the existing ROW. (b) Option B continues with an east – west alignment across Ontario, before turning north across 1st Avenue west bound traffic, tying in with existing DHR ROW. **Preferred option is B.**	Slab track with concrete or asphalt finish through intersections. Assume booted rail for stray current.	No Stations. Existing station at Ontario eliminated by SEFC works.	Single Wire Fixed Termination supported from cross span wires. Poles provided by 1st Avenue work.	As provided by 1st Avenue work.	DHR Signals required at Ontario to permit crossing from 1st Avenue on to existing ROW. 2 LRT signal heads with pre-emption loops in track bed.	New signal part of SEFC works. Advance signal for west bound traffic on 1st Avenue linked to DHR pre-emption loops at Ontario St.	No additional systems required. Communications: As per existing arrangements.

Table 1 (cont'd): DHR alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	DHR Signals	Traffic Signals	Other DHR Systems
Ontario Intersection to Science World	**Single track** (a) Option A follows existing DHR ROW. End at existing Science World station. (b) Option B would relocate DHR to future streetcar alignment. Option A is recommended subject to future development in this area.	As per existing; mixture of ballasted and paved track. Most probable is paved track solution with imprinted concrete finish.	Science World **(Existing – refurbished)**	As per existing with Single Wire Fixed Termination supported on cantilevers from side poles. Ties into span wire arrangement at Ontario intersection.	Only at Stations or existing	None required	None Required	No additional systems required. Communications: As per existing arrangements.

3.3 Description of the Proposed Phase 0

The proposed modern Streetcar follows the same basic alignment as the existing DHR, with the exception that it does not follow the current ROW linking the Ontario Street intersection to Science World, and that it extends beyond Science World to Pacific Street/Quebec Street and the future maintenance yard at Prior Street. The Streetcar alignment is also double tracked for its full length. There is an assumption that the modern streetcar infrastructure will be of a higher quality and standard than that of the DHR. By example, the finish in large sections, most notably the 1st Avenue median, is to be of a grass/green track construction.

As part of the design effort for Phase 0, HMM have evaluated a range of track finishes (see Chapter 6), from traditional ballast track to slab track with grass and/or hard surface finishes such as concrete, asphalt or paver. The following summary presents the conceptual design which allows for grass track along almost the entire length. Acknowledging the premium that quality will cost, the cost estimate offers a number of sub options with less expensive finishes for sections of the system (i.e. ballast track in the Granville rail corridor). The table below summarizes the HMM design and sub options:

Table 2: Phase 0 alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	Streetcar Signals	Traffic Signals	Other Streetcar Systems
Granville Island to Ash Street	**Double track HMM alignment** Minimum of a single crossover required for reverse movement on departure. Option for single line running into station dependent upon service pattern and operational demand for two platform berths	CoV preferred is grass track. Lower cost alternative is standard ballast. Crossovers: One immediately east of Granville Station	Upgrade Granville Island Station: single island platform 4.5m wide by 25m long. New Spruce Street Station: single island platform 4.5m wide by 25m long. Upgrade Moberly Station (Leg-in-Boot): two side platforms nominally 3.15m wide by 25m long positioned in a similar location to the existing Leg-in-Boot station.	Single Wire Auto Tensioned supported from centre poles with variations on the approach to stations. Consider span wires from station lighting columns.		Retention of existing signals at Moberly Rd. with pre-emption. Possible signal required if single line running into Granville Station proposed.	Retention of existing signals at Moberly Rd.	Current design assumes limited other systems; i.e. no CCTV, P.A., or passenger information displays. Cost estimate *does* allow for an emergency call point and duct provision for other systems. (See Chapter 9 for full listing of possible system equipment.)

Table 2 (cont'd): Phase 0 alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	Streetcar Signals	Traffic Signals	Other Streetcar Systems
Ash Street to 1st Avenue (at Wylie Street).	**Double track HMM alignment** Based on IBI report (Sept. 2005) with proposed CoV road layout from Wylie Street to Ash Street	CoV preferred is grass track with slab track (asphalt finish) at road crossings. Lower cost alternative is standard ballast. No crossovers.	New Cambie Street Station: single island platform station located opposite the Canada Line Olympic station. Min. 4.5m wide by 25m long.	Single Wire Auto Tensioned supported from centre poles and cross span wires.		New signal for connection at Commodore Rd. New signal for Wylie intersection, linked to that at Commodore, including pre-emption. Streetcar to pass in one movement from the Granville rail corridor through the Commodore connection and Wylie intersection, onto the 1st Avenue median, (and vice versa).	New signal on Commodore east bound to facilitate the connection from the Granville corridor onto 1st Avenue. Dedicated signal at Wylie intersection for left turns crossing the streetcar tracks.	Current design assumes limited other systems; i.e. no CCTV, P.A., or passenger information displays. Cost estimate *does* allow for an emergency call point and duct provision for other systems. (See Chapter 9 for full listing of possible system equipment.)

Table 2(cont'd): Phase 0 alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	Streetcar Signals	Traffic Signals	Other Streetcar Systems
1st Avenue from Wylie Street to Ontario Street	**Double track HMM alignment** Base on IBI report (Sept. 2005), within new 1st Avenue median	CoV preferred is grass track with slab track (asphalt finish) at road crossings. Lower cost alternative is standard ballast. No crossovers.	New Cook Station: Island platform restricted to 3m wide due to presence of Wilkenson Building. Consider moving Wilkenson building further north than currently planned to achieve wider platform. 25m long. New Manitoba Station: Island platform restricted to 4m wide due to Salt Building on to the north and Pinnacle development to the south. 25m long.	Single Wire Fixed Termination supported by cross span wires from street lighting poles installed as part of 1st Avenue works.	Lighting as per SEFC road works.	New signals at Columbia Street, Manitoba Street and Ontario Street installed as part of SEFC works. New signals required at Cook Street and Crowe Street for modern streetcar. All signals require streetcar pre-emption.	Dedicated signals to hold left turn vehicles on 1st Avenue from crossing streetcar.	Current design assumes limited other systems; i.e. no CCTV, P.A., or passenger information displays. Cost estimate *does* allow for an emergency call point and duct provision for other systems. (See Chapter 9 for full listing of possible system equipment.)

Table 2 (cont'd): Phase 0 alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	Streetcar Signals	Traffic Signals	Other Streetcar Systems
Ontario Intersection to Science World	**Double track HMM alignment** Based on IBI report (Sept. 2005), with new median required from Ontario Street to Quebec Street, followed by dedicated ROW along the west curb of Quebec Street. The recommended alignment requires a significant corner cut of land at 1st Avenue and Quebec St. Land is also required west of additional property from 1st Avenue to Science World.	CoV preferred is grass track with slab track (asphalt finish) at road crossings. Lower cost alternative is standard ballast. No crossovers.	Upgrade Science World Station: Side platform 3m wide by 25m long.	Single Wire Fixed Termination supported from centre poles and span wires.		Streetcar signals with pre-emption required, but priority may be lower due to traffic levels on Quebec. Consider advance loop linked to Ontario intersection for east bound and loop at Science World station for west bound, providing extra time to cycle the streetcar phase.	New signal arrangement at 1st Avenue and Quebec, permitting streetcar to have its own protect phase to transition to/from the 1st Avenue median to the streetcar ROW on the west side of Quebec.	Current design assumes limited other systems; i.e. no CCTV, P.A., or passenger information displays. Cost estimate *does* allow for an emergency call point and duct provision for other systems. (See Chapter 9 for full listing of possible system equipment.)

Table 2 (cont'd): Phase 0 alignment summary

Section	Alignment	Trackform	Station Location & Format	Traction Power & OCS	Lighting (street/ landscape)	Streetcar Signals	Traffic Signals	Other Streetcar Systems
Science World to Quebec Street/Pacific Avenue & Streetcar yard	**Double track HMM alignment** Based on IBI report (Sept. 2005), within dedicated ROW to the west of Quebec. Crossing of Quebec/Pacific to enter new Yard. Pacific Boulevard station to be considered for turn back terminal. Spring tip crossover to the south side of Pacific Station, points facing station for reverse movement on departure to Granville.	CoV preferred is grass track with slab track (asphalt finish) at road crossings and on street sections. Lower cost alternative is standard ballast for off street sections. One crossover required at Pacific Blvd. station for Phase 1 expansion.	New Pacific Boulevard Station: Island Platform Min. 4.0m wide by 25m long.	Single Wire Fixed Termination supported by centre poles, with cross span wires at stations and complex intersections.		Major intersection at Pacific and Quebec. Priority will be complex. Dependant upon access requirement to the streetcar yard.	If the streetcar phase through the intersection is infrequent (return to yard) then consideration should be given to 'ready calls' from streetcar to traffic signals. This would minimise traffic disruption.	Current design assumes limited other systems; i.e. no CCTV, P.A., or passenger information displays. Cost estimate *does* allow for an emergency call point and duct provision for other systems. (See Chapter 9 for full listing of possible system equipment.)

3.4 Conversion of DHR to Streetcar – Alignment Constraints and Solutions

It is a project requirement that, if practical, the DHR should accommodate a modern streetcar without significant upgrade. In this section we discuss how this requirement has influenced the design.

Issues related to converting the DHR to modern streetcar are discussed throughout this report. However, in this section we highlight some of the most significant issues which will need to be addressed. It is also notable that perhaps the highest concentration of constraints between DHR and modern streetcar can be seen on 1st Avenue, not least because construction is phased into Interim and Ultimate designs each of which requires a different DHR and Streetcar design.

3.4.1 Granville Corridor:

As noted in section 3.2, the track alignment along the Granville corridor will need to be slewed to the north or south of its current position in order to provide sufficient corridor width for a future double track modern streetcar. The preliminary engineering has confirmed that a modern streetcar with double track is practical within the width of the Granville corridor, albeit with the need for tree clearance, some re-grading and some short sections of retaining wall. It is anticipated that new retaining walls will be required at Granville Island Station (approx. 90m on north side) and at Moberly Station (approx. 40m on both sides). If the current track were slewed to the south this would require the removal of the existing OCS support poles and realignment of the OCS. If the slew was to the north then the alignment of the OCS would be offset too far from the track, thereby again requiring a realignment of the OCS.

It has also been noted that the condition of the existing track is generally in a poor condition and should be replaced, although it may be possible to continue to operate the existing DHRs at a low speed along the current track with some track maintenance.

Taking both track condition and alignment into consideration, it is reasonable to propose that should track replacement be progressed for the DHR single track, then it should be aligned to accommodate a modern streetcar in the future, recognising that this would also necessitate realignment and partial replacement of the OCS. Overall, it is considered that this strategy would minimise future disruption if double tracking were to be installed at a later date.

The proposed Phase 0 alignment could allow for concurrent operation of DHR and modern vehicles, assuming restricted operations are implemented. Operational restrictions would include passing at stations only, lower speeds, and limiting DHR vehicles to one of the two tracks i.e. there is not enough space for two DHR vehicles to pass one another. Further design would be required to ensure that DHR vehicles could run on both tracks concurrently, as discussed in section 4.5.

3.4.2 Wylie Street to Ontario Street

Between Wylie Street and Ontario Street the DHR and Streetcar alignments are heavily influenced by the SEFC Project schedule.

Ideally, the preferred alignment for the DHR would run as a single track on one side of the median for the full length of 1st Avenue. This would allow the future implementation of a modern streetcar infrastructure by permitting the installation of a second track along the opposite side of the median with minimal disruption to the existing track. However, two phasing constraints related to the SEFC Project interfere with this concept.

At Cook Street, the existing Wilkinson Building on the north side the of the street obstructs the 'Ultimate' 1st Avenue design until post 2010, necessitating an 'Interim' design between the construction of 1st Avenue and the future demolition of the building. In order for the DHR alignment to remain in the median throughout the Interim and Ultimate arrangements, the DHR must follow the south edge of the median.

Conversely at Manitoba Street, the alignment must follow the north side as the final property lines of the Pinnacle Development on the southeast corner of the intersection and the schedule of when they are constructed has not been confirmed.

Beyond Manitoba the alignment remains on the north side of the median until the Ontario intersection, where upon it returns to the existing DHR corridor. For a general overview of the DHR alignment along 1st Avenue, refer to the Figure 2 on page 4-15.

To accommodate the switching of the alignment from the north to south curb line, and back again it was initially proposed that two crossovers would be installed. In theory, standard railway switches could achieve these transitions over relatively short distances, but are not practical due to the relatively narrow space between the two track centrelines. Such an alignment would also create localised bulges in the median to accommodate the extra DKE where the end throw of the vehicles develop upon entry and exit from the switches. As an alternative, it is proposed that large radius curves are considered (+R1000m). The large curves will allow the DHR vehicles to cross from one side of the median to another, while eliminating the need for additional median width at the cross over points. The operating speed of the DHR will have to be slow to minimise the development of the DKE (in the order of 25kph or less).

There are three consequences of this track arrangement. Firstly, the track installed for DHR effectively sets the alignment of the future double track. The offset from the curb line required by the DHR is such that it leaves insufficient space for a similar track to run along side it in the remaining median. Therefore, the DHR vehicles will not be able to pass each other along 1st Avenue, or run in conjunction with the modern streetcar vehicles (due to a conflict with the DKE's), unless specific operational constraints are implemented. This would include timing the vehicles such that passing occurred at median stations or on passing tracks outside of the 1st Avenue median. Secondly, the track in the two transition zones (from north to south side of median) will have to be relayed to accommodate double tracking when the modern system is implemented. In the original crossover scenario the track work would simply extend onto the switch unit and would not have required any realignment. Thirdly, should Emergency Services be required to pass an obstruction on 1st Avenue, vehicles would be required to drive on the ballasted track. Upon review of the drawings, Emergency Services has indicated that this is not an acceptable arrangement.

HMM subsequently developed a centre alignment for the DHR along the 1st Avenue median in order to accommodate Emergency Services and with the understanding that the entire length of track will need to be relayed should a the streetcar be implemented in the future.

A more detailed explanation of how the DKE for the DHR and modern Streetcar has influence the cross section along 1st Avenue is provided in Chapter 4 - Vehicles.

3.4.3 Ontario Street to Science World

The DHR alignment from Ontario Street to Science World follows the existing track through a dedicated ROW. Expansion of the DHR alignment to the intersection of 1st and Quebec Street, in line with the final streetcar concept it not possible until further property is acquired along that block (Enterprise Car Rental Lot). The operation of the DHR with the modern vehicle is discussed further in Chapter 4.

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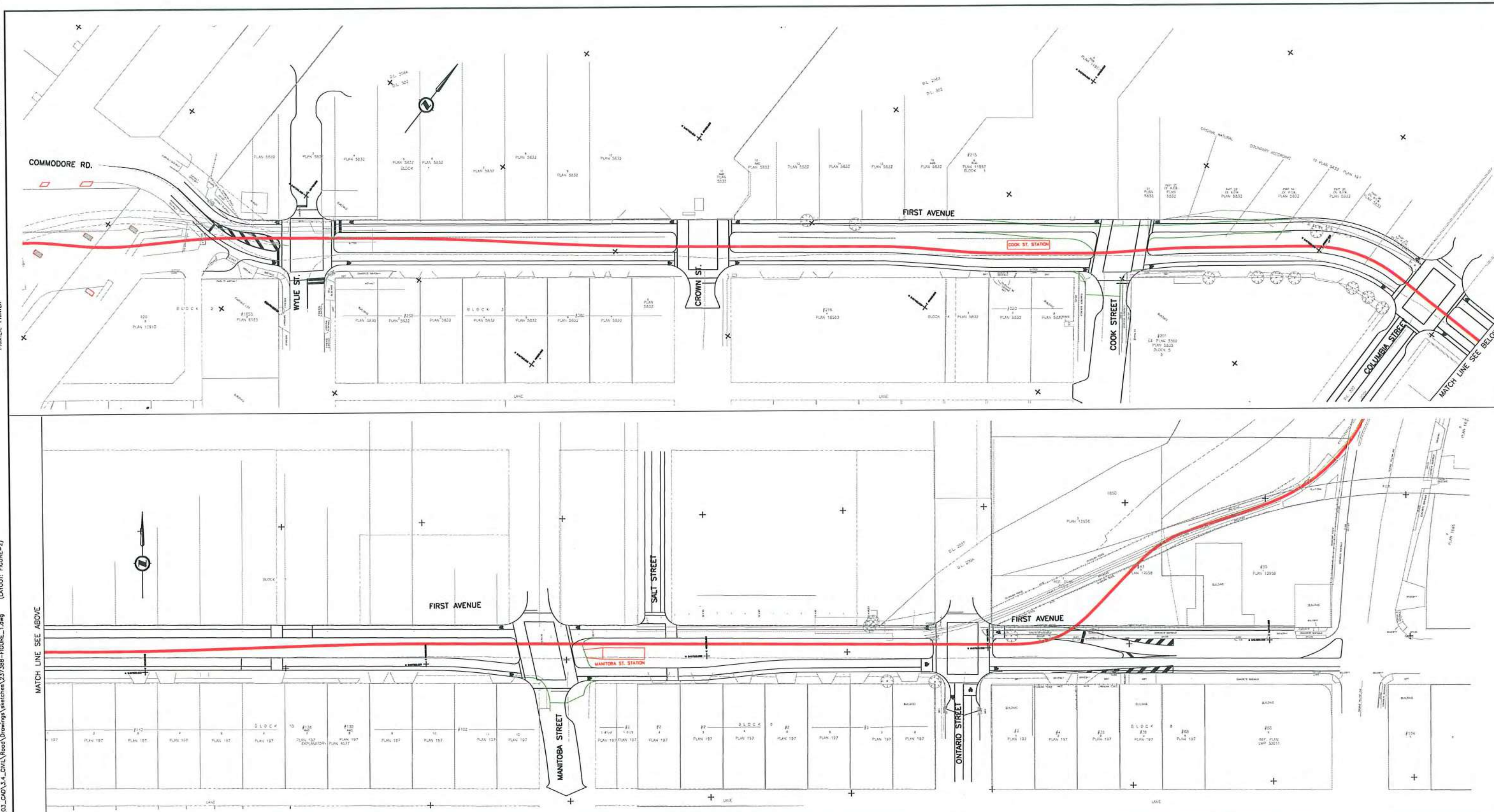

DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

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DESIGNED BY: SM	DRAWN BY: SM
DATE:	DATE:
CHECKED BY: TS	PROJECT MANAGER: DSW
DATE:	DATE:
HMM PROJECT No: 237388	DWG SCALE N.T.S

CLIENT:

CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

DHR BASELINE ALIGNMENT

FIRST AVENUE AT WYLIE STREET

DWG No:	SHT No	REV No
FIGURE-2		

PRINTED: November 9, 2007 - 8:12 AM

CAD FILE: P:\237388-Vancouver_Downtown_Streetcar\03_CAD\3.4_CIVIL\Road\Drawings\sketches\237388-FIGURE_1.dwg (LAYOUT: FIGURE-2)

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4 Vehicles

4.1 Introduction

This chapter discusses the technical specifications of the existing DHR and proposed modern Streetcar vehicles. The technical specifications or parameters, while still preliminary, are critical to the alignment design. The chapter first outlines the factual data for the vehicles and then discussions any assumptions that have been made which influence the alignment design.

It is important to note that the interaction of the DHR and modern Streetcar vehicles is complex, particularly in comparing their dynamic characteristics and envelops. In some sections the interaction of the DHR and modern Streetcars has determined that the two vehicles types are unlikely to be able to operate at the same time, primarily due to limited clearances along the 1st Avenue median. It has therefore been assumed that once the system is converted to operate modern Streetcars that the DHR vehicles would only operate on a limited basis, during special events and the like.

4.2 Downtown Historic Railway Vehicles

4.2.1 Basic Vehicle Type

There are two existing heritage vehicles operating on the DHR; cars 1207 and 1231. Car 1207 is described as a 1200 Wood Interurban rebuilt and upgraded by Steveston (the car has a long history of upgrade dating back to the 1920's). Car 1231 is understood to be a restored St. Louis Interurban. Overall, the vehicles are fairly similar in design and dimensions. There is very limited information on the performance of the vehicles and that which was obtained is contained in Appendix A .

4.2.2 Accessibility

The DHR vehicles (and the existing stations configurations) do not meet current 'Americans for Disabilities Act' (ADA) Part 38 – Accessibility Specifications for Transportation Vehicles, Subpart D – Light Rail Vehicles and Systems standards, which is considered a reasonable standard against which the DHR should be assessed. The primary deficiency is boarding access, as currently there is no provision for level boarding or other means of providing such access in the forms of lifts or access ramps.

At this time it has been assumed that no upgrades will be made to the vehicles as part of the reimplementation of the DHR. However, if ADA compliance were required then this may achieved through installing a mechanical lift to the existing vehicles. This has been undertaken on other heritage systems in North America. Systems in New Orleans and Little Rock have equipped each of their heritage cars with wheelchair lifts, two per car, with one on each side.

Advantages of this approach include the fact that no special equipment needs to be installed on station platforms and that if a unit on one car malfunctions, the following car can pick up the disabled passenger. The disadvantages include the fact that the lifts are very intrusive in the interior of the car reducing significantly the seating capacity and changing the internal ambience of the car. As well, cycle times for wheelchair lifts can be relatively long, meaning that their use can disrupt operating schedules, particularly on a line with frequent service. In the new replica cars being built for Little Rock by Gomaco, the lift has been incorporated into the front door opening in a manner that is not obtrusive.

The use of onboard lifts is considered more practical than constructing ramps on all of the stations, given the spatial requirements for the ramps, the impact upon station design, and the integration of the ramps once the system is converted for a modern streetcar.

4.2.3 Critical Vehicle Dimensions

The following table lists typical dimensions for the existing heritage vehicles. The table was compiled using vehicle drawings provided by CoV (Appendix A) in conjunction with measurements taken by HMM on site.

Table 3: Typical Vehicle Attributes DHR

Parameter	Data Source	Value
Length of car	Measured/DHR DWG 2 Measured/DHR DWG 3	15,342mm(1207) 15,546mm (1231)
Floor height above Top of Rail (TOR)	DHR DWG 1	1,270mm
Roof line height above Top of Rail (TOR)	DHR DWG 1	3,442mm
Maximum roof height above TOR, empty car and new wheels	DHR DWG 1	3,937mm
Door Handle and Roof Steps		
Handle Protrusion	Measured	76mm each side
Handle Height	Estimated	1,000mm
Handle bottom above TOR	Measured	1,588mm
Overhead Contact System		
Trolley pole operating height, under dynamic conditions	City Staff	~ typical range of 1.5m above the height of the vehicle
Maximum collector head width over horns	Not Available	Not Available
Minimum collector head carbon shoe length	Not Available	Not Available

Truck Dimensions (Truck spacing, centreline-to-centreline sufficient to comply with dynamic envelope)		
Truck wheelbase, motor truck	DHR DWGs 2 and 3	1,981.2mm
Centre of truck to centre of truck	DHR DWG 2/measured DHR DWG 3/measured	8230/8103mm (1207) 8484/8420mm (1231)
Truck wheel diameter; new, nominal;	DHR DOC. 4 Measured	889mm (1207) 889mm (1231)
Weight and Passenger Loading		
Empty Weight	DHR DOC. 4	Approx. 32, 523kg
Total Passenger Capacity	DHR DOC. 4	Approx. 56
Curves and Grades		
Minimum horizontal curve radius	Not Available	Not Available Typical vehicles of this type could achieve 15m or less
Minimum vertical curve radius, crest	Not Available	Not Available
Minimum vertical curve radius, sag	Not Available	Not Available
Maximum gradient	Not Available	Not Available Maximum on the current system is recorded at 4%

Dynamic Envelope		
Roll angle	Not Available	Not Available
Tangent track	Not Available	Not Available
Curves	Not Available	Not Available
Performance		
Top Speed	Not Available	Not Available
Acceleration, maximum rate empty	Not Available	Not Available
Deceleration, full service brake rate	Not Available	Not Available
Emergency braking	Not Available	Not Available
Parking brake	Not Available	Not Available
Jerk limits	Not Available	Not Available
System Operations		
Nominal overhead voltage	City Staff	600VDC
Maximum sustained overhead voltage	City Staff	615VDC
Minimum sustained overhead voltage	City Staff	500VDC

4.2.4 DHR Developed Kinematic Envelope

The Developed Kinematic Envelope (DKE) for the DHR vehicle was determined using HMM's internal High Floor Tram spreadsheet - version 1, which is attached in Appendix B . The DKE for a vehicle accounts for vehicle dimensions, vehicle construction tolerances, suspension characteristics, track radii, and track construction and maintenance tolerances.

During the initial assessment Car 1207 found to have the larger overall DKE and was used as the governing case for the cross section design. The roof line at the start of the nose curve governed end throw (when 25mm of cant or greater was applied), and the roof line at the centre of the vehicle governed centre throw. A 50mm tolerance was included to account for the fact that no information could be gathered regarding the suspension characteristics of the DHR vehicles, which influences DKE.

4.3 Modern Vehicle

For the purposes of this preliminary design a generic modern Streetcar vehicle must be developed. The generic vehicle considers a selection of current modern vehicles, which based upon our experience in the light rail market are likely to be offered by the leading manufacturers during procurement.

4.3.1 Basic Vehicle Type

The basic vehicle type was somewhat defined by the previous study IBI in 2005. Reference was made to a 2.46m wide partial low floor streetcar. Based upon the report and associated drawings, and following discussions with the CoV it was determined that the IBI concept was based upon the Skoda Inekon T10 vehicle operating in Portland, Oregon. Information on this vehicle has been obtained from the manufacturer and is outlined below.

However, as part of our study it was considered reasonable to consider other modern light rail and streetcar vehicles. This was to include vehicles in the 2.4m to 2.65m range, which covers almost the full spectrum of modern vehicles currently available. It is also assumed that the City's aspiration is for a low floor vehicle, with a typical floor height of circa 350mm above the top of rail. Taking account of the previous demand studies the vehicles should have at least the capacity of the Skoda Inekon T10.

The vehicles are likely to be double-articulated with each end of the car having a fully equipped operator's cab given that terminal loops are not being considered nor is space likely to be available. Initially, the vehicles will not be operated in a multiple unit configuration, although this could be technically feasible for recovery of a broken down unit. The stations have only been designed to accommodate a single unit (up to 25m between doors), however, multiple vehicle operations are possible in the future assuming that stations are extended to accommodate the longer vehicles. This is an appealing option if capacity upgrades are required.

Based upon our experience from other street running light rail systems we have developed the generic vehicle using the following industry standard vehicles:

- Skoda T10
- Siemens S70
- Bombardier Flexity Swift

Full details of the vehicle parameters are outlined below.

4.3.2 Accessibility

Unlike the DHR vehicles, the modern vehicles shall be coordinated with the platform configuration, provide level boarding, and comply with the Americans for Disabilities Act (ADA) Part 38 – Accessibility Specifications for Transportation Vehicles, Subpart D – Light Rail Vehicles and Systems. Stations shall comply with Canadian Standards Association (CSA) B651-04 – Accessible Design for the Built Environment.

4.3.3 Critical Vehicle Dimensions

The following table lists typical dimensions for two potential vehicle classes based upon a worst case for the vehicles referred to in 4.3.1.

Table 4: Typical Vehicle Attributes Modern Streetcar

	Typical Value	
Parameter	**Option #1: 2.46m Carbody Width**	**Option #2: 2.65m Carbody Width**
Overall Carbody Dimensions		
Length of car over coupler faces	21,.090mm	28,.524mm
Length of car over anticlimbers	Not Available	Not Available
Floor height above Top of Rail (TOR) – low floor section	350mm	381mm
Maximum roof height above TOR, empty car and new wheels	3,440mm	3,680mm
Pantograph		
Pantograph operating height, under dynamic conditions	3.960m - 6.250m	3.960m - 7.010m
Maximum collector head width over horns	Not Available	1,982mm
Minimum collector head carbon shoe length	Not Available	1,067mm

	Typical Value	
Parameter	**Option #1: 2.46m Carbody Width**	**Option #2: 2.65m Carbody Width**
Truck Dimensions (Truck spacing, centreline-to-centreline sufficient to comply with dynamic envelope)		
Truck wheelbase, motor truck	1,880mm	1,900mm
Truck wheel diameter; new, nominal;	610mm	660mm
Weight and Passenger Loading		
Empty Weight	Not Available	43,500kg
Total Passenger Capacity	30 seats Total 150	72 seats Total 190
Curves and Grades		
Minimum horizontal curve radius	16m	18m
Minimum vertical curve radius, crest	250m	250m
Minimum vertical curve radius, sag	250m	350m
Maximum gradient	8.5%	7%
Dynamic Envelope		
Roll angle	Not Available	Not Available
Tangent track	Not Available	Not Available
Curves	Not Available	Not Available
Performance		
Top Speed	70km/h	105km/h
Acceleration, maximum rate empty	$1.34 m/s^2 \pm 5\%$	$1.34 m/s^2$ up to 32km/hr
Deceleration, full service brake rate	$1.34 m/s^2 \pm 5\%$ to 5km/h	$1.34 m/s^2$ below 72km/hr
Emergency braking	Not Available	$2.96 m/s^2$

	Typical Value	
Parameter	**Option #1: 2.46m Carbody Width**	**Option #2: 2.65m Carbody Width**
Parking brake	Not Available	Not Available
Jerk limits	$0.45m/s^3 – 1.8m/s^3$	Not Available
System Operations		
Nominal overhead voltage	600Vdc	750Vdc
Maximum sustained overhead voltage	Not Available	1000Vdc
Minimum sustained overhead voltage	Not Available	525Vdc

4.3.4 Modern Vehicle Developed Kinematic Envelope

The Developed Kinematic Envelope (DKE) for the modern vehicles was determined by two means.

For the typical 2.46m wide vehicle, DKE tables provided by Skoda for their 10T model were used, assuming worst case of about 21mm super-elevation between the rails[2]. Refer to Appendix C .

For the typical 2.65m wide vehicle, the DKE was determined using HMM's internal 70% low floor tram spreadsheet. Input data was based on the Bombardier Flexity Swift technical specifications, assuming 25mm super-elevation and standard industry tolerances for modern vehicles[2].

[2] A value of 15-25mm is likely to be applied along 1st Avenue where DKE clearances are most constrained

4.4 Swept Path for DHR and modern Streetcar

The swept path describes a delineated zone of operation for the streetcar. It includes an additional clearance added to the DKE of the vehicle. The value of the additional clearance is based upon where the streetcar is operating or passing; for example, the clearance to a continuous solid feature (wall) or to adjacent road traffic.

Most jurisdictions and promoting authorities in North America develop their own criteria. In Europe there are more defined guidance documents; for example, in the UK the governmental organisation the 'Health and Safety Executive', provides clear guidance on clearances to be provided between light rail/tramway DKE and surrounding infrastructure. We have taken account of North American practice and used Rail Safety Publication 2 – Guidance on Tramways (RSPG) as a bench mark for the Vancouver Downtown Streetcar.

The following are some extracts from 'Railway Safety Publication 2' – Guidance on Tramways, defining some of the key clearance requirement found along Phase 0. The first image referenced Figure 2 provides clearance for when we have centre poles.

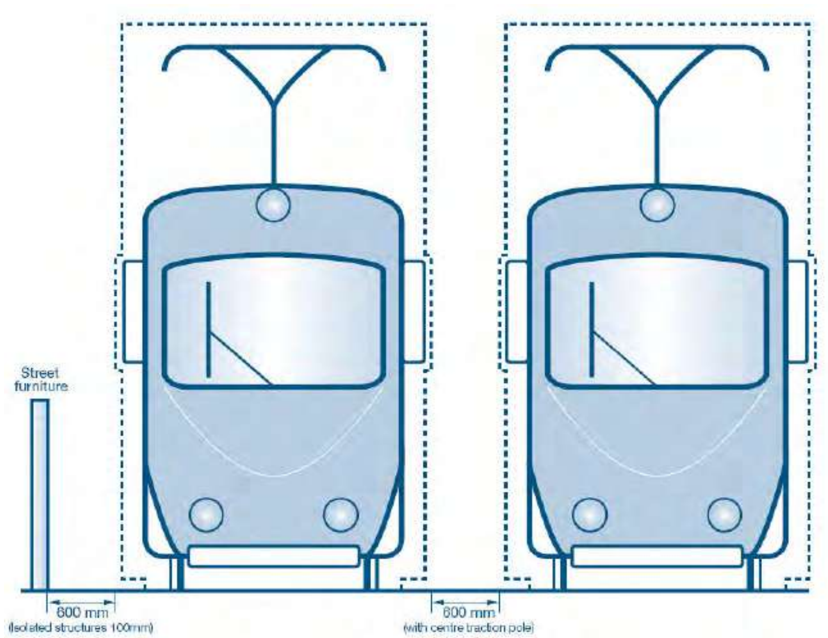


Figure 2:Minimum clearances in pedestrian-only areas

The image below referenced as Figure 4 provides guidance for a scenario similar to that along 1st Avenue where the streetcar operates in a central median. Note – the reference to the edge of carriage way was considered to relate to the edge of curb face in the scenario of 1st Avenue, given that road markings as represented in the Figure do not exist in Vancouver.

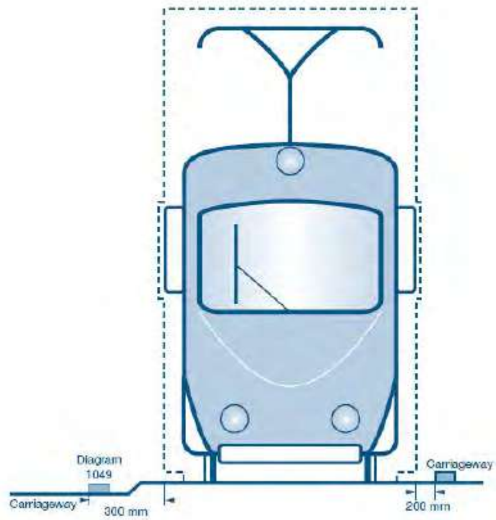


Figure 4:Minimum clearances on reserved sections of carriageway

The following image, referenced Figure 7, provides an explanation for the concern the HMM team have expressed over centre or island platforms that are 3m wide (i.e. Cook). At 3m it is difficult to provide any fixed infrastructure or platforms without encroaching on the 1500mm clearance. This dimension takes account of the comfortable space required for mobility impaired passengers (parents with stroller, wheel chairs etc…) to pass along a platform past obstructions. HMM recommends that CoV explore options to increase the Cook St. platform size to 4m. The additional space might possibly be achieved by moving the Wilkenson Building further north than originally planned.

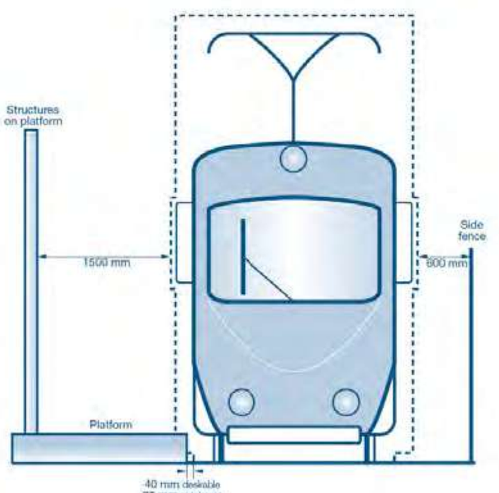


Figure 7:Clearances at tram stops and fences

4.5 Interaction of the DHR and modern Streetcar

The vehicles that can be selected for the future modern system will be determined by alignment constraints imposed by the Phase 0 corridor. The CoV have indicated an aspiration that the DHR should be able to operate in conjunction with modern vehicles, if possible. To determine the viability of this we have completed an assessment of how the vehicles will interface geometrically along the most constrained sections of alignment.

As outlined earlier four vehicles have been considered in developing the design: the DHR Car 1207, the Skoda 10T, the Bombardier Flexity Swift and the Siemens S70. It has also been determined that the median along 1st Avenue, from Wylie Street to Ontario Street, provides the greatest spatial constraints for Phase 0.

Making use of the principles for DKE and Swept Path calculation described earlier in this chapter, the following combinations of vehicle operation were considered for a double track alignment along 1st Avenue as presented in Table 5.

Table 5: **Vehicle options for Phase 0.**

	Required Median Width for Vehicle Swept Path (m)		
Vehicle	**Tangent Section**	**47.5m/50m Curve**	**OK with Design**
DHR and Skoda 10T	7566.4	7992.3	NO
DHR and Skoda 10T (without mirrors)	7211.8	7773.8	NO
Skoda 10T both sides	7354.8	7393.1	NO
Skoda 10T both sides (without mirrors)	**6645.6**	**6954.0**	**YES**
DHR and Bombardier Flexity Swift	7351.0	8093.0	NO
Bombardier Flexity Swift both sides	**6924.0**	**7614.0**	**YES**
Siemens S70 both sides	**6914.0**	**7484.0**	**YES**
DHR both Sides	7778.0	8602.0	NO

Notes:

1. Skoda 10T values based on worst case scenario of 2% cross level variation.
2. 47.5m/50m curve is the governing (tightest) radius on 1st Avenue.

3. Required median widths include 300mm on each side of median and 200mm between the vehicles for swept path.

4. Required median widths are based on the span wire arrangement proposed for 1st Avenue.

The assessment of a curved track at 47.5m/50m was undertaken to determine the spatial requirements at Columbia Street intersection. While there are tighter radii along other sections of Phase 0, such as at 1st Avenue/Quebec, there is opportunity at those locations to separate the tracks to accommodate a wider DKE.

A 6.9m median was already being considered by the SEFC Project team for their design of 1st Avenue based upon the findings of the 2005 IBI study. Critically, the design had also made no allowance for widening the median around the 47.5m radius at Columbia Street. The HMM analysis quickly determined that the median design would have to be amended were it to accommodate a double track streetcar system. The following conclusions could also be drawn:

- The median at Columbia Street needed to be widened irrespective of the vehicle chosen.

- Twin track DHR (or DHR vehicles passing each other) would require substantial widening of the median and most likely not be possible.

- The design provides adequate space for single track DHR operation. However significant operational constraints on the modern system would be required to facilitate this arrangement as DHR vehicles will only be able to operate on one of the double tracks.

- It maybe possible to fit two modern 2.46m wide vehicles, but these would likely need modifying to remove wing mirrors (the 2.46m Skoda with wing mirrors created a larger DKE that the 2.65m vehicles)

- It maybe possible to accommodate modern 2.65m wide vehicles

However, a complication not apparent from the table above is the impact that phased implementation of DHR/Streetcar has upon the setting out of the alignment within the median. The DHR has a larger overall DKE. Therefore, even if only one track is installed it must be offset from its nearest curb line by a minimum distance which is greater than that required by the modern vehicles. As a consequence, if a second track was to be installed at a later date to accommodate a modern vehicle, then the overall median width would be greater than the total dimensions presented above. The conclusion holds true on the assumption that the DHR will continue to operate, or that the track installed for DHR is not realigned if it were removed.

Further more, the manner in which the DKE of a vehicle develops when moving from a straight to a radius (such as that at Columbia Street) is such that track separation is slight greater than the theoretical values calculated above.

Taking all of the above into account, HMM recommends the following absolute minimum median requirements for 1st Avenue:

- **A median width of 7.1m on straight sections.**
- **A median width of 8.4m at its widest point on the 47.5/50m radius at Columbia Street**

The 7.1m minimum width is based on the following calculation based on the Skoda 10T (with no mirrors) on both sides of a double track tangent section.

Table 6: Minimum 1st Avenue median width calculation.

Design Component	Width Required (mm)
Vehicle DKE - modern	2922.8
Vehicle DKE - DHR	3489.0
Recommended Clearance between Vehicles	175
Recommended Clearance between Vehicles and Road Traffic	2x250 = 500
Total	7086.8

Following discussions with the CoV and SEFC Project team it has been agreed to increase the median to reflect these minimum values. An outline design was provided by HMM to the SEFC Project in October 07, which indicated the minimum spatial requirements for the median between Wylie Street and Ontario Street. This has been taken forward by the SEFC Project to develop a geometric layout for the median curb lines.

In areas where spatial constraints are less onerous, a wider rail ROW should be considered to allow for concurrent operation of modern and DHR vehicles in a double track system. In Phase 0, the Granville corridor is the only location where there is adequate space for this is option. Assuming a centre pole arrangement and a maximum curve radius on this section of the route of 180m, two DHR vehicles may operate side by side in a minimum ROW width of 8428mm on tangent sections that increases to a maximum of 8542mm at curves.

5 Traction Power

5.1 Introduction

This section of the report discusses the traction power requirements for the Downtown Streetcar Project both for the DHR and the modern Streetcar. The traction power system for the Project consists of the overhead contact system (OCS) and the traction power substations (TPS). There is also a discussion on the requirements for the duct bank system (underground conduits) for the feeder cables that feed power from the TPS to the OCS. As any duct installation will have an impact on the streetscape and there is an obvious desire not to cause further disruption in the future, the duct bank requirements for future communications and signal systems have also been considered in this report.

Stray currents caused by the DC powered transit operation can have a negative impact on surrounding metallic utilities and structures. Mitigation methods must be considered in order to prevent corrosion damage to the metallic infrastructure. This issue is reviewed and mitigation methods are discussed.

5.2 Traction Power - Overhead Contact System (OCS)

5.2.1 OCS General

The OCS for a streetcar system in a city environment typically consists of a single contact wire above each track. Where trolley pole operation is used for current collection by the streetcar, the contact wire follows the centre of the track and needs to be continuous from one end of the system to the other. At crossovers and turnouts, the contact wires are connected using trolley frogs that guide the trolley pole down the contact wire above the correct track. This single wire fixed termination (SWFT) system (variable tension during temperature range) is typically used where track speeds do not exceed 50km/hr.

Where pantograph operation is used for current collection, the contact wire is staggered at the support structures alternating from left to right of the track centreline. This sweeping effect on the pantograph carbon distributes the wear caused by the contact wire on the carbons, increasing their lifecycle. At crossovers and turnouts, trolley frogs are not used on the contact wire unless there is a mixed operation of trolley poles and pantographs. Where mixed operation is used, the trolley frogs require gliders be installed to stop pantograph damage.

If pantograph operation is exclusive, it is possible and preferable to break the contact wire into tension sections, typically 1.5km maximum, with overlaps between adjacent tension sections. These overlaps allow for simpler maintenance and adjustment of tensions during seasonal changes as well as contact wire creep (stretching over time). Overlaps also allow auto-tensioning of the contact wire which is beneficial when track speeds are above 50km/hr. These systems are known as automatic tensioned systems, either single wire (SWAT) or simple cantenary (SCAT).

The OCS must be designed in conjunction with the Substations and the streetcars to be used on the line. Modern streetcars typically require higher currents than historic vehicles. Also, voltage on the contact wire at the pantograph (or trolley pole) must be maintained above a minimum level. Meeting these requirements impacts the size and placement of substation(s) and the size of conductor and/or parallel feeders on the line.

5.2.2 OCS Layout for DHR

The accompanying drawings show the proposed OCS layout for the DHR.

(i) Granville to Cambie

For the alignment between Granville Street and Cambie Street, a SWFT contact system design is required which will accommodate heritage vehicles as well as modern streetcars. Due to the fixed termination the tension in the contact wire varies with the surrounding ambient temperature. To allow for both heritage vehicle operation (trolley pole) and modern streetcar (likely pantograph) minimal contact wire stagger of 80 – 120 mm would be inserted into the installation. The design of the contact wire will need to consider natural curves in the alignment in order to maximize sweep across a pantograph and at the same time allow the trolley pole collector shoe to track as smoothly as possible. Even with reduced stagger some de-wirements of the trolley pole may be experienced, especially as vehicle speed increases. Care must be taken in the design in locating hardware such as frogs for turnouts to ensure the stagger does not negatively affect trolley pole operation. Gliders at the frogs will be required for pantograph operation.

Where possible, the existing wooden DHR poles will be used for the new DHR. Where these existing poles are not suitable, new poles will be required. Cantilever type OCS installation will be used to support the contact wire except for certain specific situations where cross spans are necessary. A3E poles will be sufficient for most new pole locations as tensions are below the 13,245kN pole rating. Larger A23E poles will be used at some turnout and certain curve locations where there are heavier loads. These locations have been identified on the drawings.

(ii) 1st Avenue

Two arrangements for the OCS along 1st Avenue were explored in the preliminary design of the DHR.

Option 1 is to place a set of wooden poles in the centre of the 1st Avenue median. In order to accommodate the phasing of the SEFC works, HMM initially recommended a DHR alignment that alternated between the north and south side of the median, necessitating poles placed in the centre of the median. The potential for the new poles to interfere with the GVRD force main under the median between Columbia St. and Ontario St. and the implications of a third set of poles from an urban design perspective, it was agreed that this was not an ideal solution.

Subsequently, HMM was asked to design a 1st Avenue DHR alignment centred in the median due to concerns about accessibility from emergency services. Given this centre alignment, it may be technically feasible to utilize a side pole arrangement subject to further utility investigation. It appears, however that locating the poles on one side also interferes with emergency vehicles. The poles are spaced a maximum of 30m apart and it is not possible for a fire track to pass a broken down vehicle (located in the middle of two poles) in this distance. The poles would then have to be staggered to allow this manoeuvre which would then have greater risk of impacts on adjacent utilities and a greater intrusion on the new streetscape. After reviewing the economic (see chapter 12) and aesthetic costs, it was agreed that Option 1 was not practical.

Option 2 is to suspend the OCS from cross span wires that utilize the street lighting poles being designed for the 1st Avenue road contract. The OCS for this section is also based on the single wire fixed termination (SWFT) design. To accommodate the possibility of pantograph operation minimal stagger will be introduced. Once again the design of the contact wire will need to consider the natural curves in the alignment in order to maximize sweep across a pantograph while at the same time allowing the trolley pole collector shoe to track as smoothly as possible. The slower vehicle speeds anticipated in this area will reduce the expectation of trolley pole dewirements.

The poles to be used on 1st Avenue have been identified as being type A3E. As mentioned previously, these poles are rated for 13,345kN. The following standard criteria were used to verify the adequacy of these proposed poles, for a SWFT design.

Table 7: Contact Wire Standard Criteria

Contact Wire (CW)	2/0 bronze alloy 80
Tension	
@ 15 ^{o}C (normal tension)	11.1 kN
@ -35 ^{o}C, 13 mm radial ice, no wind	21.02 kN
@ 50 ^{o}C, no ice, no wind	5.5 kN
@ -35 ^{o}C, no ice, no wind	20.91 kN
Max basic wind speed (structural design)	160 km/h

Luminaries on the poles were conservatively assumed to have 0.55 m^2 of wind surface area and weigh 90 kg, 3m away from the pole. Transit loads on the pole were calculated to include 1 contact wire for the single DHR track and a 2nd contact wire for a double track streetcar installation.

Calculations have conservatively determined that the A3E poles are structurally adequate for most locations for the DHR. Smaller A7E poles are not sufficient structurally for cross span installations. At certain outside curve locations where spider guying arrangements are necessary higher strength A23E poles (rated for 26, 690 kN) will be necessary. These locations (poles 2, 8, 29, 38, 40, 42, 79 and 82) have been identified on the drawings.

Although we have used conservative values in our calculations for the one track DHR only scenario, the A3E poles appear to be the only pole available that meets the structural requirements. Calculations have shown the smaller A7E pole to be structurally undersized for this application. Under a two track Modern Streetcar scenario the A3E poles remain suitable for the purpose. At the curve locations indicated the larger A23E poles are required for both DHR and Modern Streetcar.

(iii) Ontario to Science World

For the alignment between Ontario Street and Science World it is recommended the SWFT contact system design be continued in order to allow pole operation and heritage vehicle pantograph operation. Rather than the cross spans that were required for the centre street operation along 1st Avenue, single poles with cantilevers is the preferred design for this section. For most poles A3E type will be suitable while for some heavier load locations the A23E type will be required. Some pull-off bridal assemblies will be necessary for certain curves.

5.2.3 OCS Layout for Modern Streetcar

The accompanying drawings show the proposed OCS Layout for the modern streetcar.

Continued operation of heritage vehicles with pole operation is a key issue in the recommendations for OCS design. Pole operation cannot operate with discontinuous contact wire as required for automatic tensioning. Thus a fixed termination design is necessary. The introduction of a vintage pantograph (or similar) on heritage vehicles is an option which would allow auto tension configuration and thus higher operational speeds. However, this may not be possible or desired.

(i) Granville to Cambie

In the Granville Street to Cambie Street area the two track modern streetcar alignment is slightly different than for the DHR alignment. In order to accommodate the pole operation of heritage vehicles a SWFT arrangement is necessary. None of the existing, wooden poles are likely to be suitable for the two track modern Streetcar design. Supporting the two contact wires for the two tracks would require the installation of new poles opposite each of the existing wood poles. This would result in an aesthetically unpleasing situation where wooden poles are matched with steel poles to carry the cross spans. As new poles must be installed the use of centre poles that can serve both tracks is a better option and is recommended. The wooden poles would be removed. In some locations where a single centre pole cannot serve both tracks, additional poles will be necessary. For specific situations side poles and cross spans may be required.

The OCS design would include stagger of the contact wire to accommodate the modern Streetcar pantograph operation. With continued operation of the heritage vehicles the amount of stagger would have to be reduced accordingly.

(ii) 1st Avenue

The 1st Avenue two track modern streetcar design follows generally the same alignment as the DHR and would utilise the same pole cross spans and continue as a SWFT design. This includes the curve locations where larger poles are required. The cross spans provided under the DHR design would be of sufficient size to accommodate the 2nd contact wire required for the modern streetcar design. There wouldn't be any benefit or economy to use a smaller sized cross span for the DHR design.

Some modifications may be required to accommodate crossovers in the two track design. Plans presently include crossovers at two locations. Modifications could include additional cross spans required to support the special OCS hardware (frogs and gliders) associated with the crossovers. These modifications would depend on the specific final location of the crossovers and their relationship to the lighting poles as installed.

The OCS design on 1st Avenue would also be influenced by modern streetcar pantograph operation which would require some stagger to be introduced into the contact wire design, again 80 - 120 mm on either side of centre. Again, care must be taken in the design to ensure this stagger does not negatively affect trolley pole operation especially as it relates to locating hardware such as frogs for turnouts.

(iii) Ontario to Science World

The alignment for the section between Ontario Street and Science World changes for the modern streetcar, following 1st Avenue up to the corner of Quebec Street where it turns north and side runs to Science World. For this alignment the SWFT contact system design is again recommended as the section must accommodate the heritage vehicle trolley pole operation. Side poles with cross spans would be utilized up to the point where the alignment turns north and then centre poles provided north up to Science World.

Again, OCS design to accommodate both pantograph and trolley poles must be considered.

5.3 Traction Power - Substations

5.3.1 DHR

Traction power substations are used to convert AC power from the utility to 600 VDC power for use by the streetcar vehicles. The existing DHR traction power substation is located near 1st Avenue and Moberly Rd. approximately 400 m west of Wylie Street, at approximately the midpoint of the alignment. The substation unit is rated at 322 kVA and can provide 500 A output at 600 VDC.

City representatives have indicated that electrical devices on the DHR heritage vehicles restrict the maximum starting current on the vehicles to 175 Amperes. Two vehicles operate on the line at any given time, one starting from each end on the hour and ½ hour.

Based on past operation, this single substation is sufficient to operate the DHR with two heritage vehicles. Calculations show voltage drop along the short DHR line is not sufficient to warrant a parallel power feeder. The use of continuously welded rail (CWR) will serve to reduce the overall power circuit resistance and mitigate the amount stray current (See section 5.5).

Successful operation of a modern streetcar on the DHR (for demonstration purposes) with power being supplied from the single existing substation cannot be confirmed at this time. Without specific details of the electrical requirements of a modern streetcar it is not possible to make such a decision. However, based on our knowledge of typical modern streetcars (see section 5.3.2) it is unlikely that this single substation would be sufficient, even for demonstration purposes.

5.3.2 Modern Streetcar

Power requirements for the modern streetcar system can be better developed with the aid of a traction power computer simulation. It is recommended this be completed in the next phase of the program when the specific vehicle physical and electrical characteristics are available. Modern streetcars are known to have higher power requirements than historic vehicles. It is also likely that, in a full operating scenario, there will be an increased number of vehicles operating on the line. Consequently, the single DHR substation would either have to be replaced and/or augmented by additional substations.

Substation requirements and spacing are based on many factors and include:

- the physical and electrical characteristics of the vehicle to be used on the line
- the availability of, and primary voltage level of the local utility power
- physical space availability for substation placement
- the electrical distribution system (contact wire size, parallel feeders, etc.)
- stray current parameters

Modern streetcars generally operate at between 600 and 800 Vdc with minimum voltage requirements on the contact wire that must be met at all locations along the line. Based on typical streetcar system designs, substations are generally placed up to 2 km apart and provide 1000 KW of power at 600 Vdc. Utility power is provided at 12.5 kVac. However, if any of the requirements noted above become more significant it may be preferred to deviate from the typical. For example, if 600 Vac is the utility's only service supply then additional smaller (500 KW) substations spaced more closely together may be the preferred design. Closer substation spacing would also be beneficial for stray current reduction. In either case the size of the contact wire and/or need for a parallel feeder would need to be determined. As heritage vehicle operation is likely to be retained the modern streetcar operating voltage will likely remain at 600 Vdc.

Electrical distribution from the substation would be through feeder breakers. Initially two feeder breakers would be provided, feeding on opposite sides of an insulated gap at the substation. The modern streetcar alignment is approximately 3000 m in length. This could be powered by two large substations, placed at approximately sta. 0+750 and sta. 2+250. If smaller substations are preferred, then four or five smaller substations spaced along the alignment would be provided. Increasing the size of the contact wire or adding a parallel positive feeder cable (500 kcmil) may be necessary to ensure voltage levels above the minimum are maintained along the line. Risers from the parallel feeder at about 150 m intervals up the poles and out to the contact wire would be provided.

Substation sizing and spacing along with contact/feeder distribution requirements will be finalized with the aid of a simulation.

5.4 Ducting

5.4.1 DHR

It is considered that the DHR will not require any significant conduits along the length of the route because there are few systems requiring supply. There are no traction power parallel feeds for the DHR and providing the system continues to operate only the two existing heritage vehicles then this should not change.

The stations have no or limited systems equipment, such as Passenger Address (PA), CCTV, Passenger Emergency Call points (PEC), Passenger Information Displays (PIDS) and the like, and therefore do not require any duct provision. Some local lighting may be installed and this would require some ducts to carry the electrical supply.

5.4.2 Modern Streetcar

Ducts for the Modern Streetcar system would include those for traction power as well as those that would be required for communications and signal systems that are provided in the future.

- Traction Power parallel feeds
- Signal and Communication cables (CCTV, SCADA, PIDS, PEC's, PA, and streetcar signal loops)

For traction power, as for the DHR, three ducts from the substation are required. One duct runs from the substation to the nearest point on the track and serves as a negative return. The remaining two ducts (one of which is a spare) will run between the tracks in 150 mm conduits to provide a parallel positive feed. Risers positioned approximately every 150 meters along the alignment from the power duct (pull box) up specific power poles would be required. For aesthetic purposes it would be preferable for the power cable to be routed on the interior of the power pole. If this option is not provided an external conduit would be necessary on the pole.

Modern Streetcar communications systems could include systems such as;

- Supervisory Control - for remote operation of substations or other wayside systems,
- CCTV links - to a Central Control location,
- Ticket Vending Machines (TVM's) – interfaced to Central Control,
- Passenger Information Systems (PIS) – visual message boards, intercoms,
- Other systems (that are not stand alone along the route).

A modern streetcar may also be equipped with a signalling system that requires connection along the route and to the Operations and Maintenance Centre. Conduit connections may also be required between the transit signal system and regular wayside traffic controllers at signalled intersections. These connections would be necessary to implement prioritized or pre-emptive traffic signals for transit operation. See Chapter 7.

Communications systems generally are provided with two dedicated 100 mm conduits paralleling the line that can be equipped with inner-duct if so needed. Two ducts would also be provided for Signalling. Each would have a spare conduit and thus a total of 6 conduits are required. When combined with the two Traction Power ducts a total of 8 ducts are required.

The traction power ducts can be located separate from the signals and communications ducts. However for low voltage DC traction systems such as this separation by more than several inches is generally not necessary. In fact many agencies utilize a combined systems duct (CSD) which includes traction power, communications and signals for routing cables. The CSD can either be a concrete encased duct bank or a trough system. In a trough system, power cables can be separated from the communication/signal cables by dividers.

5.4.3 Advance Conduit Installation on 1st Avenue

Two new duct banks are proposed for the 1st Avenue redevelopment with one bank running along each side of the street. Communications (GCOMM) are proposed for the north duct bank and hydro is proposed for the south duct bank.

Following a review of the SEFC proposals it was determined that the six ducts for streetcar communications and signals equipment could be incorporated into north GCOMM duct bank. Stantec is currently exploring the implications associated with the expansion of the larger north duct bank.

The SEFC Project team have confirmed that the south sidewalk duct bank cannot be used for the traction power conduits. B.C. hydro requires a 300mm offset between its conduits and adjacent conduits, and there is not adequate space to meet this criterion. The traction power conduits will remain in the median. The arrangement is illustrated in Appendix D .

Laterals for both traction power and communications must cross the median at various locations. Details of these crossing locations have been identified to the SEFC Project team and will be incorporated in their design (see Appendix E).

5.5 Stray Current

5.5.1 What is Stray Current

Stray current is an undesirable characteristic of DC powered transit systems that utilise the running rails as the electrical negative return. A certain portion of the electrical current required to run the vehicles returns to the substation other than on the intended path, the running rails. Often the unintended path is a parallel metallic gas, water or electrical utility or other buried infrastructure. The leakage current travels along the utility path and then leaves near the substation. Where this stray current leaves the utility, corrosive action occurs that, with time, seriously damages the buried infrastructure. The amount/rate of damage increases proportionately with the amount of current that strays from the running rails. Given the same track (running rail) design there would likely be higher stray current and thus higher damage associated with the modern streetcars over DHR vehicles due to the higher currents associated with the former. Prudent traction power designers design the system to minimize the amount of stay current.

5.5.2 Stray Current Strategy

The stray current problem is solved by controlling the leakage at the source, in the track and in the power system. Modern transit systems utilize various methods to mitigate and minimize the amount of stray current. These methods can include floating (insulating) the negative traction power return above ground using high resistance fastener components. Safety is provided by controlled diode grounding. The use of continuously welded rail (CWR) and track bonding to reduce the resistance of and improve the continuity of the running rails is standard. Maintaining high rail-to-earth resistance through proper maintenance is essential. Where track is installed as tie-and-ballast (private ROW) maintaining isolation of the track from the ballast, keeping the ballast clean, and using insulated track fasteners are key mitigation methods. For buried track (street running or grass track) the use rubber type "insulated boots" around the rail can be an effective measure. Minimizing the spacing between traction power substations also serves to reduce stray current by reducing the voltage drop along the route. Also positioning substations near to locations of heavy current usage is beneficial.

Our strategy for the Downtown Streetcar Project will be to identify and evaluate the potential stray current impact on surrounding utility structures. This will require investigation to determine the soil corrosivity along the alignment by obtaining soil samples and performing resistivity testing. This will identify where there is increased potential for corrosive activity.

Available design criteria will be examined for applicability to the Downtown Streetcar Project. Based on this evaluation a stray current simulation may be recommended. This complete analysis will allow effective design of the traction power system for the Downtown Streetcar Project. With proper design it is not anticipated that relocation of utilities or the application of cathodic protection will be required.

6 Trackform

6.1 Introduction

This chapter discusses the preferred trackform for the reinstated DHR between Wylie Street and Ontario Street, and for the proposed future modern streetcar system along the entire Granville Island to Science World corridor.

6.2 Typical Streetcar Track Forms

The following describes the various types of trackforms found on streetcar, tramway and light rail systems globally.

6.2.1 Ballasted Track

Ballasted track is the traditional method of constructing track for railways and uses proven technology that is well understood. The rail section, typically tee rail, is fixed to horizontal ties using a variety of techniques. A pad is placed between the rail and the ties in order prevent stray current leakage into adjacent ground and ensure efficiency in returning the current to the sub-stations. Ballast, on which the ties rest, forms the base of the track.

Ballasted track is economical, relatively quick to construct, and is the most structurally flexible option for streetcars. A commonly quoted disadvantage of ballasted track is that the surface finish is not suitable for pedestrian or vehicular trafficked areas. In addition, the use of horizontal radii less than 1000m, which are common in urban systems, can result in increased lateral forces on the track, for which ballasted track is less well suited. An illustration of ballasted track is provided in Figure 3.

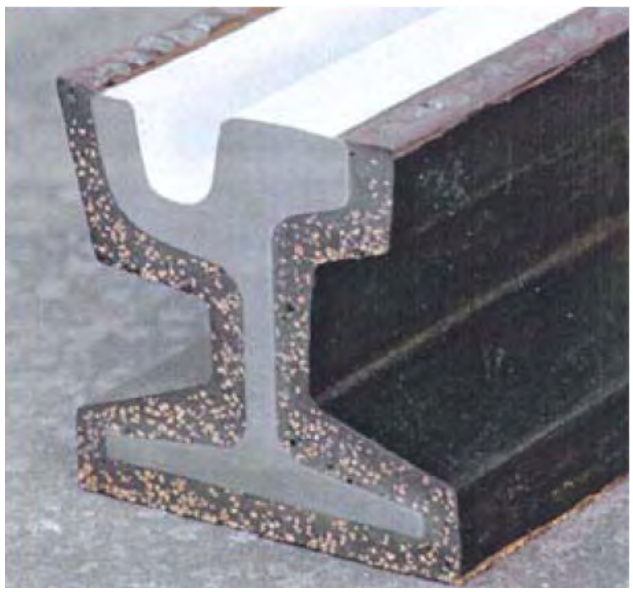
Figure 3: Ballasted track.

6.2.2 Embedded Track

Embedded track refers to any track form in which the rails are surrounded up to and including the railhead, with the exception of those with grass as a surface finish (discussed separately). Typical finishes include concrete, block paving or asphalt.

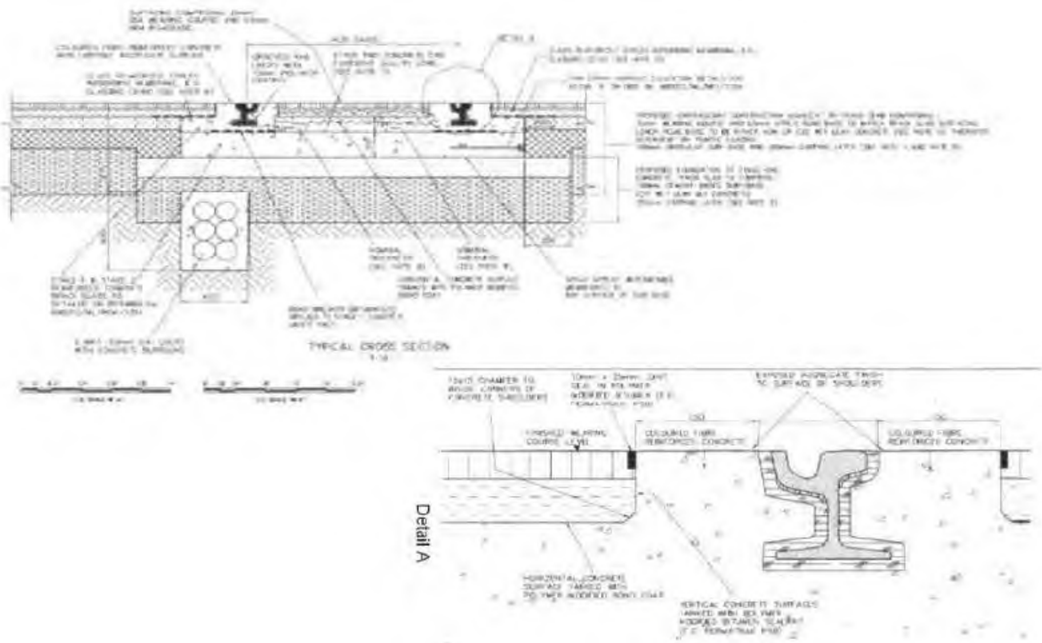
Embedded track often makes use of rail sections with a built in flange way, commonly known as grooved rail. A typical section is shown in Figure 4. In addition, it requires greater levels of insulation of the rail than ballasted track in order to prevent stray current leakage into adjacent ground and ensure efficiency in returning the current to the sub-stations. This is typically achieved by surrounding the rail in a rubber boot, either on or off site.

Figure 4: Grooved Rail.



Fixing the rails in place is achieved by grouting or casting the rails in concrete or using clips and pads as in ballasted track. Many bespoke systems are also available. Fixing the rail in place with a system that allows for easy, quick and cheap replacement of the rails is an ongoing challenge with embedded track. An example of embedded track is shown in Figure 5.

Figure 5: Embedded track.



Detail A

6.2.3 Grass Track

The design of grass track tends to take one of two approaches, either a variation on ballasted track or on embedded track.

The embedded track variation is arguably the most common and based on a structural slab or sleeper/tie system cast in concrete to which the rails are fixed. There are numerous variations on how the base slab is constructed, track is fixed, and soil and grass are retained. Between the rails and to either side, a void is left in which soil and drainage is installed and upon which grass (or similar plant material) is grown. An edge retainer/isolation detail is typically placed around the rail, for example a rubber boot. In some designs this will also include a concrete upstand (100-125mm wide) which provides separation between the rail and the grass/ top soil. The rubber boots and concrete upstands are included to improve the electrical isolation of the rail and reduce the risk of stray current.

The ballasted track variation involves placing growing media on top of the ballast on either side of the rail. A geotextile membrane is placed between the soil and the ballast to stop the washing of fines into the ballast, which would reduce the track bed's structural efficiency. As with the embedded designs isolation details are provided around the rail, although due to the flexible nature of ballasted track this would typical be a polymer or rubber based boot or block, and would not incorporate a concrete upstand. An example of grass track is illustrated in Figure 6.

Figure 6: Embedded grass track.

Irrespective of the type chosen, it is possible to create a grass/green streetcar track that will accommodate vehicular loading. For the most part, however, green surface exposed to regular driving tends to be less visually attractive and vehicular loading would ideally be restricted to emergency or maintenance access.

Grass track has met with a variety of success (where success is based upon the ongoing visual appearance and sustainability of the grass track). Some of the best examples are to be seen in Europe, particularly in France, Germany and Spain. Although, grass track has been considered for a number of UK schemes few lengths of track have been implemented and with limited success. There are a limited number of applications in North America, and these are primarily restricted to heritage based systems.

Successful schemes have paid particular attention to the detail in the design and the appropriateness of grass track to their jurisdiction and the environment. Careful consideration of maintenance, stray current, and selection of plant species is required for the system to flourish. By way of example, it is commonly noted that French systems, where some of the most attractive grass track forms have been produced, have less onerous requirements on stray current and therefore have not created complex edge details around the rail to achieve high levels of isolation. They are also more likely to accept greater maintenance costs where aesthetic design is given greater priority, and therefore readily chose a traditional grass and accept the increase cost of grass cutting and maintenance. By comparison, UK schemes have particularly onerous stray current requirements and this has resulted in more costly designs that are perhaps less visually appealing.

There are two basic options for vegetation: turf (grass) and sedum (or other succulent plant type). These are discussed in greater detail below. The depth of soil available for the planted material to grow in is critical and with rail sections typically 150-180mm tall, the depth between the rails can be somewhat restricted. It is for this reason that planted material that requires more than 225mm of depth are often discounted. However, there are some trackform designs appearing in Europe where the depth between the rails has been greatly increased by adopting a longitudinal beam design to support the rail. The precise detail of this system, such as drainage to the subgrade/substructure is not known at this time and would need further investigation to verify its durability.

Figure 7: Construction of embedded grass track. Note additional depth between rails.

(i) Turf

Turf (grass) typically requires an embedded track that provides a recessed planted area with adequate drainage. It also requires mowing, maintenance, and possibly irrigation; however drought resistant turf can be used to minimize irrigation needs.

The following cool season grasses are well adapted for the Pacific Northwest coastal regions with relatively cool summers and wet milder winters:

- *Festuca rubra*, Creeping Red Fescue
- *Festuca caesia*, Blue Fescue
- *Lollium perenne*, Perennial Ryegrass.
- *Poa pratensis* ‘Adelphi’, Dwarf Kentucky Bluegrass.
- *Poa trivialis*, Rough Bluegrass

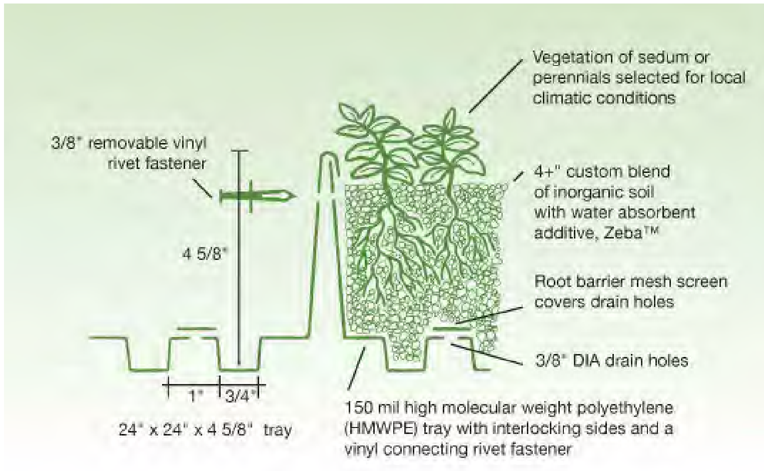
(ii) Sedum/succulents

A wide variety of sedum and succulent plant species are available, providing winter and summer colour. Contrary to turf tracks, sedum maintenance is limited to infrequent spot weeding, usually while plants are filling in, and periodic watering during the first year while plants are establishing. Periodic irrigation may be required during drought conditions.

Sedum/succulents are feasible with an embedded track and have been used in a number of locations, most notably on the European systems (see Figure 8). An adaptation to a sedum based system that has been investigated for the preliminary design is a new tray based system called Advanced Vegetative Roof System (AVRS) which holds the growing medium. There is potential for this system to work both in an embedded track and potentially with a ballasted track profile. The trays are 115mm deep and are planted with the desired ground covering.

Figure 8: Succulents in place on a European system help to delineate the rail corridor.

Figure 9: Advanced Vegetative Roof System (AVRS)



The system has the benefit that it can be pre-grown and should be quick to install and establish. Equally, it should be possible to temporarily remove the tray should maintenance to the track structure/bed be required. This is could be very relevant if used in conjunction with ballasted track as access to ballast for tamping and rail component maintenance is a concern, particularly where the top soil and grass are grown directly on top of the ballast without means of easily removal.

It should be noted that according to the manufacturer non sedums have not been successful in the AVRS.

As can be seen in Figure 9 sedum do not necessarily provide a lush green appearance and there use along 1st Avenue may not provide the desired aesthetic finish, and this issue needs further investigation. A further critical factor for the AVRS solution is that it cannot accommodate vehicular traffic loading, making it unsuitable for 1st Avenue. It's most suitable application for the Streetcar project maybe in the Granville Island and Science World Corridors where it could be used to disguise a ballast track form.

6.3 Trackform for DHR

At the commencement of the preliminary design HMM received two CoV requirements on trackform design that influence the selection for the DHR:

- An aspiration for a grass track solution for the ultimate streetcar, and
- DHR design should accommodate, where practical, the ultimate streetcar design in order to minimise future development costs.

While an aspiration for grass track along the Granville rail corridor is reasonable, it has been assumed that that ballast track would continue to be used. This would be the most cost effective solution and not out of keeping with the current environment.

Ballast track was also recommended for the reinstatement of the DHR along the 1st Avenue median, initially for reasons of cost effectiveness. However, it has been recognised that ballast track along 1st Avenue has its limitations. There is a requirement for emergency vehicles to have access across the median. Ballasted track would make such a manoeuvre very difficult and restricts emergency services. As a compromise, single line DHR track along the centre of the median that allows extra width adjacent to each curb line for vehicles to track over, is recommended. At stations the track would have to slew to one side in order to create sufficient space for a platform, which again is considered reasonable. The track facing the platform would likely need to be paved in this scenario. Alignment selection is discussed in greater detail in Chapter 3.

From 1st Avenue to Science World the track would again be a form of ballast, as per the existing.

6.3.1 Reuse of DHR Rail Components

The original DHR track along 1st Avenue was removed in late 2007 to allow for the reconstruction of 1st Avenue. A number of the rail components were salvaged and stockpiled. HMM was asked to evaluate the possibility of reusing these components for the reinstatement of the DHR. Based on the results of HMM's inspection, reuse of the stockpiled components for the reinstatement of the DHR is not recommended. A detailed account of the inspection and recommendations is included in Appendix F.

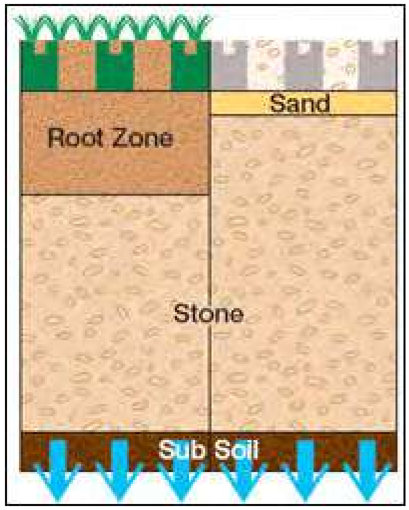
6.4 Trackform for Streetcar

A combination of track forms is recommended for the Streetcar From Granville Island to Cambie Street, ballast track is again proposed. Should the CoV desire grass finish, embedded grass track is recommended. The cost estimate in Chapter 12 is based on ballasted track and would increase should the embedded grass track option be selected.

An embedded track, using pre-coated or booted groove rails, is recommended for the rest of the route. Based on the CoV's concept for the Streetcar a grass finish will be provided from Wylie Street intersection on 1st Avenue through to Cambie Street to Pacific Boulevard. A hard finish, concrete, asphalt or stone setswill be applied at road crossings , the approach into the yard along Quebec Street and in areas around stations.

In the early stages of design, CoV indicated that any trackform selected for the streetcar system had to accommodate loading by road vehicles. Specifically, this included emergency vehicles and a commercial truck turning movement out of a proposed grocery store on the north side of 1st Avenue between Manitoba Street and Ontario Street. In order to meet this requirement, Golpla ® or a similar product, is recommended for grass track sections along 1st Avenue. Golpla ® is a rigid plastic grass reinforcement system (see Figure 10) that perpetuates the growth of grass under repetitive traffic or pedestrian loading by protecting the root system. The CoV's preference for consistent green cover and vehicle loading in the grass track sections precludes the sedum options outlined in 6.2.3 (ii) and hence the turf option is recommended. Small element paving may be applied to delineate pedestrian crossings and stations.

Figure 10: Golpla ® grass paving system.



Drainage will be achieved by sloping the surface of the structural slab in each trough towards a 100mm diameter central drainage pipe, that outlets to the local storm system via a 200mm diameter longitudinal drainage pipe running parallel to the alignment.

It is important to note that this is only one of a variety of trackform designs that could be accommodated. It does not precluded future scheme development and innovation but has been used to confirm spatial and technical requirements within the median.

7 Traffic and LRT Signals

7.1 Introduction

The chapter discusses the signal requirements along the route for both DHR and modern Streetcar.

The existing electrical design along 1st Avenue was undertaken as part of the 1st Avenue Works, and initially completed in isolation to the Streetcar/DHR preliminary engineering. A functional design for the traffic signals along the 1st Avenue corridor was completed for both the DHR and modern Streetcar proposals. The objective was to identify additional infrastructure required to integrate the DHR and Modern Streetcar into the proposed 1st Avenue Works designed by Stantec and recommend additional signalling infrastructure where required.

7.2 Assumptions

The following assumptions were made for the traffic signal design along 1st Avenue:

- The DHR scenario will be implemented with limited operating times, typically occasional weekend usage. The operators will operate as if sharing the roadway with other road users and obey the traffic signals. There will be no dedicated DHR signals with the exception of Moberly where an existing signal will remain in place or be upgraded and at Ontario St. to allow DHR to transition from the median to the existing ROW.
- Along 1st Avenue, traffic signals were only included at intersections that were signalised in the Stantec design.
- The modern streetcar scenario will be operating daily with greater frequency then the DHR. Traffic signals and “No Left Turn Train Xing” signage will be required at the majority if not all intersections along the corridor to prevent conflicts with cross street traffic and left turning vehicles.
- Industry standard pre-emption indication lights should be installed on poles and should be visible to operators in order to provide them with indication that a pre-emption call has been received.
- The laning on 1st Avenue westbound at Ontario Street during the modern streetcar scenario operation will include the ultimate width to Quebec Street and queuing will not back up onto the streetcar tracks. Traffic micro/macro simulation will be required to assess the queuing.
- Ducting to the median nose at intersections will be adequate for tie-in to pre-emption track sensors and ducting will be installed to connect pre-emption track sensors to the pre-emption system in the traffic controller.
- Non-electrical signing has not been considered at detail as part of this design.
- Pole capacity analysis has not been undertaken to verify the adequacy of the existing pole structures with the addition of signs. Traffic pole capacity analysis will be undertaken by Stantec and will include the wind loading from the additional LED signage (NB. Assessment of lighting poles for OCS loading has been completed by HMM).

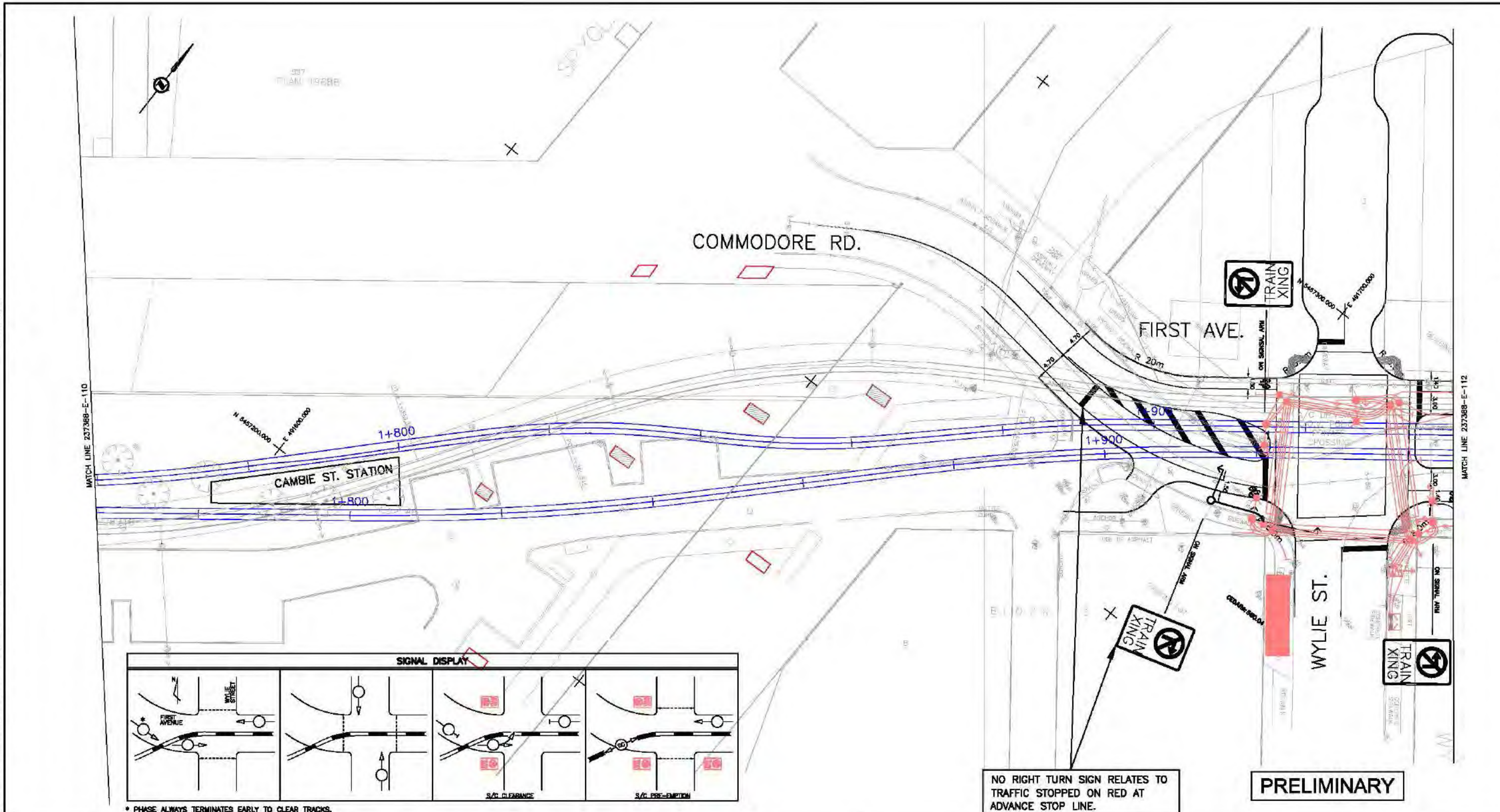
7.3 DHR

The following is a summary of the requirements at each intersection along 1st Avenue for the DHR scenario.

7.3.1 Wylie Street

There is a conflict caused from the DHR track crossing the 1st Avenue eastbound lane in advance of the traffic signal. To eliminate this conflict, the Wylie traffic signal will require a DHR clearance and pre-emption phase. The clearance phase will stop traffic at a nearside stop bar while allowing traffic downstream to clear the tracks. The pre-emption phase will allow the DHR to traverse the eastbound lanes in and out of the median without conflict with eastbound vehicles. An additional stop bar and an additional set of traffic signal displays are also required.

In addition, a “No Right Turn ON RED Train Xing” LED sign will be active during the pre-emption sequence to prevent conflicts with right turning vehicles off 1st Avenue eastbound to the laneway just west of the nearside stop bar. Refer to Figure 11. This is only required if access to the new development on the southwest corner of 1st Avenue at Wylie Street is retained as currently shown on the plans. These signs will be installed overhead on the traffic signal arms and will rest in a blank state.



DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

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NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

ENGINEER STAMP:

REV.	ISSUED FOR	AUTH. BY	DATE
0	ISSUED FOR CoV REVIEW	DSW	11/02/07

ISSUE AUTHORIZATION

Hatch Mott MacDonald

DESIGNED BY: CE
DATE:
DRAWN BY: –
DATE:
CHECKED BY:
DATE:
PROJECT MANAGER:
DATE: DSW
HMM PROJECT No: 237388
DWG SCALE FULL SIZE: 1:250 HALF SIZE: 1:500

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

STREETCAR ALIGNMENT ELECTRICAL PLAN

FROM STA. 1+760 TO STA 1+940

DWG No: FIGURE-11
SHT No
REV No: 0

7.3.2 Crowe Street, Cook Street, Columbia Street, and Manitoba Street

There is no specific DHR signalling requirements at these intersections; DHR operates using traffic signals. At Cook Street and Crowe Street where no signals are provided as part of SEFC work, the DHR will operate by line of sight, passing through the intersection when the way is clear. New signals at these locations are included in the modern system only.

7.3.3 Ontario Street

There is a conflict caused by the DHR track crossing the westbound lane of 1st Avenue in advance of the traffic signal. To eliminate this conflict, the Ontario Street traffic signal will require a DHR clearance and pre-emption phase. The clearance phase will stop traffic at a nearside stop bar while allowing traffic downstream to clear the tracks. The pre-emption phase will allow the DHR to traverse the westbound lanes to transition in and out of the median without conflict with westbound vehicles. An additional stop bar and an additional set of traffic signal displays are required.

7.4 Modern Streetcar

The following is a summary of the requirements at each intersection along 1st Avenue for the modern streetcar scenario.

7.4.1 Wylie Street

There is a conflict caused from the streetcar track crossing the 1st Avenue eastbound lane in advance of the traffic signal. To eliminate this conflict, the Wylie Street traffic signal will require a streetcar clearance and streetcar pre-emption phase. The clearance phase will stop traffic at a nearside stop bar while allowing traffic downstream to clear the tracks. The pre-emption phase will allow the streetcar to traverse the eastbound lanes in and out of the median without conflict with eastbound vehicles. An additional stop bar and an additional set of traffic signal displays are also required.

Turning movements across the streetcar path will be addressed with the installation of LED signs on the overhead traffic signal arms. “No Left Turn Train Xing” LED signs will be active during the pre-emption sequence to prevent conflicts with left turning vehicles off of 1st Avenue “No Right Turn Train Xing” LED signs will be active during the pre-emption sequence to prevent conflicts with right turning vehicles off of 1st Avenue eastbound to the laneway. These signs will rest in a blank state.

7.4.2 Crowe Street and Cook Street

The modern system will require new traffic signals at Cook Street and Crowe Street. The signals will require a pre-emption phase to activate “No Left Turn Train Xing” LED signs.

7.4.3 Columbia Street, Manitoba Street and Ontario Street

The traffic signals at Columbia Street, Manitoba Street and Ontario Street will require a modern street car pre-emption phase to activate “No Left Turn Train Xing” LED signs.

7.4.4 Quebec Street at 1st Avenue

The current intersection of Quebec and 1st Avenue is unsignalized with a stop condition on 1st Avenue

There is a vehicular conflict with the streetcar where the tracks cross 1st Avenue at 90 degrees from the median to an adjacent ROW West of Quebec St. The conflict exists with westbound traffic along 1st Avenue as well as right and left turning vehicles from Quebec to westbound 1st Avenue. In order to control these movements it is proposed to fully signalize the intersection.

To eliminate the conflicts with westbound vehicles, the traffic signal will require a streetcar pre-emption phase. The pre-emption phase allows the streetcar to traverse 1st Avenue. while the signal rests on Quebec St.

To alleviate the conflict with vehicle turning off of Quebec St. a “No Right Turn Train Xing” LED sign and a “No Left Turn Train Xing” LED sign will be active during the pre-emption sequence and will otherwise rest blank. The signs will be installed overhead on the traffic signal arms and will rest in a blank state.

7.4.5 Quebec Street at National Avenue – Science World Entrance

The current intersection operation is as a pedestrian traffic signal on Quebec St. The signal rests on flashing green until pedestrians activate pushbuttons to cross Quebec St.

There is a vehicular conflict with the streetcar where the tracks cross the proposed Science World Entrance leg of National Avenue The conflict exists with eastbound and westbound traffic on National as well as vehicles turning right into and left into Science World from Quebec. In order to control these movements it is proposed to fully signalize the intersection.

To eliminate the conflicts with eastbound and westbound vehicles, the traffic signal will require a streetcar pre-emption phase. The pre-emption phase allows the streetcar to traverse the proposed Science World Entrance while the signal rests on Quebec St.

To alleviate the conflict with vehicle turning off of Quebec St. a “No Right Turn Train Xing” LED sign and a “No Left Turn Train Xing” LED sign will be active during the pre-emption sequence and will otherwise rest blank. The signs will be installed overhead on the traffic signal arms and will rest in a blank state.

7.4.6 Quebec Street at Expo/Pacific Blvd.

The current intersection operates as a fixed time traffic signal with bike and pedestrian activation.

There are vehicular conflicts with almost all movements as the streetcar track crosses through the centre of the intersection. The right turn from Quebec St. to Expo Blvd. does not conflict with the track.

To elevate the conflicts the traffic signal will require a streetcar pre-emption phase. The pre-emption phase allows the streetcar to enter the intersection the signal rests all red.

To alleviate the conflict with right turning vehicles off of Expo St. to Quebec St. a “No Right Turn Train Xing” LED sign will be active during the pre-emption sequence and will otherwise rest blank. The signs will be installed overhead on the traffic signal arms and will rest in a blank state.

The Prior St. leg of the intersection consists of right in and right out movements only. A train crossing warning sign should be installed in advance of the crossing.

7.5 Conclusions and Outstanding Issues

Several outstanding design considerations not conveyed on the electrical drawings and must be addressed prior to the implementation of the modern streetcar system.

7.5.1 Traffic Controllers

The traffic controller specifications will need to be reviewed to ensure they will operate as proposed in our functional design. This includes accommodating the proposed phasing, LED turn restriction signs, and pre-emption capabilities. Pre-emption signalling to the traffic controllers also requires some design work. Consideration must be given to the location of sensors and the proximity of the median platforms to the intersections. Additional equipment will be required to provide isolation between the CoV traffic controller and any pre-emption equipment. This typically includes a pole mounted enclosure which houses the interfacing relays.

7.5.2 Traffic Modelling

Traffic macro/micro simulation should be undertaken along the corridor to analyze queue build-up, the effects of pre-emption phasing, required signal timing, and the impacts of the additional traffic signals proposed by PBA.

7.5.3 Left Turns

The design has identified that there is a lack of left turn storage and that this may have an impact on the operation of intersections. With the addition of a modern streetcar activated “No Left Turn Train Xing” signage, road drivers may become frustrated. A driver may be waiting for a gap to turn left at an intersection when a streetcar approaches. The “No Left Turn Train Xing” sign will activate to prevent conflicts with left turning vehicles but the through movement will still have a green ball. Drivers may decide to proceed to the next intersection or sit and wait for the sign to turn off. As there is no left turn storage, the queue will build until the car clears. Left turn delays are compatible with the role of 1st Avenue as a neighbourhood collector road. Through traffic will be encouraged to use 2nd Avenue.

7.5.4 Power Supply

In order to ensure that pre-emption operates correctly when hydro service is interrupted, it is recommended that streetcar pre-emption be equipped with uninterruptible power supplies. If traffic signals are not operating due to power failure then it will not be safe for street cars to enter signalized intersections, and streetcar service will be disrupted.

7.6 Road Safety Review

This section of the report discusses the Road Safety Review (RSR) of the proposed DHR and Phase 0 alignments. The RSR was undertaken by iTrans Consulting Inc. and is included in Appendix G. The purpose of the RSR was to identify concerns pertaining to the HMM preliminary design. Some of the issues raised are beyond the scope of the preliminary engineering and are to be resolved during detailed design.

7.6.1 DHR

The following comments pertain to the reinstatement of the original DHR:

Table 8: RSR comments on DHR Alignment.

Location	RSR issue/concern	HMM response
Granville Corridor	Is trespassing an issue today? How is it prevented or deterred? Are there fences?	Trespassing has not been raised as in issue by the DHR group. There are some existing fences along the Granville Corridor. DHR level of service is not expected to change in this section and hence no new fence is planned.
Granville Corridor	With increasing frequency of [DHRs], how will pedestrians or users be notified of increased service during weekday periods?	Not applicable: frequency of DHR service is not expected to change.
Granville Corridor	What is the provision for pedestrian facilities at the Hemlock Street pedestrian overpass? Where is access provided?	No changes are planned for the Hemlock Street pedestrian overpass. Access will be as per existing
Granville Corridor	At grade crossing at Moberly Street. Any warning /signals for motorists, pedestrians, and cyclists for approaching streetcar? How are pedestrians prevented from crossing tracks when [DHR] is approaching the station?	Pedestrians are not currently prevented from crossing the tracks. No change to DHR infrastructure or level of service is planned for this area, and hence signals and warnings will be as per existing.
General	With surrounding vegetation, are pedestrian, cyclists, and motorists' sight lines compromised?	This issue is beyond the scope of the preliminary design and is to be resolved at next stage of design.

T-104	Are motorists turning right out of Moberly Street prevented from turning on red? What traffic control device is planned for Moberly Street and Lamey's Mill Road intersection? Stop controlled or signalized?	Motorists are not currently prevented from turning right out of Moberly Street. No additional traffic control devices are planned for this location as no changes to DHR infrastructure or level of service is planned for this area. The DHR will continue to operate as it has in the past.
Drawing T-105	There is a public pedestrian crossing as noted in the plans: how are pedestrians warned of approaching [DHR]?	Pedestrians are not currently warned of an approaching streetcar. The DHR bell/warning will be sounded as required upon approach to crossing.
1st Avenue from Wylie St. to Ontario St.	How are pedestrians prevented or directed from crossing the tracks?	Pedstrians are not currently prevented or directed from crossing the tracks. No change to DHR infrastructure or level of service is planned for this area. The DHR will continue to operate as it has in the past.
1st Avenue from Wylie St. to Ontario St.	If median track is green/grass what left-turn storage is provided for motorists or cyclists?	Not applicable; grass track is not proposed for DHR, intersections will be slab track.
1st Avenue from Wylie St. to Ontario St.	Will left turns be restricted for vehicles or cyclists crossing [DHR] tracks? Without a protected left turn phase, how are left turn movements accommodated.	No new signage or signalization has been designed for this section. The DHR will approach all intersections as a stop. The infrequent operation should not significantly impede left turns.
1st Avenue	There is a concern that bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection?	Flangeway filler or similar product will be considered when bicycle approach angle is less than 60 degrees.
1st Avenue	How are cyclists warned of approaching [DHR vehicles] from behind?	The DHR will be running in the median and therefore it will not be sharing the roadway. The DHR bell/warning will be sounded as required upon approach to cyclists.

1st Avenue	Motorists/on-road cyclists turning left will queue at median and possibly sit on tracks. What type of visibility would a conductor have of a cyclist sitting on the tracks?	Investigation of sight lines was not included in the preliminary engineering and should be resolved at the next stage of design. However, the DHR will approach all intersections 'at caution', and only cross when clear. Use of DHR bell/warning sound as required.
1st Avenue	How will emergency vehicle (police) be pre-empted at this intersection and/or coordinated with the increased frequency of the [DHR] service? Will they have an exemption from the left turning restriction?	No emergency vehicle pre-emption is included in the preliminary signal design for intersections along 1st Avenue. Further consultation with Emergency Services is required.
1st Avenue	There is a serious concern with the lack of signals [along 1st Avenue], signals must be provided.	DHR level of service is to be limited to infrequent weekend service. The DHR will approach the intersection 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.
T-106	How are pedestrians directed to cross from Cook St. station?	Pedestrians are directed to cross from the median via the west crosswalk at Cook St. It is anticipated that infrequent service and low passenger volumes do not justify a second crosswalk at this location.
1st Avenue	If median track is green/grass, what left-turn storage is provided for motorists or cyclists?	Intersections will be slab track. No left turn storage is provided for motorists and cyclists.
T-107	Will left-turns be restricted outside of protected phase for vehicle or cyclist crossing [DHR] tracks?	No signals or left turn restrictions are planned for Cook St. The DHR will approach the intersection 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.
1st Avenue	Which locations have proposed dedicated signals to hold left-turn vehicles on 1st Ave from crossing the [DHR]?	The infrequent operation of DHR does not warrant dedicated signals to hold left turn vehicles and none are planned. The DHR will approach all intersections 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.

1st Avenue	What are the access points to the surrounding developments? Access points should be minimized.	Known access points as shown.
1st Avenue	How are cyclists protected from right turning vehicles? How are cyclists protected from vehicles encroaching into bike lanes?	This is a road design issue to be resolved by CoV and Stantec.
T-108	With a stopped [DHR] at Manitoba Street station, and potential left-turning motorist from 1st Avenue heading south queued in the median, what type of sight lines are available for left-turning motorist turning northbound on Manitoba Street?	Investigation of sight lines was not included in the preliminary engineering and should be resolved at the next stage of design. However, the DHR will approach all intersections 'at caution', and only cross when clear. Use of DHR bell/warning sound as required.
T-108	At entrance/road east of Manitoba Street is there a pedestrian crosswalk across 1st Avenue? Are pedestrians forced to cross the crosswalk at the intersection? No details of the station are provided to show how pedestrian movements are directed.	Pedestrians will be forced to cross at the intersection crosswalk. No crosswalk will be provided for the entrance/road east of Manitoba.
T-108	How do you prevent westbound traffic on 1st Avenue, east of Ontario Street, from sitting on the tracks past the stop bar east of the new DHR alignment?	No measures are planned to prevent motorists from sitting on the track at this location. In the event a vehicle obstructs the tracks, the DHR will wait for the traffic to clear before proceeding.
T-110	At the driveway entrance/exit to Science World; are motorists, pedestrians and cyclists warned of an approaching [DHR] vehicle?	DHR level of service is to be limited to infrequent weekend service. The DHR will approach the intersection 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.

E-141	DHR pre-emption signal display: Motorists travelling westbound on 1st Avenue turning south on Wylie St. During the DHR pre-emption stage, how are these motorists informed if the DHR is approaching from behind? Are left-turn movements prohibited in this phase?	The infrequent operation of DHR does not warrant left turn restrictions at Wylie St. The DHR will approach all intersections 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.
E-146	DHR pre-emption signal display: motorists travelling eastbound on 1st Avenue turning north on Ontario Street. During DHR pre-emption stage, how are these motorists informed if the DHR is approaching from behind? Are left-turn movements prohibited in this phase?	The infrequent operation of DHR does not warrant left turn restrictions at Ontario. The DHR will approach all intersections 'at caution' by line of sight operation, and only cross when clear. Use of DHR bell/warning sound as required.

7.6.2 Phase 0

The following comments pertain to the implementation of Phase 0:

Table 9: RSR comments for Phase 0 Alignment.

Location	RSR issue/concern	HMM response
Granville Corridor	How are pedestrians prevented from trespassing? Any existing fences?	Pedestrians are currently prevented from trespassing by incomplete existing fences. New fences should be reviewed with detailed design.
Granville Corridor	Is there any warning device (signage/signals/bells) to be used to warn pedestrians of the reverse movement of the streetcar on departure?	To be developed further at the detailed design phase.
Granville Corridor	How are pedestrians made aware of which track is in use? How are they informed if the train crosses over to the other track?	Trains will use both tracks. To be developed further at the detailed design phase.
T-151	Where is the access to the pedestrian overpass by Hemlock Street?	Access via Lamey's Mill Road.

T-151	Are there any sidewalks or bike lanes provided on Lamey's Mill Road?	Sidewalks and bike lanes on Lamey's Mill Road as per existing.
Granville Corridor	With higher speeds and increased frequency of the LRT service, how are pedestrians protected from crossing the double tracks?	Detailed design should consider replacement and/or repair of existing fences.
T-153	Access to station to be reviewed. Are two side platforms being considered?	Side platforms were considered. There is not adequate space between existing retaining wall on the south side and the slope on the north side.
T-153	What pedestrian access is provided from the station to Lamey's Mill Road? How are pedestrians directed to cross the track to the north side?	Two pedestrian access routes to Lamey's Mill Road are provided at either end of the platform. A ramp is provided on the west side of the station to gain access to the road and at grade access is provided at the east end. As noted on the drawings, some curb realignment and pedestrian crosswalk may be required on Lamey's Mill Road.
T-153	Is there any warning for the second approaching streetcar?	To be developed further at the detailed design phase.
T-154	At grade crossing at Moberly Street. Any warning/signals for motorists, pedestrians and cyclists for approaching streetcar? How are pedestrians prevented from crossing the tracks when a streetcar is approaching the station?	Signal pre-emption will stop motorists, pedestrians and cyclists upon approach of streetcar. No crossing restrictions for pedestrians are planned; pedestrians treat as road crossing. Cautionary signage will be considered.
Granville Corridor	With the surrounding vegetation are pedestrian, cyclists, and motorists' sight lines compromised?	To be developed further at the detailed design phase.
General	How are pedestrians prevented or directed from crossing the tracks?	No crossing restrictions for pedestrians are planned; pedestrians treat as road crossing. Cautionary signage will be considered.
T-154	Are motorists turning right out of Moberly Street prevented from turning right on red? Is Moberly Street and Lamey's Mill Road stop controlled or signalized?	Moberly Street and Lamey's Mill Road junction is signalized. The signalization design will be undertaken at the detailed design stage.

T-154	How are pedestrians prevented from crossing the tracks from one platform to the other? How are pedestrians warned of a second approaching streetcar?	Pedestrians are not physically restricted from crossing the tracks. However, exit signs will be used to direct pedestrians to the formalized routes. Warning of the second approaching streetcar will be considered at detailed design.
T-155	At the pedestrian crossing; how are pedestrians warned of approaching streetcars? How are pedestrians warned of approaching streetcar from the opposite direction?	A review of existing pedestrian crossings will be undertaken at the detailed design stage.
T-155	With the increased frequency of the LRT, how are pedestrians protected from crossing the tracks? Will there be alternate access points to the recreational facilities (tennis courts on the north side of the track).	A review of existing pedestrian crossings will be undertaken at the detailed design stage.
General	Are LRT signals and/or LRT switch signals discernable from traffic signals?	Yes LRT signals are discernable from traffic signals.
1st Avenue	If median track is green/grass, what left-turn storage is provided for motorists or cyclists?	Intersections will be slab track. No left turn storage is provided for motorists and cyclists.
1st Avenue	Will left-turns be restricted outside of protected phase for vehicle or cyclist crossing streetcar tracks?	No signals or left turn restrictions are planned for Cook St. outside of protected phase.
1st Avenue	Which locations have proposed dedicated signals to hold left-turn vehicles on 1st Avenue from crossing the streetcar?	All cross streets from Wylie to Ontario of left turn restrictions to hold left-turn vehicles on 1st Avenue from crossing the streetcar.
General	How will emergency vehicle (police) be pre-empted at this intersection and/or coordinated with the increased frequency of the LRT service? Will they have an exemption from the left turning restriction?	The existing protocol for emergency vehicle pre-emption on 1st Avenue as designed by Stantec and CoV should be reviewed at detailed design.

1st Avenue	There is a concern that bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection?	Flangeway filler or similar product will be considered when bicycle approach angle is less than 60 degrees.
1st Avenue	How are cyclists warned of streetcars approaching from behind?	The streetcar runs on fixed alignment in the median and cyclists will be expected to undertake a blind spot check prior to manoeuvring at any junctions and abide by no left turn restrictions activated by streetcar.
T-157	How are pedestrians directed to/from Cook St. station? Are there barriers to restrict crossing at the crosswalk?	Pedestrians will be directed to cross from the median via the west crosswalk at Cook St. Station layout and pedestrian control measures to be reviewed at detailed design.
1st Avenue	What are the access points to the surrounding developments? Access points should be minimized.	Known access points as shown.
1st Avenue	How are cyclists protected from right turning vehicles? How are cyclists protected from vehicles encroaching into bike lanes?	This is a road design issue to be resolved by CoV and Stantec.
T-158	How are pedestrians exiting at Manitoba Street station prevented/directed from crossing the roadway or across the tracks? At entrance/road east of Manitoba Street, is there a pedestrian crosswalk? Are pedestrians forced to cross at the crosswalk at the intersection? No details of station are provided to show how pedestrian movements are directed.	Bollards and/or barrier type vegetation will be used to direct pedestrians to one of two crosswalks, one at Manitoba Street and the other opposite Salt Street.

T-158	Concrete portion of the median created to accommodate delivery vehicles. How are other vehicles, pedestrians or cyclists prevented from using this paved median for making turning movements? How are delivery trucks controlled from entering/exiting when the streetcar is in operation?	It is anticipated that this manoeuvre will be controlled by signals. Further development of signal controls, restrictive controls, and enforcement measures to be resolved at detailed design.
T-159	Provision for sidewalk to be reviewed. Are there any barriers to prevent pedestrians /off-road cyclists from crossing over tracks to cross the street? Any warnings?	To be developed further at the detailed design phase.
T-159	Is sight distance adequate for the conductor and pedestrians/cyclists at the intersection of 1st Avenue and Quebec St?	To be developed further at the detailed design phase.
T-159	Right turns on red must be prohibited for vehicles turning from Quebec Street onto 1st Avenue. How will drivers react at the intersection during all-red movements?	Refer to revised signalization section of this report (Chapter 7).
T-160	Science World Entrance: How are vehicles entering Science World from Quebec Street protected/directed during turning movements into the entrance?	Details of this entrance/exit to be resolved by CoV at the next stage of design.
T-160	How are motorists exiting Science World protected from the streetcar? How are they prevented from sitting on the tracks?	Details of this entrance/exit to be resolved by CoV at the next stage of design.
T-160	There is a concern with the counterflow (onto one side of the cross section); what separation is provided to clearly meet the needs of the motorists with respect to glare and flow of traffic?	A minimum 1.5m wide verge is recommended in the counter flow areas. This will include a barrier for glare reduction.

T-160	What are the speeds along Quebec Street? Is there any potential for motorists to sideswipe the streetcar?	Cruise speed on Quebec between 1st Avenue and Science World station is 20-40 km/h. A minimum 1.5m wide verge and glare fence will separate the LRTs from road traffic minimizing opportunity for sideswipes.
T-160	What protection is provided for cyclists and pedestrians?	This is a detailed design issue.
T-161	Science World station: what provisions are made to accommodate pedestrians crossing over the tracks and crossing [Quebec St] to get to Terminal Ave?	It is intended that pedestrians will used the existing crosswalk extended through to Science World to cross Quebec St. and the tracks. Control of pedestrian movements will be developed at the detailed design stage.
T-161	Are sight lines for the conductor or pedestrians compromised because of the location of SkyTrain columns?	To be developed further at the detailed design phase.
T-161	What provisions/warnings are given to acknowledge a second oncoming streetcar?	To be developed further at the detailed design phase.
T-161	Science World car park or access roads? Limiting pedestrian access may encourage crossing the tracks at locations where crossing is not permitted.	This entrance is to be eliminated and pedestrians are to use the path on the west side of the parking lot.
T-162	Pedestrian walkway: how are pedestrians notified of oncoming streetcars?	To be developed further at the detailed design phase.
T-162	Pacific Boulevard Station: how are pedestrians crossing the tracks mitigated?	Control of pedestrian movements will be developed at the detailed design stage.
T-162	Warning should be provided of crossover switch location to pedestrians to inform which track the streetcar may be utilizing when crossing through the pedestrian walkway.	To be developed further at the detailed design phase.

T-162	Need to detail how the signal at National will operate.	This is indicated on the enclosed drawings and in Chapter 7.
T-163	Potential for serious conflicts with vehicles making turning movements off or onto Quebec Street.	This is indicated on the enclosed drawings and in Chapter 7.
T-163	Signalization to be reviewed to determine how to incorporate mixing the streetcar back into vehicle traffic to arrive at maintenance facility.	To be developed further at the detailed design phase.

7.6.3 Integration with Cyclists

The redesigned 1st Avenue includes a provision for westbound and eastbound cycle traffic. As such, the issues surrounding the interaction of cyclists and LRTs must be considered.

The LRT tracks themselves pose the primary risk to cyclists. Cyclists' tires can become stuck in the flangeway if the crossing angle to the rail is too shallow. In order to minimize the risk of an accident, current best practice is to design bicycle tracks to achieve a maximum crossing angle of 60 degrees (Road Safety Publication 2, 2006). At locations where this is not possible, such as the intersection of 1st Avenue/Quebec St. and Wylie St/Ontario St., another option is to use a flangeway filler product. Made of a rubber type material, these products are flexible enough such that they are displaced by the weight of the vehicle as it passes over the track. At all other times, the filler is stiff enough to support bicycles thereby reducing the hazard to cyclists. It is not anticipated that this will be a significant problem, as the LRT tracks are, for the most part, isolated from cyclist traffic.

Another risk to cyclists will be making left turns across the LRT tracks. At cross streets along 1st Avenue for example, cyclist approach angles may be inadequate for safe crossing and hence flangeway filler should again be considered. In addition, cyclists may attempt to make left hand turns across the streetcar path against the "No Left Turn" signals. This risk is anticipated to decrease as cyclists become accustomed to LRT operation, however, cyclists should treat the streetcar as any other road vehicle. The streetcar runs on fixed alignment and cyclists will be expected to undertake a blind spot check prior to maneuvering at any junctions.

These issues must be revisited at the detailed design stage to ensure that the needs of the cyclists are balanced with the needs of the Phase 0 system.

8 Utility

8.1 Introduction

A detailed review of the utilities along the Granville Island to Science World rail corridor was conducted. HMM reviewed the 1st Avenue Works design drawings in conjunction with the existing utility drawings provided by Stantec and CoV. In some cases, the drawings provided do not present adequate vertical profile information to confirm or discount potential conflicts.

This chapter identifies *probable* utility conflicts resulting from the reinstatement of the DHR and the construction of a modern streetcar system. A 'conflict envelope' was defined based on the geometry of the more complex modern streetcar trackform, as opposed to the simple DHR track. The envelope extends horizontally 1.2m on either side of the outer rail, and vertically to a depth of 1.4m. A 1.4m depth was selected to encompass all of the proposed streetcar infrastructure, including:

- Concrete track slab
- Traction power conduits, lateral and longitudinal, including draw pits
- Communication and signal conduits, lateral and longitudinal, including draw pits
- Sub grade drain pipe, including and laterals to storm sewer

Utilities encroaching into this envelope were considered conflicts which must be resolved with the appropriate utility companies prior to detailed design. It should be noted that storm drain manholes are not included in the envelope and are expected to extend beyond the 1.4m limit locally.

Key utilities located outside the conflict envelope were also considered, if significant disruption to the streetcar system would result from their failure.

For the purposes of this chapter, the corridor was divided into three sections:

- **Section 1** – Granville Island to Wylie Street
- **Section 2** – Wylie Street to Ontario Street
- **Section 3** – Ontario Street to Science World

8.2 Granville Island to Wylie Street

No new works are anticipated in Section 1 and hence only existing utilities were reviewed.

8.2.1 Data Sources

Plans of existing utilities were provided by the CoV. Invert elevations were not provided.

8.2.2 Summary

Thirty two potential conflicts were identified. HMM cannot confirm these conflicts due to lack of invert elevations. HMM recommends additional investigation should a future modern system be installed. However, if the existing trackform is maintained conflicts are not anticipated. A detailed breakdown of utility location and type are provided in the Appendix F H.

8.3 Wylie Street to Ontario Street

The 1st Avenue works include significant changes to underground utilities in section 2, necessitating a detailed review of both existing and proposed utilities. It was critical to identify potential conflicts before the commencement of the 1st Avenue works such that existing utilities could be relocated as part of the works and proposed utility conflicts could be resolved prior installation. The goal was to minimize future construction scope, cost and traffic disruption should the modern system be implemented.

8.3.1 Data Sources

Plan and profile of existing and proposed utilities were included in the SEFC Integrated Site Servicing drawings as part of CoV contract number C1111.

8.3.2 Existing Utilities

(i) Water

A total of ten transverse water mains cross under the proposed streetcar ROW. The transverse mains vary in size from 150mm to 300mm in diameter. Two are to be abandoned. Eight will be transferred to a new longitudinal water main running along the north edge of 1st Avenue. The tender drawings provide inverts for the connections. However, without a longitudinal section for each pipe, HMM is unable to identify conflicts Based on the elevation of the inverts, a number of conflicts are anticipated.

(ii) Sanitary

Conflicts are anticipated at three of the five existing sanitary crossings. The first, a 600mm diameter force main at Crowe Street has an invert at about 3.0m, however additional information is required to confirm cover. The second, a 900mm diameter steel force main is located just south of the median centreline running longitudinally from Columbia Street to Ontario Street. The force main is concrete covered from where it joins 1st Avenue at Columbia Street to approximately 0+560. Although the force main does not encroach into the conflict envelope, Metro Vancouver has indicated that they do not support construction of streetcar infrastructure over top of it. Their primary concern is accessibility in the event of a force main failure. Several options are being explored to resolve this issue and are presented in Appendix G . The third, a 1500mm diameter combined sewer crossing at Crowe Street was found to have about 1.2m of cover.

(iii) Storm

The existing storm system is limited. A longitudinal storm drain, ranging in size from 300mm to 550mm in diameter runs along the south side of the median for most of the section between Wylie Street and Ontario Street. It runs under the south side of the proposed median for approximately 75m between Cook Street and Columbia Street. No direct physical conflict with the track infrastructure is anticipated. Five transverse pipes cross under the proposed median. Without additional information for each pipe, HMM is unable to identify conflicts at this time

(iv) Hydro Conduits

Two existing hydro conduits cross 1st Avenue west of Crowe Street and west of Manitoba Street. Conduit inverts are required to determine whether there will be a conflict.

(v) Telephone and Communications

Two existing telephone conduits cross 1st Avenue, at Wylie Street and at Cook Street. Conduit inverts are required to determine whether there will be a conflict.

(vi) Electrical and Signals

No existing electrical or signalization conduits were identified as conflicts.

(vii) District Heating System

No existing infrastructure.

(viii) Gas

Eight gas lines, seven of them dead, pass under the proposed streetcar median. The single live line is expected to have 0.5m – 1.0m cover. Profile information is required to confirm.

8.3.3 Proposed Utilities

(i) Water

A new longitudinal water main is to be installed along the north side of 1st Avenue. It is to be well outside the median and no conflict is anticipated. Eight new transverse water mains are to be installed, connecting the new longitudinal water main with developments on the south side of the street. The mains at Columbia Street, Ontario Street, and Manitoba Street have clear cover of 2.0m, 2.8m and 0.8m respectively, with the latter expected to be a conflict. No longitudinal section was provided for the five remaining pipes, and hence HMM is unable to identify conflicts at this time. Based on the elevation of the inverts, a number of conflicts are anticipated.

(ii) Sanitary

Longitudinal sanitary pipes are to be located outside the proposed median. Five transverse sanitary pipes are proposed along 1st Avenue Cover ranges from 1.8m to 4.0m based on inverts. Two are potential conflicts lacking adequate longitudinal information.

(iii) Storm

The new longitudinal storm pipe is to be located outside the proposed median.

Two types of storm water management systems are proposed along 1st Avenue, both of which were identified as conflicts.

The first type, operating between Wylie Street and Columbia Street, relies on traditional catchbasins along the median gutter to conduct water to a new 300 diameter storm sewer running longitudinally along the south side of the median via transverse leads. The leads cross the median 14 times. Assuming that the catchbasins will be installed as per the CoV's standard details, 0.35m cover is anticipated.

The second type, operating between Columbia Street and Ontario Street, relies on the traditional catchbasins in conjunction with to infiltration galleries. The gallery leads cross the median approximately 16 times at an approximate depth of 0.9m.

(iv) Hydro Conduits

A total of six transverse hydro conduits of varying size are proposed for 1st Avenue, crossing at each intersection. Review of the tender drawings indicates a cover of 2.0m to 3.5m. Conflict is not anticipated.

(v) Telephone and Communications

Eight new transverse telephone conduits are proposed for 1st Avenue. Based on the tender drawings, the cover was found to range from 1.5m to 3.0m and no conflicts are anticipated.

(vi) Electrical and Signals

Traffic signal conduits cross the median ten times at a typical depth of 0.6m.

(vii) District Heating System

The proposed District Heating System (DHS) will be comprised of one longitudinal segment running from Wylie Street to Ontario Street and five transverse branches, one at each cross street except Columbia Street. No conflict is anticipated with the 250mm diameter longitudinal segment as it is well north of the median. Typically, the 150mm diameter transverse components do create a problem as cover ranges from 0.8m to 0.9m.

(viii) Gas

No longitudinal gas lines are proposed. Two transverse gas lines are proposed. Profile information is required to determine whether a conflict exists.

8.3.4 Summary

The SEFC redevelopment group has been informed of all the potential conflicts in section 2. In order to meet the CoV's goal of minimizing future rework, HMM recommends that these issues be resolved during the 1st Avenue works. Discussions between the CoV, Stantec, and Metro Vancouver regarding the sanitary force main conflict are ongoing. A detailed breakdown of utility location and type are provided in the Appendix F .

8.4 Ontario Street to Union Street

No new works are anticipated in section 3 and hence only existing utilities were reviewed in this section.

8.4.1 Data Sources

Plan and profile drawings of existing utilities were provided by Metro Vancouver.

8.4.2 Existing Utilities

(i) Water

Five transverse and one longitudinal water pipes pass under the proposed streetcar corridor, of which one has been identified as a conflict, and four are lacking adequate information to confirm depth. Invert elevations are required to evaluate potential conflict.

(ii) Sanitary

A Metro Vancouver 600mm diameter force main running along the west side of Quebec Street is expected to be a significant conflict. Cover ranges from 0.6m to 1.2m. In addition, there are six transverse pipes, five are conflicts, and invert elevations are required to evaluate the remaining one.

(iii) Storm

Ten transverse storm sewers pass under the proposed route. One is a conflict, and invert elevations are required to evaluate four others. The remaining five are below the design envelope.

(iv) Hydro

One longitudinal hydro conduit runs along west side of Quebec Street with laterals running to the east side of Quebec Street five times from 1st Avenue to Pacific Blvd. Three are conflicts, with cover ranging from 0.75m to 1.2m. Invert elevations are required to evaluate potential conflict with the remaining three.

(v) Telephone and Communications

Transverse phone lines occur five times, three are conflicts with 1.0m – 1.2m of cover. In addition, two longitudinal lines run along the east side of Quebec Street and pose a potential conflict as the alignment cuts east across Quebec Street to the proposed maintenance facility. Invert elevations are required to evaluate potential conflicts.

(vi) Electrical and Signals

One street lighting conduit runs longitudinally along the proposed route north of Science World to Pacific Boulevard. Invert elevations are required to evaluate potential conflicts.

(vii) Gas

Three longitudinal gas lines were identified as potential conflicts; one is dead (26mm diameter) and two live (88mm diameter); invert elevations are required to evaluate potential conflicts. 3 - 60mm diameter and 1 - 42mm diameter transverse gas lines pass under the streetcar corridor: three were confirmed as conflicts, with cover ranging from 0.19m to 0.65m. Invert elevations are required to evaluate potential conflicts with the remaining one.

8.4.3 Summary

Additional investigation is required prior to implementation of the modern streetcar system to confirm or rule out the potential conflicts detailed above. However, if the existing trackform and service is maintained conflicts are not anticipated. A detailed breakdown of utility location and type are provided in the Appendix F H.

8.5 Recommendations

In summary, it is always recommended to relocate utilities out of the swept path of any streetcar system. This limits the impacts from the system on the utilities and also provides service reliability to the system. However, given that relocation is not always practical, discussions must be held with utility providers and other stakeholders in order to balance the cost of relocation and/or protection with the risk to the utility and/or streetcar service. Along 1st Avenue, likely utility conflicts have been issued to Stantec via HMM memo of August 27th, 2007 (Appendix I) such that proposed utilities may be relocated prior to installation.

9 Stations

This chapter discusses the proposed station design for the DHR and Streetcar.

There will be two different approaches to the design of the stations due to the phased nature of this project. The DHR initial phase will see the refurbishing and minimal upgrades for the stations outside of the 1st Avenue corridor and the installation of two new basic stations within the 1st Avenue corridor. The Streetcar phase will add to the basic stations with new weather protection canopies, finished track ways and medians, additional stations along the Granville corridor and in some cases an increase in platform size.

An important issue that must be addressed for the DHR phase is the need to accommodate the mobility challenged and the people in wheelchairs who will have little or no ability to access the raised level of the historic cars that are 920mm above platform levels. Temporary platform ramps are possible but impractical and it is recommended that a study be done to investigate the possibility of adapting the historic cars with hydraulic lifts (reference discussion in Chapter 4).

9.1 DHR Stations

Outside the 1st Avenue corridor, the existing three stations at Granville Island, Moberly Road, and Science World will be accepted as workable in their present locations with minimal upgrading. Granville Island will be a centre platform and Moberly Road and Science World will both be side platforms. Along 1st Avenue, the decommissioned Ontario Street Station will be replaced with two new stations at Cook Street and Manitoba Street. A hard surface trackform will be used in the areas surrounding the stations in lieu of ballasted track.

9.1.1 DHR Matrix

Table 10: DHR station equipment inventory.

DHR Streetcar	Granville Island Stn	Spruce St. Stn	Leg 'N' Boot Stn	Cambie St. Stn	Cook St. Stn	Manitoba St. Stn	Science World Stn
Platform	Yes	No	Yes	No	Yes	Yes	Yes
Platform Layout (Centre / Side / Split)	Centre	Centre	Twin Side	Centre	Centre	Centre	Twin Side
Platform Dimensions	4.5 m x 25.0 m	4.5 m x 25.0 m	3.15 m x 25.0 m	4.5 m x 25.0 m (varies)	3.0 m x 25.0 m	4.0 m x 25.0 m	3.15 m x 25.0 m
Weather Protection Canopy	√	-	√	-	-	√	√
Canopy Dimensions	4.0 m x 7.5 m	-	3.0 m x 7.5 m	-	-	4.0 m x 7.5 m	3.0 m x 7.5 m
Information Panel (Fares/Using TVM/Schedule/Map)	√	-	√	-	√	√	√
Ticket Vending Machines (onboard train)	-	-	-	-	-	-	-
Ticket Validating Unit (onboard train)	-	-	-	-	-	-	-
Seating	2 seats	-	2 seats	-	-	2 seats	2 seats
Wastebasket	√	-	√	-	√	√	√
Advertising Panels	-	-	-	-	-	-	-
Paving Materials	?	-	?	-	?	?	?
Platform Edge Safety Strip	√	-	√	-	√	√	√
Platform Slope	-	-	-	-	-	-	-
Safety / Security							
CCTVs	-	-	-	-	-	-	-
Speakers	-	-	-	-	-	-	-
Passenger Emergency Call Point (PEC)	-	-	-	-	-	-	-
Power Supply							
Overhead Catenary Support (Centre/Side Poles/Span Wires)	Centre & Side Poles	-	Side Poles	-	Cross Span	Cross Span	Side Poles
Signage							
Station Identification Sign (seen from train)	√	-	√	-	√	√	√
Sidewalk Signs	-	-	-	-	-	-	-
Platform Services / Utilities							
Electrical Receptacle	√	-	√	-	√	√	√
Platform Drainage	√	-	√	-	√	√	√
Conduit Access Pits	√	-	√	-	√	√	√
Lighting							
Canopy Lighting	√	-	-	-	-	√	√
Platform Lighting	√	-	√		√	√	√
Access / Sidewalk Lighting	√	-	-	-	-	-	-
Track Finish							
In Front of Platform (Ballast / Hard Surface / Grass)	Hard	Hard	Hard	Hard	Hard	Hard	Hard
Approach to Station (Ballast / Hard Surface / Grass)	Ballast	Ballast	Ballast	Ballast	Grass	Grass	Grass
Accessibility							
Linear Textured Floor Tile?	-	-	-	-	-	-	-
NOT IN CONTRACT							
Adjacent Sidewalk Precinct (for info only)							
Substation							
Telus Phone Booth							
Bike Rack							

DHR Streetcar	Granville Island Stn	Spruce St. Stn	Leg 'N' Boot Stn	Cambie St. Stn	Cook St. Stn	Manitoba St. Stn	Science World Stn
Guardrails							
Bollards with Lights							
Bus Stop Shelter							
HandiDart Parking							
Street Trees							
Emergency Parking							
Fire Hydrant							
Other							
Art Feature							

9.2 Modern Streetcar Station

For the modern Streetcar phase, the three existing refurbished stations will be developed to a finalized design. In addition, new centre platform stations will be added at Spruce Street, Cambie Street (near the Canada Line Olympic Village Station) and at Pacific Boulevard close to the maintenance facility. Along 1st Avenue, the two new stations at Cook Street and Manitoba Street (see 9.1) will be upgraded to modern configuration. A sketch of the possible modern station treatments is included in Figure 12.

The stations will have a range of different platform sizes as follows:

Centre Platforms	4.5 x 25.0m (ideal)
	4.0 x 25.0m (minimum recommended)
	3.0 x 25.0m (absolute minimum)
	Varied Width x 25.0m
Twin Side Platforms	3.15 x 25.0m

The constant platform length of 25.0m will accommodate the length of the modern streetcars of approximately 25.0m – 30m in length depending on spacing between the vehicle doors.

All of the platforms will be accessible with at least one entry ramp at 5% with guardrails on both sides. Where possible a secondary access will be located at the other end of the platform to give patrons a sense of safety with a second choice. This second access may not be accessibility compliant with a steeper than 5% ramp or may include steps, if necessary.

The platforms will include a weather protection canopy primarily for rain protection supported on columns which will be designed for hiding drainage and electrical conduits. The canopies will include a longitudinal sign visible to patrons on the cars for station identification, and there will be a centrally located cluster of furniture elements typically including two seats, a waste basket and information panels. For patron safety there will be a Passenger Emergency Call Point. It is assumed that the Ticket Vending Machines and the Ticket Validating Units will be located onboard the trains and not on the platforms. In addition to ambient street lighting, there will be both platform and canopy lights.

Where stations are located in the middle of streets with a median, the sidewalk and crosswalk leading to the station will be clearly defined and organized with bollards and guardrails leading patrons to a refuge point with the ramp extending up the 350mm to an elevated platform.

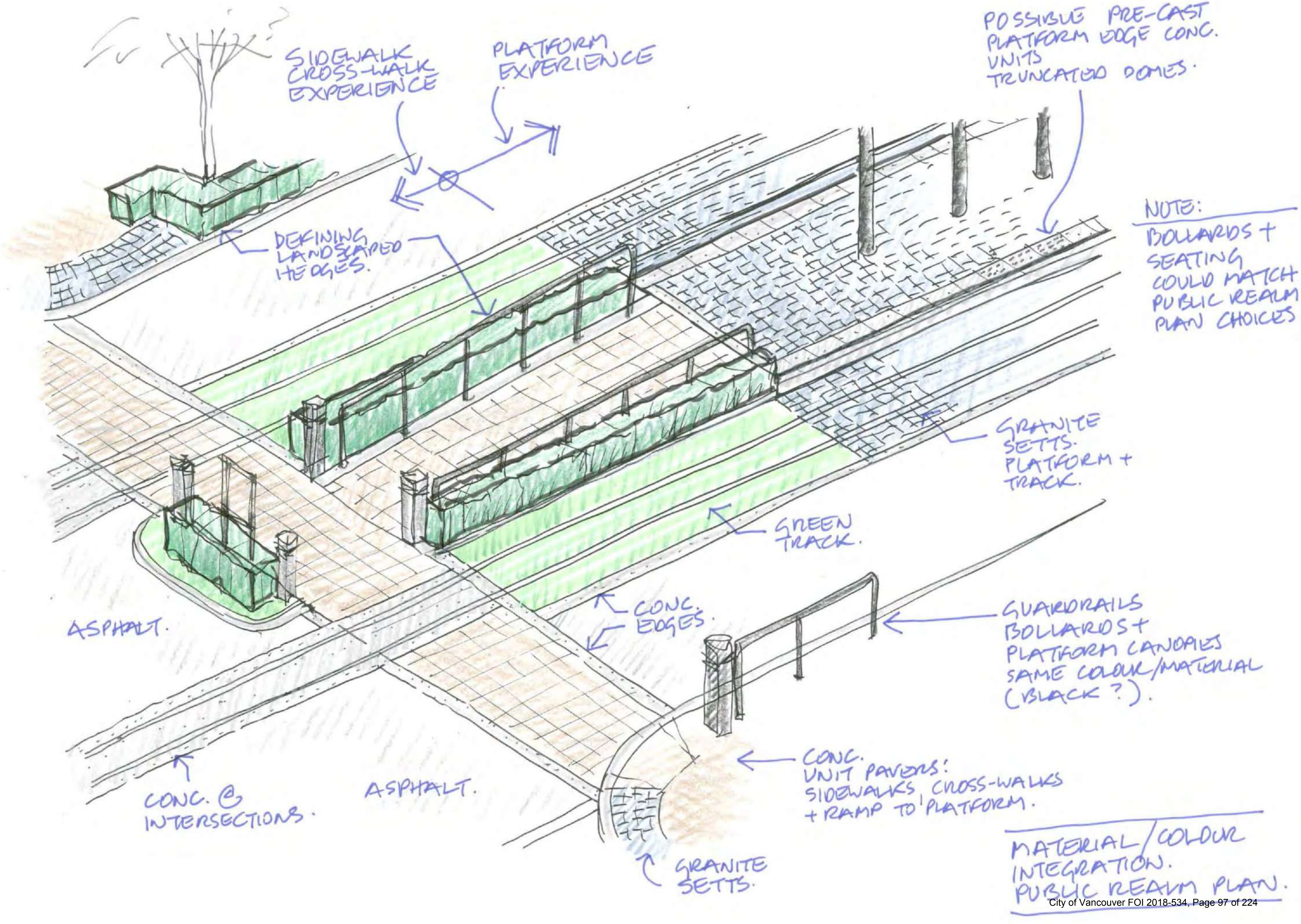
The canopies will have a steel structure with a painted finish using high quality paint for longevity and graffiti-resistance. Glass in the canopy roofs will be fritted or with a frosted translucent look rather than clear to help disguise accumulated dirt and leaves. For platform surface and crosswalk finish materials there are two possible approaches. Either all the paving materials should match the surrounding context so that the platform blends into the streetscape or alternatively the paving of the platform itself can have a system wide higher quality hard surface paving material that distinguishes the platform from its context. Since some of the future phases will include platforms in the downtown area with only brushed concrete as a context, the latter alternative is recommended.

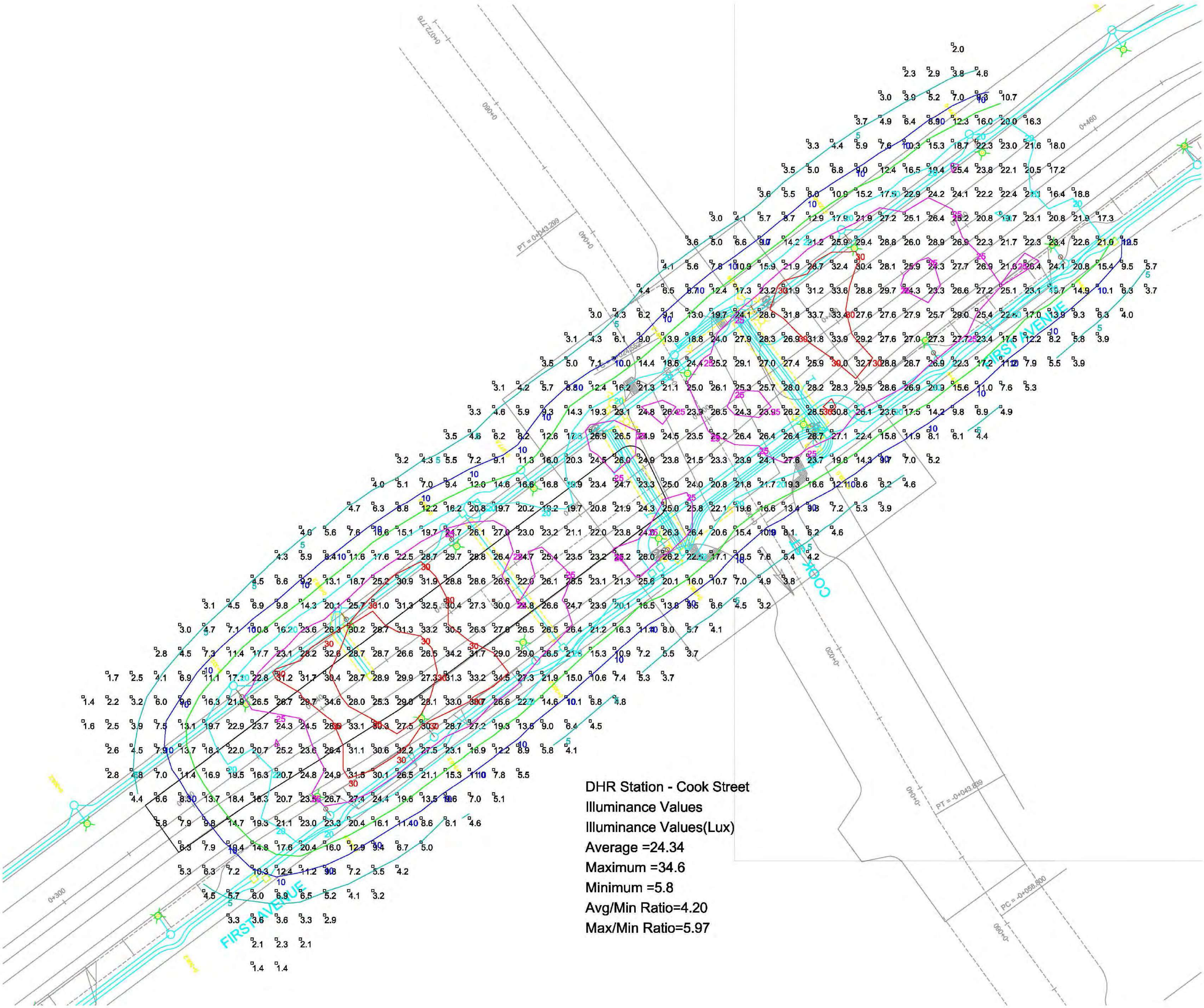
The trackform will likely be concrete or asphalt at intersections, with green medians in the higher profile areas such as 1st Avenue. However at the stations, the trackform adjacent to the platforms will be a hard surface. Consideration could be given to granite cobblestones or setsas a finish material as it will help distinguish the platform in the landscape and will be an echo of the historic granite cobblestone track ways of Vancouver's original streetcar lines. The cobblestone finish would only apply to the area directly in front of the platform and access ramps, typically a length of less than 40m.

The design of the canopies are intended to be similar for all the stations but will need to be flexible enough to accommodate both centre and side platform conditions and the different widths of the various centre platform conditions. The modular components can be a "kit of parts" that will be pre-fabricated and with all the parts able to fit on a flatbed track so that no site welding is required.

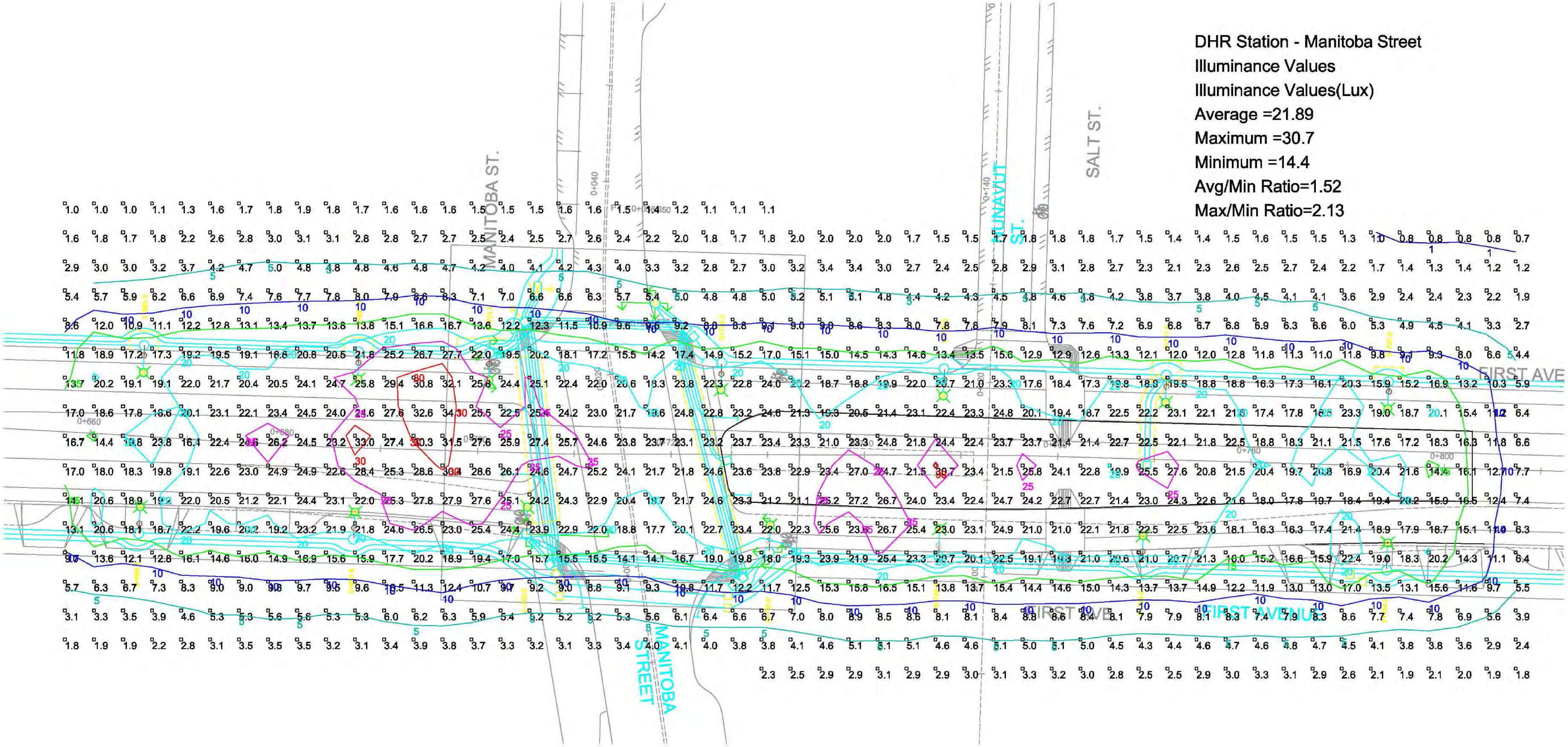
The design of the stations should be simple and straightforward in character with a balance found between being clearly visible, iconic, and recognizable without being "showy" or obstructive elements in the urban landscape. The station design approach should be to create a modern forward-looking character without resorting to overt historic references.

A minimum of 50 lux of average horizontal luminance is typically required at transit facilities around Vancouver. The lighting levels at existing stations are assumed to be less than 50 lux, and hence it is assumed that a streetlight will be required at each station. Additional lighting will be definitely be required at the locations of the proposed Cook Street station and Manitoba street station along 1st Avenue as the design levels are less than 50 lux. See Figure 13 and Figure 14.


SIDEWALK CROSS-WALK EXPERIENCE
PLATFORM EXPERIENCE
POSSIBLE PRE-CAST PLATFORM EDGE CONC. UNITS TRUNCATED DOMES.
NOTE: BOLLARDS + SEATING COULD MATCH PUBLIC REALM PLAN CHOICES.
DEFINING LANDSCAPED HEDGES.
GRANITE SETTS. PLATFORM + TRACK.
GREEN TRACK.
CONC. EDGES.
GUARDRAILS BOLLARDS + PLATFORM CANOPIES SAME COLOUR/MATERIAL (BLACK?).
ASPHALT.
CONC. @ INTERSECTIONS.
ASPHALT.
CONC. UNIT PAVERS: SIDEWALKS, CROSS-WALKS + RAMP TO PLATFORM.
GRANITE SETTS.
MATERIAL/COLOUR INTEGRATION. PUBLIC REALM PLAN.


FIRST AVENUE
DHR Station - Cook Street
Illuminance Values
Illuminance Values(Lux)
Average =24.34
Maximum =34.6
Minimum =5.8
Avg/Min Ratio=4.20
Max/Min Ratio=5.97

DHR Station - Manitoba Street
Illuminance Values
Illuminance Values(Lux)
Average =21.89
Maximum =30.7
Minimum =14.4
Avg/Min Ratio=1.52
Max/Min Ratio=2.13



9.2.1 Streetcar Matrix

Table 11: Streetcar station equipment inventory.

Modern Streetcar	Granville Island Stn	Spruce St. Stn	Leg 'N' Boot Stn	Cambie St. Stn	Cook St. Stn	Manitoba St. Stn	Science World Stn	Pacific Boulevard
Platform	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Platform Layout (Centre / Side / Split)	Centre	Centre	Twin Side	Centre	Centre	Centre	Twin Side	Centre
Platform Dimensions	4.5 m x 25.0 m	4.5 m x 25.0 m	3.15 m x 25.0 m	4.5 m x 25.0 m (varies)	3.0 m x 25.0 m	4.0 m x 25.0 m	3.15 m x 25.0 m	4.5 m x 25.0 m (varies)
Weather Protection Canopy	√	√	√	√	TBC	√	√	√
Canopy Dimensions	4.0 m x 7.5 m	4.0 m x 7.5 m	3.0 m x 7.5 m	4.0 m x 7.5 m	-	4.0 m x 7.5 m	3.0 m x 7.5 m	3.0 m x 7.5 m
Information Panel (Fares/Using TVM/Schedule/Map)	√	√	√	√	√	√	√	√
Ticket Vending Machines (onboard train)	-	-	-	-	-	-	-	-
Ticket Validating Unit (onboard train)	-	-	-	-	-	-	-	-
Seating	2 seats	-	2 seats	-	-	2 seats	2 seats	2 seats
Wastebasket	√	√	√	√	√	√	√	√
Advertising Panels	-	-	-	-	-	-	-	-
Paving Materials	?	?	?	?	?	?	?	?
Platform Edge Safety Strip	√	√	√	√	√	√	√	√
Platform Slope	√	√	√	√	√	√	√	√
Safety / Security								
CCTVs	?	?	?	?	?	?	?	?
Speakers	?	?	?	?	?	?	?	?
Passenger Emergency Call Point (PEC)	?	?	?	?	?	?	?	?
Power Supply								
Overhead Catenary Support (Centre/Side Poles/Span Wires)	Centre & Side Poles	Centre	Centre	Centre & Side Poles	Span Wires	Span Wires	Side Poles	Centre & Side Poles
Signage								
Station Identification Sign (seen from train)	√	√	√	√	√	√	√	√
Sidewalk Signs	√	√	√	√	√	√	√	√
Platform Services / Utilities								
Electrical Receptacle	√	√	√	√	√	√	√	√
Platform Drainage	√	√	√	√	√	√	√	√
Conduit Access Pits	√	√	√	√	√	√	√	√
Lighting								
Canopy Lighting	√	√	√	√	√	√	√	√
Platform Lighting	√	√	√	√	√	√	√	√
Access / Sidewalk Lighting	√	√	-	√	-	-	-	√
Track Finish								
In Front of Platform (Ballast / Hard Surface / Grass)	Hard Ballast	Hard Ballast	Hard Ballast	Hard Ballast	Hard Ballast	Hard Grass	Hard Grass	Hard Grass
Approach to Station (Ballast / Hard Surface / Grass)	Ballast	Ballast	Ballast	Ballast	Grass	Grass	Grass	Grass
Accessibility								
Linear Textured Floor Tile?	-	-	-	-	-	-	-	-
NOT IN CONTRACT								
Adjacent Sidewalk Precinct (for info only)								
Substation								
Telus Phone Booth								

Modern Streetcar	Granville Island Stn	Spruce St. Stn	Leg 'N' Boot Stn	Cambie St. Stn	Cook St. Stn	Manitoba St. Stn	Science World Stn	Pacific Boulevard
Bike Rack								
Guardrails								
Bollards with Lights								
Bus Stop Shelter								
HandiDart Parking								
Street Trees								
Emergency Parking								
FireHydrant								
Other								
Art Feature								

9.2.2 Streetcar Station Specific Design Issues

In this section we discuss issues that have been identified for some of the key stations along the Phase 0 corridor.

(i) Granville Station

As the terminus station, Granville Station will be situated in the existing location off the streets and intersection at the entry to Granville Island. It is a site that is not constrained by roads or alignment issues but it is on sloping topography as the land rises south from Lamey's Mill Road. An existing retaining wall runs along the north side of the station which means that any secondary platform access at the east end drops approximately 1.0m requiring steps or ramps. At the west end the topography allows a level entry. This station location is designed for possible future alignment extensions to Granville Island or to the west though the existing Granville Bridge columns.

(ii) Cook Station

The configuration of Cook station is constrained by the Wilkenson Building to the north, which restricts platform width to the minimum allowable 3.0m. HMM understands that the Wilkenson building is to be moved north to accommodate the expansion of 1st Avenue. As such, the possibility of moving the building an additional metre north should be considered in order to achieve a platform width of 4.0m.

(iii) Manitoba Station

As a centre platform located in the median, this station is constrained by the width of the proposed upgrading to 1st Avenue with narrow traffic lanes on each side. Located near the middle of the Olympic Village area and adjacent to the Salt Building, this area is expected to have a high volume of pedestrian activity. The platform width of 4.0m is the maximum that can be accommodated. In addition the station is also constrained by its location between two crosswalks very close together serving the two intersections created by the Salt Building. Since the highest volumes of pedestrian movement is expected to be at the west crosswalk, the accessible ramp for the raised platform will be to the west, but the east access will either be a non-compliant ramp or steps.

(iv) Science World Station

The Science World Station location at the entry to Science World and at the intersection of Terminal Avenue and Quebec Street is probably the most challenging station location of the system. The Skytrain elevated alignment passes over this intersection with the columns on the west side of Quebec Street conflicting with the off-street counter-flow alignment of the streetcar line. Although various station types and locations have been analyzed, the twin side platform configuration is considered the most successful with the tracks splitting to avoid the columns with minimal clearances and minimal radii. This difficult geometry forces the tracks onto Science World's parking and entry areas requiring property acquisition. The minimal 3.15m twin side platforms are considered adequate for the anticipated pedestrian volumes.

(v) Pacific Boulevard Station

As the alignment continues north from Science World Station to the Maintenance Facility at Prior Street and Quebec Street, it must be organized to avoid Skytrain columns, avoid conflicts with Pacific Boulevard, and turn sharply to the east through an intersection to access the Maintenance Facility, in addition to allowing for future continuation of the line towards Gastown. This extremely constrained condition means that the Pacific Boulevard Station will have an awkward tapered geometry approximately 4.0m wide at the south end and approximately 6.5m at the north end. The entry crosswalk will be at the south end. One of the Skytrain columns will be centred in the platform where a weather protection canopy would normally be located.

10 Maintenance Yard

This chapter discusses the provision of maintenance facilities for the DHR and modern Streetcar.

10.1 DHR Storage and Maintenance

As a consequence of the SEFC Project works on 1st Avenue, the CoV has relocated the DHR storage facility to a site at Ash Street on the north side of the current tracks. By the end of October 2007 the CoV were completing a new shed facility to accommodate the two existing vehicles, with a west bound connection on to the tracks. The facility is relatively simple and primarily provides dry and secure storage for the heritage vehicles.

The preliminary engineering scope did not include a study of this facility or its operation; the focus was on the modern Streetcar.

10.2 Modern Streetcar Storage and Maintenance

The IBI 2005 study identified a site for streetcar storage and maintenance. The report confirmed a fleet size of six cars for Phase 1 and in principle laid out the yard to accommodate them. The proposed yard is located at Quebec Street and Prior Street, under the Dunsmuir Viaduct and on a CoV plot currently being used by the police department for storage of impounded road vehicles.

For the Phase 0 Preliminary Engineering, the proposed site layout was reviewed and recommendations made on an alternative layout. Further information on the site has been collated, including a more detailed topographic survey to verify vertical clearance beneath the viaduct.

10.2.1 IBI Concept Layout

A review of the existing yard layout identified a number of concerns, but the two most significant are:

- Inadequate storage space for six modern streetcars.
- Operational performance – routing pattern for vehicles entering and existing the yard.

The layout as drawn would not accommodate the modern vehicles being proposed (such as the Skoda T10), which are at least 25m in length (note that other vehicles from suppliers such as Siemens, Ansaldo Breda and Bombardier would likely be near 30m). The layout appears more suited to the existing DHR heritage vehicles, which are approximately 15m in length. The design also includes a length of siding that would most likely extend beyond the current boundary fence to the east and require substantial removal of embankment around the Dunsmuir viaduct. While this maybe feasible it has not been confirmed and could add some significant civil costs to the project.

Operationally, the layout appears inflexible. It does not appear to permit entry of vehicles into service south bound (therefore vehicles would head north towards Gastown before turning back to Granville). In the 2005 study, the alignment description identifies a cross over near Hastings station. In assessing the alignment plans it was initially assumed that the cross over would be used for turning back vehicles during service start-up, as just described. However, it is clear from the report that this was only intended to be used during special events.

The arrangement would also require vehicles leaving service to stop in a shared section of road (on the north bound streetcar track), reverse travel direction and operate in counter flow to road traffic. This would be operationally difficult to achieve and highly unusual to undertake in a street running scenario, except under emergency protocols.

It should be recognised that reverse shunt movements in streetcars require drivers to change ends within the vehicle, adding significantly to the time it takes to enter vehicles into and out of service.

Most critically, the track arrangement is designed for Phase 1 and assumes that the streetcar line extends towards Gastown. As currently proposed it would not permit entry of vehicles into service unless they were to run in counter flow from the yard southbound across the Pacific Boulevard intersection.

10.2.2 Phase 0 Preliminary Design

The preliminary design focused on resolving the issues with the 2005 study design outlined above. Limited effort, except for the purpose of pricing, was made on designing or specifying the maintenance facilities.

(i) Site Constraints

Prior to describing the new Yard concept it is worth noting the major constraints that need to be overcome.

- Site geometry – the distance west to east from Quebec Street is approximately 50m. Beyond the east boundary there is an embankment and structures that form part of the Dunsmuir Viaduct. There are also a number of columns (8 no.) supporting the viaduct spaced evenly across the site.
- In line with the 2005 study we have assumed that Quebec Street needs to accommodate at least two lanes of road traffic south bound and one north bound and a streetcar line in each direction (i.e. one southbound lane for traffic, one southbound lane for streetcar and one shared northbound lane or vice versa). The street must also provide sidewalks and cycle lanes in both directions. There is only 20m cross sectional width on average from back of existing sidewalks available. Beyond the sidewalks there are numerous physical constraints including columns to the Dunsmuir and Georgia viaducts which are considered at this stage immoveable constraints. Therefore, at least one of the lanes of road traffic will likely need to be shared with the streetcar. Setting out typical dimensions across the street we can quickly surmise the following – *sidewalk, cycle, 3 lanes for road & streetcar, cycle, sidewalk*:- 2m+1.5m+3.5m+3.5m+3.5m+1.5m+2m = 18m, confirming that 20m is just enough without taking into account other intricacies of interfacing the streetcar and road design.

These constraints make it difficult to produce an efficient use of the land. Ideally, track geometry would allow for a delta or half-union type layout that would permit entry and exit to service in both directions. Historically, this was a very common layout for streetcars storage yards and depots that were located in central city locations. However, such layouts were possible because of the shorter length vehicles and tighter operating curves that traditional streetcars could achieve, such as the existing DHR inter-urbans. Modern vehicles are not so operationally flexible (refer to Chapter 4).

(ii) Alternative Layout

Figure 15 provides an extract from the Preliminary engineering plans as of November 07, of an alternative Yard design. The following summarises the key features:

- Designed for Phase 0 operation; entry and exist of service to/from Granville.
- Accommodates six modern streetcars of approximately 25m length (in line with Phase 1 requirements)
- Adopts standard 25m radii streetcar (European tramway) switch units.
- 400 square metres of security and operations buildings including office and welfare areas
- 600 square metre maintenance building. Two bays for streetcar maintenance, one with maintenance pit.
- Parking for staff. Nominally 10-15 spaces; not confirmed or based on any precise operational staffing numbers. However, the site is well serviced by transit buses and SkyTrain for staff travelling within the hours of operation for these systems.
- Lay down areas for material storage (spare ballast, track components and the like)

The track geometry has been designed to fit with the general track configuration provided by the CoV in for Quebec Street. This assumed that northbound streetcar movements were in a shared lane along the east curb line, and that immediately adjacent was southbound streetcar in a segregated lane. A further road lane was provided to the west of the southbound streetcar.

The track was configured so that north and south bound movements could be achieved for Phase 0. This requires a single line section of track into the depot with a switch providing the split between the north and south bound tracks.

It should be noted that there is insufficient space for a streetcar to stop when travelling south bound across Pacific, without it blocking other road traffic. This effects how streetcars will enter service from the Yard. It will likely necessitate a streetcar only phase for departing vehicles south bound, so that they cross Prior Street, Pacific north bound and Pacific south bound traffic in one movement. Similarly for north bound vehicles returning to the Yard.

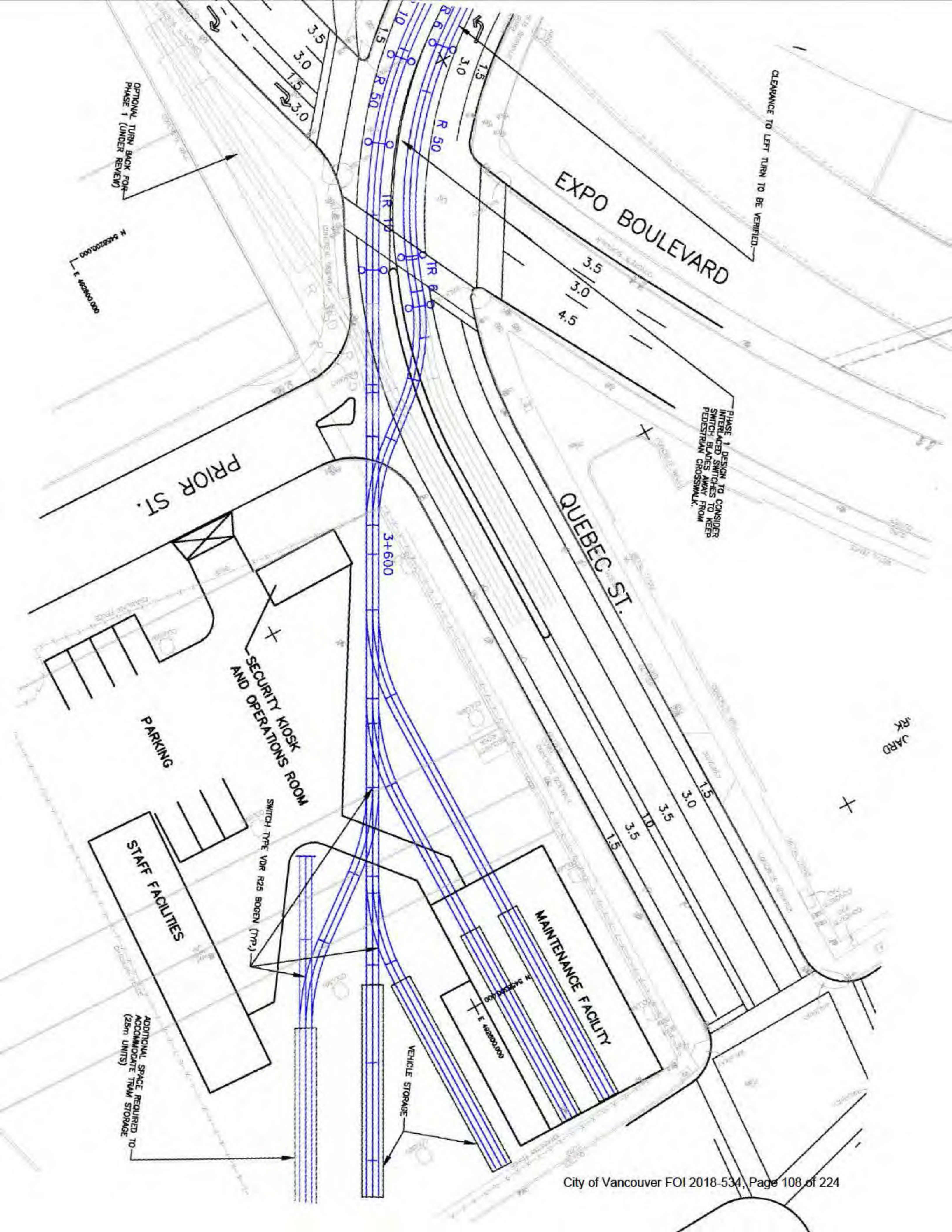
The track design within the Yard is only preliminary and will require more detailed design to confirm its precise arrangement. The layout has just sufficient space to store six vehicles (assuming 25m long).In addition, the angle of the mainline into the yard requires optimising to ensure that there is sufficient space for two vehicles on the first storage line (one unit within the maintenance building and one outside). It is likely that a small amount of space will be required outside of the northern and eastern fence lines once features such as block ends are included.

As noted above the track switches used in the depot and on the approaches are based upon European style tramway units (see drawings for details). These units benefit from a shorter overall length that the more typical No.6 and No.8 units installed on rail in North America, allowing for more compact designs. However, such units could cost more and be more difficult to procure. Overall, the preliminary design has sought to standardised switch unit size so making initial procurement and future spares provision more efficient and cost effective.

Although not solely related to the Yard, it is worth noting at this point that streetcar wheel profiles are very different from those found on traditional railway rolling stock, and that selection of compatible rails units is important in achieving a satisfactory ride quality, operational safety and low whole life costs.

10.2.3 Additional Considerations

Plans exist for a storage barn at Granville Island for the DHR vehicles. These have been reviewed and it may be possible to incorporate these plans into the footprint of the Granville Island Station. A detailed review should be undertaken at detailed design to determine the track alignment and modern vehicle storage requirements. It is not anticipated that this will replace the proposed yard, however, it may serve as permanent storage for the DHR vehicles.


EXPO BOULEVARD
PRIOR ST.
QUEBEC ST.
CLEARANCE TO LEFT TURN TO BE VERIFIED
OPTIONAL TURN BACK FOR PHASE 1 (UNDER REVIEW)
PHASE 1 DESIGN TO CONSIDER INTERLACED SWITCHES TO KEEP SWITCH BLADES AWAY FROM PEDESTRIAN CROSSWALK.
3+600
SECURITY KIOSK AND OPERATIONS ROOM
PARKING
STAFF FACILITIES
MAINTENANCE FACILITY
SWITCH TYPE VDR R25 BOGEN (TYP.)
VEHICLE STORAGE
ADDITIONAL SPACE REQUIRED TO ACCOMMODATE TRAM STORAGE (25m UNITS)

11 Operations - Runtime Analysis

In this section we present the findings of our preliminary operational model. The purpose of this model is to verify that the approximate runtime and vehicle numbers in the Concept Report by IBI remain reasonable. A runtime assessment has only been completed for the modern Streetcar system as it is considered that the DHR system (two existing heritage vehicles) will continue to operate on an informal basis without a fixed timetable.

11.1 Reference Drawings and Chainage Takeoff

The alignment along with the proposed station locations and junctions indicated on HMM drawings of November 07 were used as the basis for run time calculations. The chainage was calculated from the Pacific Boulevard station location through to Granville Island station.

11.2 Parameters, Acceleration/Deceleration Rates, Dwell Times and Speeds

The following parameters have been developed based on experience with similar tram/streetcar schemes being operated around the world:

- The following acceleration and deceleration rates have been adopted for the runtime model. These are approximately 75% of the maximum values for the vehicles in Chapter 4 (Skoda T10, Bombardier Flexity Swift and Siemens S70), which is considered reasonable for normal operation (vehicles are not driven at there maximum potential on a continual basis). Given the relatively low maximum speeds that are reached along the system, runtime sensitivity to different acceleration and deceleration rates is relatively small.

Table 12: Runtime model acceleration and deceleration rates.

Track	Description	Accel (m/s2)	Decel (m/s2)
H	Highway running	1.0	1.0
P	Pedestrian areas	1.0	1.0
T	Segregated track	1.0	1.0

- The station dwell times have been set at 20 seconds for all stations along the route. This could be adjusted at a later date depending on the demand requirements of the system.

- All intersections have been designated as either a type 1 or 2 priority Type 1 priority allows the vehicle absolute priority at the intersection. Type 2 requires the vehicle to slow to a halt but continue immediately. These are relatively high levels of priority and should be confirmed as acceptable with the CoV Road and Traffic units. It should be noted that Pacific Boulevard/Quebec intersection (perhaps the most complex on the Phase 0 system, is not included in the runtime model because under Phase 0 the intersection is only passed during entry and exit to the Yard and not part of the operating timetable.
- For intersections type 1 where the streetcar demands a green in advance and approaches/departs on road, the stop line approach speed is 25kph or half speed unless constrained by some other parameter. The streetcar then accelerates to the posted speed unless constrained by some other parameter. If the approach speed is lower than 48kph and the tram can proceed at 25kph this speed will be used and not half the lower approach speed. This approach is adopted to reflect the need for drivers to approach and pass through intersections at cautions, irrespective of there being a green phase. This is considered good operational practice considering the urban environment through which the streetcar is passing, where hazards from pedestrians and other road vehicles exist.
- For pedestrian areas and segregated track where the streetcar moves onto or crosses a road, the approach speed to the pedestrian crossing was set at 25kph.
- The chainage for the intersections has been given to an estimated stop line. This adds the deceleration time to the link on the approach line. Similarly, it adds the dwell time for the intersection to this link if any are specified.
- It should be noted that significant lengths of the streetcar route does not lend itself to the full application of super-elevation due to the urban environment through which it passes; such as on 1st Avenue and Quebec (For example, it is limited to 15-25mm on a 45m radius on the approach to Columbia). This has an impact upon the operational speed of the streetcar and this is reflected in the runtime model. However, the alignment is only at a preliminary stage of design and this aspect of the operational speed must be reviewed as the design develops.
- The design speed through stations has been kept at 15kph but as the detailed design takes place there could be scope to increase this speed dependant on the alignment geometry. This would therefore provide a saving in the runtime. A sensitivity exercise should be carried out at the detailed design stage to determine if this is possible.

11.3 Speed Assumptions and existing Alignment Constraints

The following comments highlight areas where certain assumptions have been made concerning alignment design in order to increase the line speed, or where existing assumptions are onerous. It will be prudent to note these and carry out design checks in the near future to ensure that these can be achieved without compromising other areas of the design.

- Science World - the constraints of the existing Sky train support columns has resulted in tight reverse 50/50 curves into the station location;
- Quebec/1st Avenue junction - tight radius (25m) through this junction.

11.4 Comparison of Previous Results with New Results

Table 13: Summary of the run times from the 2005 IBI Group report.

Stations/Major Junctions	Chainage (m)	Link/Track Type	Total Link Time (Secs)	Cumulative Time (Secs)
Granville Island Station	0	STN	0	0
Sitka Square (Spruce) Station	722	STN	78	78
Moberly Road/6th	1327	SGN	48	126
Moberly Road Station	1380	STN	30	156
2nd Avenue/Olympic Station (RAV Station)	1721	STN	60	216
1st/Wylie Street	1901	SGN	24	240
1st/Columbia Street	2306	SGN	36	276
Columbia Street Station	2345	STN	36	312
1st/Ontario Street	2647	SGN	36	348
Ontario Street Station	2680	STN	36	384
1st/Quebec Street	2787	SGN	30	414
Quebec Street/Street A	2992	SGN	18	432
Quebec Street/Terminal	3129	SGN	12	444
Science World Station	3179	STN	36	480
Quebec Street/National	3322	SGN	18	498
Pacific Boulevard Station	3449	STN	36	534

Table 14: Summary of runtime based on the HMM designed alignment.

Stations/Major Junctions	Chainage (m)	Link/Track Type	Total Link Time (Secs)	Cumulative Time (Secs)
Granville Island Station	33	Station	10	10
Spruce Square Station	845	Station	105	115
Moberly Road	1374	Highway	73	188
Moberly Road Station	1404	Station	29	217
2nd Avenue/Olympic Station	1800	Station	78	295
Wylie Street	1882	Highway	22	317
Crowe Street	2054	Highway	27	344
Cook Street Station	2200	Station	57	401
Cook Street	2200	Highway	0	401
Columbia Street	2270	Highway	19	420
Manitoba Street	2515	Highway	32	452
Manitoba Street Station	2575	Station	36	488
Ontario Street	2706	Highway	23	511
Quebec Street	2745	Highway	8	519
Development Access	3030	Highway	56	575
Science World Station	3166	Station	51	626
Pacific Boulevard Station	3495	Station	81	707

Below is a comparison of the IBI and HMM runtimes.

Table 15: IBI and HMM runtime comparison.

Alignment	Chainage (m)	Runtime (sec)
IBI	3449	534
HMM	3495	707

While the chainage of the proposed alignment is slightly longer (46m, 1.33%) there is a significant increase in the runtime (160 sec.). Having compared the two runtimes and analysed the IBI numbers the following are possible explanations for the difference in runtimes:

- The HMM runtime is more sensitive to track geometry; significantly more detail exists for the new preliminary track design which has identified various geometric constraints. Sections of track, such as the Granville corridor, were found to have lower average track speeds than were originally expected. From Granville to Moberly the IBI results have an estimated speed of 30kph, where as HMM's is nearer 25kph.

- Vehicle speeds at junctions; as noted in the HMM runtime model assumes that vehicles slow down at intersections even when a green phase is in operation. This is to reflect the design of the road and urban environment on 1st Avenue where conflict with left turns and pedestrian movements can be expected to provide an extra operational hazard to the streetcar.

- Station dwell times; it is not clear whether any dwell time was allowed in the IBI runtime model. The HMM model assumes 20 seconds per station. This value could be reduced to say 15 seconds on less well used stations, such as Cook and perhaps the Leg N Boot. However, less than 15 seconds is unlikely to be achieved, as the time includes for driver activation of brake, door to open, check that door is clear of passengers, door closing time and vehicle restart.

12 Cost Estimate

12.1 Introduction

This chapter discusses the basis and scope for the cost to upgrade the existing DHR system. The three options estimated were:

- **DHR**: Basic *repair* of the existing system outside of the 1st Avenue corridor with new track along the new HMM alignment within the 1st Avenue corridor.
- **DHR Plus**: As DHR except with *replacement* and *realignment* of single track outside 1st Avenue corridor, following one of the new HMM full modern alignments to facilitate straightforward upgrade to the full modern in the future.
- **Full Modern**: Installation of twin track system with new trackwork, power, systems, stations, vehicles, and an Operations and Maintenance Centre

12.2 Basis of Estimate

The cost estimate is based on the following assumptions:

- The prices are based upon a competitive tendering process, with civil, building, and trackwork being carried out as one contract, with a separate contract for the power supply and installation.
- The construction and associated costs included in the estimate are September 2007 as spent costs that would reflect expenditure and inflation over the project design and construction period as if the project was commencing in September 2007.
- Schedules as set out below, with detailed design commencing in parallel with the permitting process.

  - DHR – 18 months
  - DHR Plus – 18 months
  - Full Modern – 24 months

- The estimate is a conceptual estimate with assumptions and allowances covering work that cannot be quantified. No existing condition surveys, engineering or physical ground investigation has taken place. The assumptions are described in the scope of the works, and are able to be used as a basis of a budget for the complete work.
- The system is assumed to operate by line of sight only, with limited connections to traffic signalling at Moberly Rd. and along 1st Avenue, in addition to the entrance to Science World and on Pacific Blvd. for the full modern system.
- The estimates exclude the following:

a) Upgrading the existing street cars, or provision of new cars except to the Full Modern option
b) Fare collection systems

c) Street works except as required at intersections to accommodate the track slab
d) Joint development costs or opportunities
e) Spares
f) Maintenance equipment except to the Full Modern Option
g) An operations and maintenance facility except to the Full Modern Option
h) Operating costs
i) Financing costs beyond the construction period
j) Property costs
k) Demolition of any existing structures
l) Temporary diversions to carry out the work, any that would be necessary are assumed to be carried out as part of the 1st Avenue street works
m) Any train control or signalling
n) Operations preparation and training
o) GST

12.3 Option 1: DHR

The DHR option involves carrying out basic repair of trackwork and power distribution to the existing system, and providing a new alignment with single line ballasted track between Cambie Street and Quebec Street. This work is treated as a repair and rehabilitation contract with minimal project and construction management, except to the length between Cambie Street and Quebec Street. The line ends at the existing Science World Station.

(i) Site Preparation

- Surveys and setting out the work
- Clearing the site
- An allowance of $40,000 for contaminated material removal
- Taking up existing track between Cambie and Quebec Streets
- Grading and fill to those areas that are not in the median of 1st Avenue
- Protection of existing utilities

(ii) Roadworks

- Rebuilding existing roads at intersections.
- Loops and equipment to provide pre-emption at traffic lights provided by others, the traffic lights are not included.

(iii) Track bed

- **Granville Corridor**: Repair of the existing with an allowance to repair 10% of the existing trackbed
- **1st Avenue median**: New track-bed suitable for tie and ballast

- **1st Avenue intersections:** Reinforced concrete track bed grooved for track approximately 6900mm wide for two tracks with grounding and track drainage, finished level with the street at intersections
- **Ontario Street to Science World:** Repair of the existing with an allowance to repair 10% of the existing trackbed
- Minor landscaping to the ballasted track bed

(iv) Trackwork

- **Granville Corridor**: Repair existing with an allowance of $500 per metre to repair existing tie and ballast trackwork
- **1st Ave:** New continuously welded tie and ballast with insulation as required weighing approximately 54 kg per metre.
- **1st Avenue intersections:** Continuously welded trackwork with a detail to form a groove and insulation as required. 54kg per metre.
- **Ontario Street to Science World:** Repair of existing with an allowance of $500 per metre to repair existing tie and ballast trackwork
- Four manual switches are included for future crossovers.
- Track drainage

(v) Civil and Building Works in Connection with Systems

- Overhead power line support column foundations where required
- Power and communication ducts under the track bed in cross streets. This is a provision for the modern streetcar system.

(vi) Power Distribution

- Overhead streetcar single conductor overhead power supply fixed to existing street lights along 1st Avenue between Cambie Street and Quebec Street
- An allowance of $150 per metre for repair of the existing overhead line, where not replaced
- Connection to the existing traction power supply

(vii) Testing and Commissioning

Testing and commissioning the system prior to operations.

(viii) Stations

Two new stations at Cook Street and Manitoba Street with a platform 25 metres long including:

- A single centre platform
- A shelter
- Seats and signage
- Concrete paving finish, with a separately marked platform edge
- Platform drainage
- Two street lights per station
- Station landscaping

Repair of the remaining existing stations along the existing streetcar line.

(ix) Management, Design and Engineering

- Design of the system including architectural, civil and system works both prior to construction and providing design support through construction.
- Minimal project management to cover small works contracts for the repair work, with more detailed management on the section between Cambie Street and Quebec Street.
- Construction management of the contractors constructing the project

(x) Contingencies

An allowance of 20% on all costs covering unforeseen ground or commercial conditions contract reserve during construction, and rates of exchange charges on imported material.

(xi) Interest during Construction (IDC)

Financing interest of 6% on all funds spent between the commencement of the project and revenue service.

12.4 Option 2: DHR Plus

The DHR Plus option is the same as the DHR option except that the track in the Granville Corridor is replaced and realigned (where practical) to follow one of the full modern alignments and the track between Ontario St. and Science World is replaced. Existing OCS will be repaired and replaced as is required.

(i) Site Preparation

- Surveys and setting out the work
- Taking up all existing track
- Clear undeveloped land at the end of 1st Avenue
- An allowance of $40,000 for contaminated material removal
- An allowance of $50,000 for utility protection and stray current along 1st Avenue
- Grading and fill to those areas that are not in the median of 1st Avenue
- Prepare and grade new median for track bed excavation
- Protection of existing utilities

(ii) Roadworks

- Rebuild roads at street crossings after installation of track
- Make good road or median surface to track bed
- Loops and equipment to provide pre-emption at traffic lights provided by others, the traffic lights are not included
- 600mm deep granular bed to support ballast (excavation presumed by Stantec), concrete track bed at street crossings, Full Modern - a grass track bed for twin tracks with in street track at street crossings

(iii) Trackbed

- **Granville Corridor**: A complete repair of the existing tie and ballast trackbed with new trackbed where required by realignment.
- **1st Avenue median**: New 600mm deep granular bed to support new ballast.
- **1st Avenue intersections:** Reinforced concrete track bed grooved for track approximately 6900mm wide for two tracks with grounding and track drainage, finished level with the street at intersections.
- **Ontario Street to Science World:** A complete repair of the existing tie and ballast track bed with new track bed where required by realignment.
- Minor landscaping (grass) to the area beside track.

(iv) Trackwork

- **Granville Corridor:** Replace all existing trackwork with new tie and ballast trackwork weighing approximately 54 kg per metre.
- **1st Ave:** New continuously welded tie and ballast with insulation as required weighing approximately 54 kg per metre.
- **1st Avenue intersections:** Continuously welded trackwork with a detail to form a groove and insulation as required. 54kg per metre.
- **Ontario Street to Science World:** Replace all existing trackwork with new tie and ballast trackwork weighing approximately 54 kg per metre.
- Four manual switches are included for future crossovers.
- Track drainage

(v) Civil and Building Works in Connection with Systems

- An allowance for 24 pole foundations where span wire would not work at tie in to 1st Avenue
- Under track duct for a power connection under roads

(vi) Power Distribution

- Connection and work to existing sub-station
- New single line overhead power line, mainly connected to existing street lights along 1st Avenue between Cambie Street and Quebec Street.
- Stray current monitoring
- 6 blue light stations.
- New power and communication cable for future power and communication connections.
- An allowance of $150 per metre for repair of the existing overhead line, where not replaced

(vii) Testing and Commissioning

- Testing and commissioning the system prior to operations

(viii) Stations

- Two new stations at Cook Street and Manitoba Street with a platform 25 metres long including:
  - A single centre platform

- A shelter
- Seats and signage
- Concrete paving finish, with a separately marked platform edge
- Platform drainage
- Two street lights per station
- An emergency phone to each station
- Station landscaping

Repair of the remaining existing stations along the existing streetcar line.

(ix) Management, Design and Engineering

- Design of the system including architectural, civil and system works both prior to construction and providing design support through construction.
- Project management, covering the overall management by project staff and consultants for the duration of the project
- Construction management of the contractors constructing the project

(x) Contingencies

- An allowance of 20% on all costs covering unforeseen ground or commercial conditions contract reserve during construction, and rates of exchange charges on imported material

(xi) Interest during Construction (IDC)

- Financing interest of 6% on all funds spent between the commencement of the project and revenue service

12.4.2 Assumed SEFC Advanced Works

Following discussions with SEFC and CoV, it is understood that the following tasks are included in reconstruction of 1st Avenue (Contract C1111):

- Site clearance between Wylie and Ontario
- Environmental remediation between Wylie and Ontario
- Remove existing track
- Construct curb lines for median
- Provide 650mm deep granular bed up to underside of ballast elevation

12.5 Full Modern

Construction of a new twin track system with new trackwork, power, systems, stations, vehicles, and an Operations and Maintenance Centre between Granville Street at Lamey's Mill Road and a new Operations and Maintenance Centre east of Quebec Street at Prior Street.

(i) Site Preparation

- Surveys and setting out the work
- Clearing the site including tree removal in the existing CP cut
- An allowance of $815,000 for contaminated material removal
- New retaining walls in the CP cut
- Taking up all existing track
- Grading and fill to those areas that are not in the median of 1st Avenue
- Protection of existing utilities

(ii) Roadworks

- Rebuilding existing roads at intersections and where the track runs parallel with the road
- Loops and equipment to provide pre-emption at traffic lights provided by others, the traffic lights are not included

(iii) Trackbed

- **Granville Corridor:** Complete repair and replacement (where required by realignment) of the existing tie and ballast track bed and enlarging the profile to receive two tracks.
- **1st Avenue median:** Reinforced concrete track bed, suitable for insulated grooved track, approximately 6900mm wide for two tracks, with a central sunken area lined with insulation and filled with top-soil finished with grass, including grounding and track drainage.
- **1st Avenue intersections:** Reinforced concrete track bed suitable for insulated grooved track approximately 6900mm wide for two tracks with grounding and track drainage, finished level with the street at intersections.
- **Ontario Street to Maintenance Yard (off street):** Reinforced concrete track bed, suitable for insulated grooved track, approximately 6900mm wide for two tracks, with a central sunken area lined with insulation and filled with top-soil finished with grass, including grounding and track drainage.
- **Ontario Street to Maintenance Yard (on street):** Reinforced concrete track bed suitable for insulated grooved track approximately 6900mm wide for two tracks with grounding and track drainage, finished level with the street at intersections.
- Minor landscaping to the trackbed

(iv) Trackwork

- **Granville Corridor:** Replace all existing trackwork with new double tie and ballast trackwork, weighing approximately 54 kg per metre
- **1st Avenue:** Two tracks of continuously welded street grooved trackwork with a rubber boot or epoxy coating as track insulation, weighing approximately 54 kg per metre.
- **Ontario Street to Maintenance Yard:** Two tracks of continuously welded street grooved trackwork with a rubber boot as track insulation, weighing approximately 54 kg per metre.
- Four manual switches are included for crossovers.
- Track drainage

(v) Civil and Building Works in Connection with Systems

- Power duct is taken for the complete length to full modern
- Full length communications duct
- Operators' washroom facilities
- New sub-station building
- Overhead power line support column foundations where required

(vi) Power Distribution

- Twin overhead street contact wires
- Two substations, one on the line and the other in the Operations and maintenance Centre
- Six blue light stations
- Connection to B.C. Hydro power supply

(vii) Testing and Commissioning

Testing and commissioning the system prior to operations

(viii) Stations

Eight new stations with platforms 25 metres long including:

- A single centre platform or double side platforms
- A shelter
- Seats and signage
- Concrete paving finish, with a separately marked platform edge

- Platform drainage
- Two street lights per station
- An emergency phone to each station
- Station landscaping

(ix) Operations and Maintenance Facility

A 4,000 square metre facility under the existing Dunsmuir Viaduct east of Quebec Street consisting of:

- 250 metres of track and overhead power line
- Six manual switches
- Track stops
- 400 square metre operations building
- 600 square metre maintenance building and maintenance pit
- Yard lighting
- Yard services
- Paving
- Security fencing
- An allowance of $1 million for maintenance equipment

(x) Vehicles

- Six type 10T Skoda vehicles or similar vehicle.

(xi) Management, Design and Engineering

- Design of the system including architectural, civil and system works both prior to construction and providing design support through construction.
- Project management, covering the overall management by project staff and consultants for the duration of the project
- Construction management of the contractors constructing the project

(xii) Contingencies

- An allowance of 20% on all costs covering unforeseen ground or commercial conditions contract reserve during construction, and rates of exchange charges on imported material

(xiii) Interest during Construction (IDC)

- Financing interest of 6% on all funds spent between the commencement of the project and revenue service

12.6 Cost Summary

Table 16: Cost estimate summary. Refer to Appendix L for a complete breakdown.

VANCOUVER STREET CAR - SYSTEM SUMMARY			
SUMMARY	DHR	DHR Plus (Recommended)	Modern
SITE PREPARATION	502,410	1,014,410	3,149,590
ROADWORKS	131,720	89,720	815,720
TRACK BED	1,082,920	1,817,760	9,700,600
TRACKWORK	2,943,400	4,118,400	13,015,000
CIVIL AND BUILDING WORKS IN CONNECTION WITH SYSTEM	83,100	55,000	4,168,900
POWER SUPPLY AND DISTRIBUTION	953,900	842,700	4,020,800
TESTING AND COMMISSIONING	47,695	42,135	986,200
STOPS	825,000	900,000	3,159,500
OMC			6,903,145
VEHICLES			15,703,209
TOTAL CIVILS AND SYSTEMS	**6,570,145**	**8,880,125**	**61,622,664**
DESIGN	394,209	532,808	2,755167
PROJECT MANAGEMENT	483,952	888,013	4,591,946
CONSTRUCTION MANAGEMENT	254,338	444,006	2,295,973
TOTAL	7,702,643	10,744,951	71,265,750
CONTINGENCIES	1,540,529	2,148,990	11,112,508
TOTAL	9,243,172	12,893,942	82,378,258
IDC	554,590	773,636	8,237,826
TOTAL ESTIMATE	**$9,797,762**	**$13,667,578**	**$90,616,084**

13 Risk Register

The risk register will play a key role in the project going forward. It identifies all the issues that must be resolved in the detailed design process and the risk to the overall success of the project associated with each issue. The Risk Register will be a live document that should be revised up to and through the detailed design process. The Risk Register is included in Appendix L.

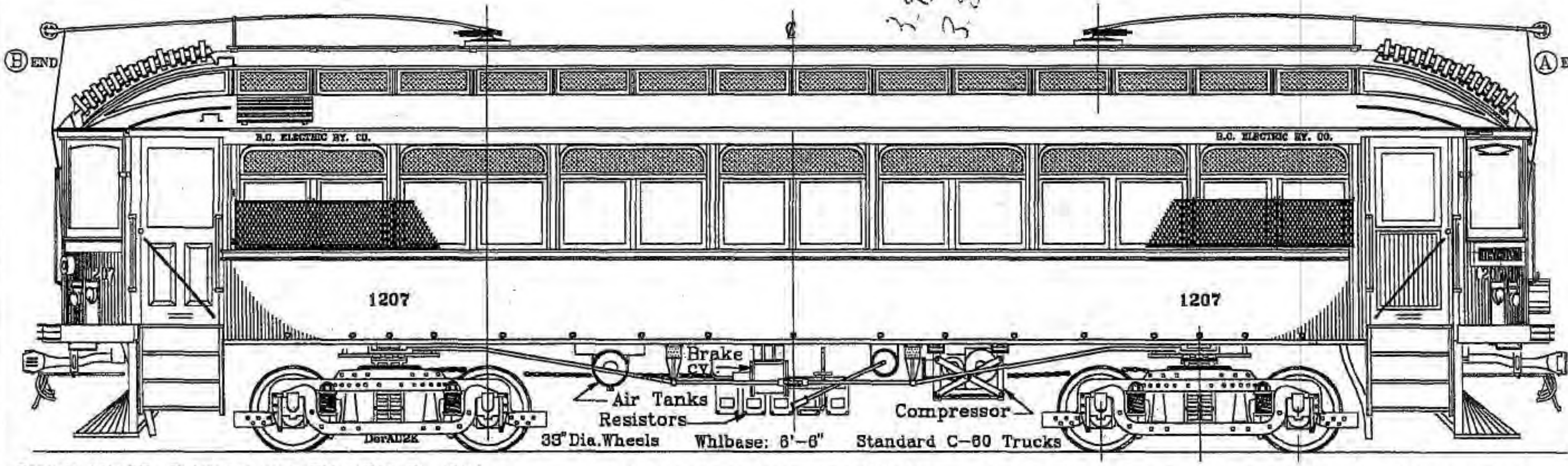
Appendix A DHR Vehicle Information

This Car Was First Called Steveston (June 1946)

Built	B.C.E.R. July 1st, 1905.
Rebuilt	B.C.E.R. Sept.27 1912 with 204 motors and Type M control installed.
Weight	71,550 lbs.
Capacity	Parlour 32, Smoker 24 = 56.
Length	50 ft.
Lamps	32.
Type	Double End Multiple Unit.
Fender	Pilots (2).
H. Brakes	[illegible], Stamdard National
T. Base	Sterling (2).
Type of Seats	Parlour - Rattan), (Smoker - Slat.)
Type of Floor	Softwood Slat
Heaters	10 Inside (1 each Vestibule 1375 Watts).
Wheels	35 in. Steel Tires.
Control	C.G.E. Type M.
Trucks	Standard C - 60.
Wh. Base	6 ft. 6 in.
Axles	6 In.
Journals	M.C.B. 5" X 9".
Gears	57 Teeth.
Motors	C.G.E. 204 (4).
H. Power	75 each.
Pinion	20 Teeth.
Brake	WH. A.M.M.
Brake Valve	WH. M.15 D.
Compressor	WH. D 2 - E G.
Governor	WH. Type J.
Tanks	WH. 2 Main 16" X 42" (1 aux.12" X 33").
Brake Shoes	WH. M - 931.
T. Levers	Live 19½" X 7" (Dead 19½" X 7").
C. Levers	13" X 21".
Cylinder	WH. 14" X 12".
Resistance	C.G.E. 5 Frames
Motors Leads	Standard
Triple	WH. M. 2 B.

Sold to Puget Sound Railway Historical Assn. Feb. 1958.

Car 1207 was one of four interurban coaches to operate on B. C. Electric's last day of interurban service, February 28, 1958.



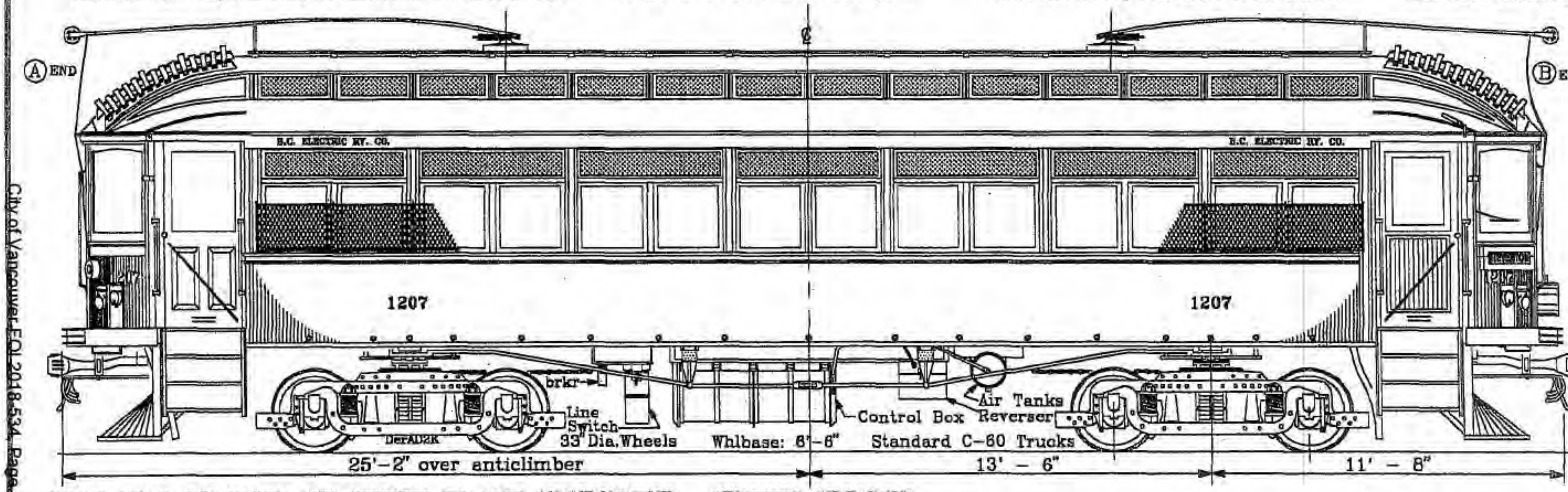
PHASE THREE: REBUILT AND RUNNING IN 1920

For Phases 1 & 2 see dwg BCERSTON

By March 31, 1920, H.M.Lloyd signed the new BCER Standards. The "Wooden Twelves" had new end platforms, steps, roof ends, based on wide elliptical bumpers instead of the circular style.

1. To match new eqpt.: new anticlimbers; M.U.connections; Standard C-60 trucks; Std.Roof Mats; Headlights; Retrievers; etc.
2. Radial couplers c/w locking device.
3. Type'M' Multiple Unit control gear.
4. Union Standard trolley pole base No.6 set directly above the second axle.
5. New std. roller destination signs
6. Green ripple glass in upper sashes.
7. Additional stay bolt above truck center.
8. 'A.M.M' Air Brakes.
9. 75 hp GE 204A Motors.

However, they retained the prevalent Dark Green Livery with black underbody.



PHASE FOUR: UPGRADED AND RUNNING TO 1958 ABANDONMENT   OPPOSITE SIDE VIEW

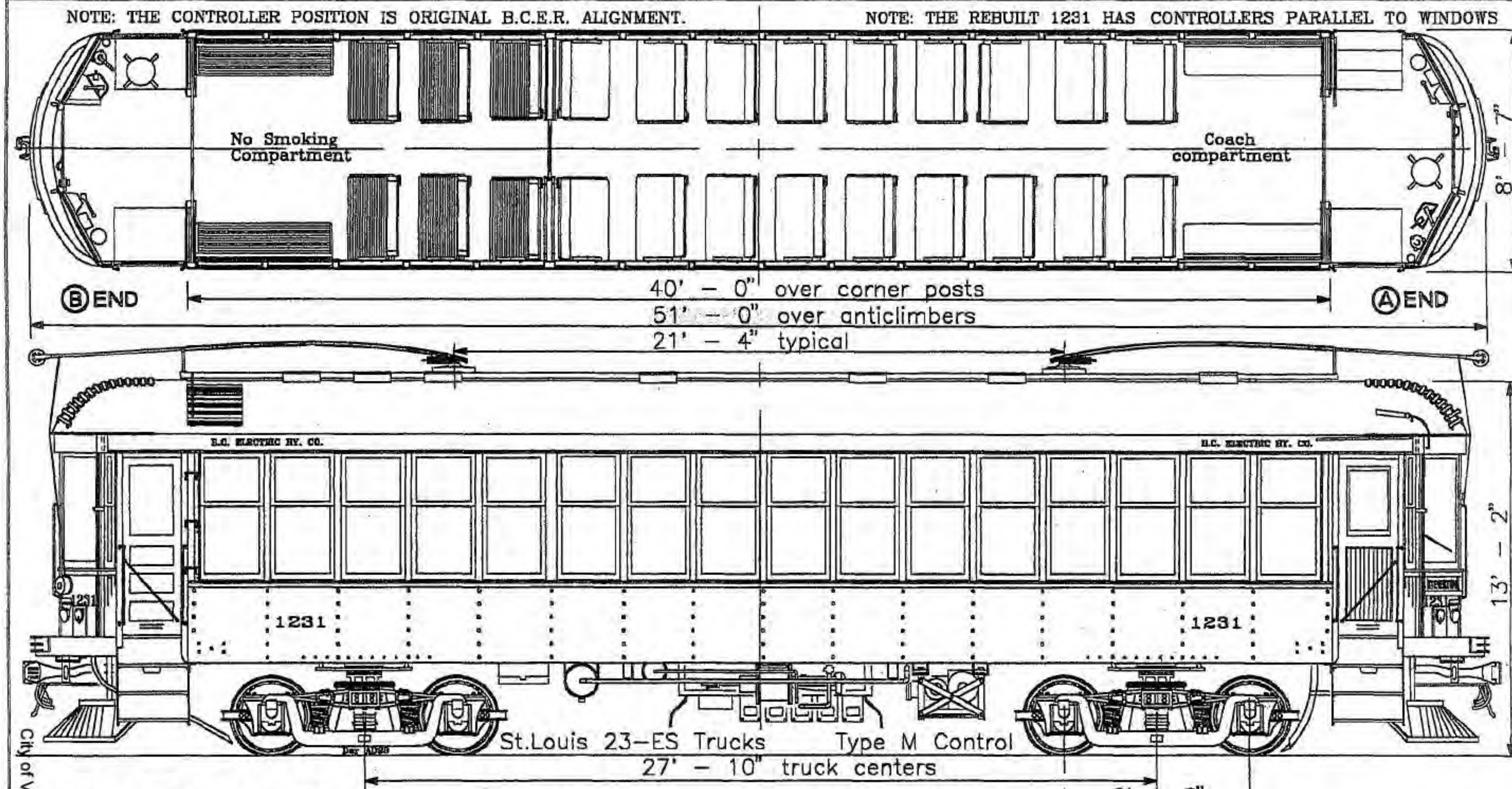
Many changes gradually appeared after the initial 1920 standardizing. The most impressive was the Red and Ivory Livery which began to be applied after 1925. However, each routine overhaul brought improvements such as better wipers. The upper sash windows received square corners for frames and glass, probably for wartime 'Utility'. To avoid icing and oil dripping on windows, whistles were turned up above roof ends. The Edwardian pilots lasted through till the last run in 1958 and export to U.S. Credit Richmond drivers.

For PHASE FIVE: As running again in 1998 see dwg DHR1207

0 C H E C K 5 F E E T 10

Should be 1 and 7/8 inches.

BCER HOME-BUILT '1200 WOOD' INTERURBAN 1207	
'STEVESTON' REBUILT AND UPGRADED	
Dwn: D.E.Reuss FEB.1,2K	Data: BOB WEBSTER
Scale: 3/16" = 1'-0"	Dwg: BCER1207 P.35



Well, here it is -after almost forty years, the first St. Louie restored to operating condition and back on home rails on Vancouver's Downtown Historic Railway. First thanks go to the far-sighted U.S. fan, Andy Hansen who rescued No.1231.

This was one of 28 built to brighten the rails between Vancouver and Seattle, but it is enough for this veteran to show last century's potential to needy commuters today.

Many volunteers as well as professionals are putting in the months of rebuilding these grand old cars require so they can earn their own upkeep. Bill Bailey and Victoria helpers completed #1231 beautifully.

Four other St.Louis-built interurbans exist of the same class but original drawings seem to be lost. Perhaps the series started here may extend in its significance for all these cars in B.C. (3), California (1), Ottawa (1).

Although Bill Bailey replaced MU wiring on #1231, there is no other car ready, nor has traffic reached that level. But note new pilots, insulated poles sanders, etc.

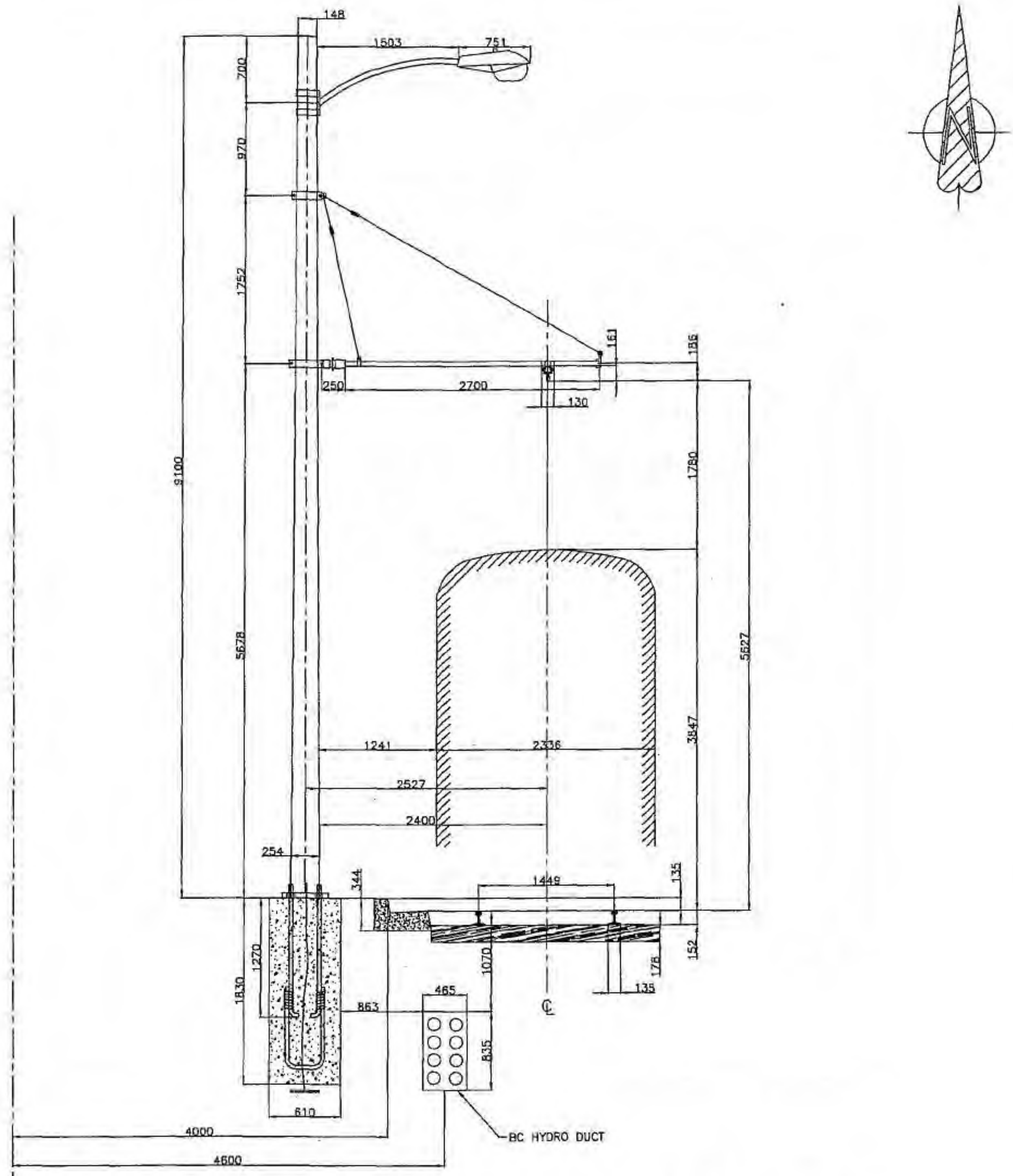
0 5 10
CHECK SCALE FEET

BCER/D.H.R. ST. LOUIS 1231

GENERAL ARRANGEMENT

Dwn: D.E.Reuss July1,1999	Data: BILL BAILEY
Scale: 3/16" = 1'-0"	Dwg: BCER1231 P.16

3



TROLLEY COMBINATION STEEL POLE A7E ELEVATION DETAIL

POLE #95 W/S OF QUEBEC AT TERMINAL

NO.	REVISION	BY	DATE

CITY OF VANCOUVER – ENGINEERING SERVICES

DIV./BR. STREET LIGHTING		PROPOSED POLE LOCATION ADJACENT BC HYDRO DUCT	SCALE: NTS
DATE: MAR 02	DESIGN: –		DIRECTORY: H:stre\s–387
DWG: AY	CHK: CH	REF: BC HYDRO DWG: #455-U07-D802, 8–5" DUCTS SECTION	DWG. NO. JJE–402
REFS: SEE TITLE			SHEET 1 OF 1 REVISION:......

THIS PRINT SUPERSEDES ALL PRINTS OF THIS DRAWING BEARING PREVIOUS REVISION NUMBERS

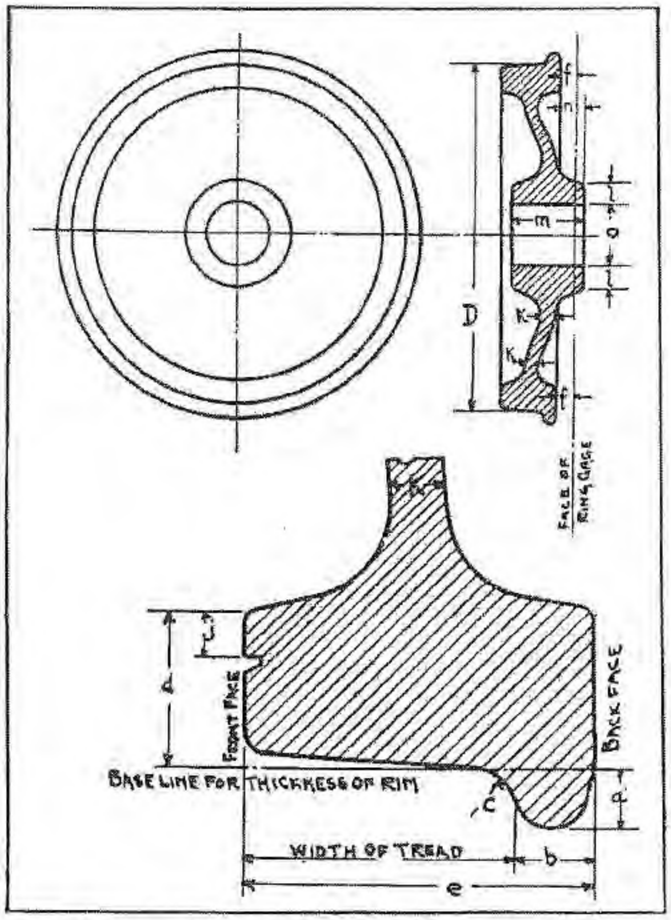


FIG. 1—DIAGRAM SHOWING POINTS AT WHICH THE DIMENSIONS COVERED BY SPECIFICATIONS ARE MEASURED. FOR THE PERMISSIBLE VARIATIONS IN THESE DIMENSIONS SEE TABLE 1 AND PAR. 401 OF MANUAL SECTION E7.

Note.—The letter used for each dimension in this figure is the same as that in Table 1 and par. 401 on permissible variations covering that dimension in Manual Section E7.

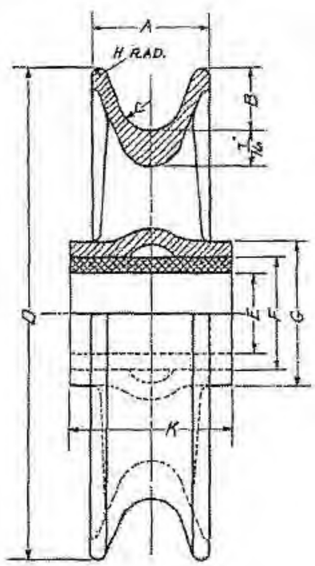


TABLE OF PRINCIPAL DIMENSIONS
(ALL FIGURES IN INCHES)

A	B	C	D	E	F	G	H	K
1 7/16	3/4	3/8	4 1/4	5/8	1 1/8	1 1/2	3/32	1 1/2
1 7/16	3/4	3/8	5	3/4	1 1/8	1 1/2	3/32	1 1/2
1 9/16	3/4	5/8	6	1	1 3/8	1 3/4	3/32	1 1/2 & 2

FIG. 4—RECOMMENDED DESIGNS OF TROLLEY WHEELS OF 4¼ IN., 5 IN., AND 6 IN. DIAMETER

Advantages of Large Wheel. Following are some of the advantages of the large wheel: It affords greater mileage between turnings, gives lower journal surface speed with consequently less wear and axle steel fatiguing stresses per car mile, causes smaller stresses to be set up in wheel and rail surfaces, strikes lighter blows on the track and is less likely to give trouble at a defective frog, switch point or rail. A large wheel makes possible the use of a large gear and maximum gear reduction with a corresponding high motor speed which permits the use of a comparatively small light weight motor and necessitates the least energy consumption. Special installations may be such that the above advantages would be inferior to the advantages accompanying the use of small wheels. Thus, the satisfactory design of many low floor cars has demanded wheels of small diameter.

Truck Wheel Base. The use of 4 ft. wheel base trucks for purely city service is desirable only by reason of the ease with which they may be operated over short radius curves. The inside hung motor truck of an approximate 6 ft. wheel base is superior to outside hung motor trucks of short wheel base for the following reasons: the lesser displacement of tractive effort between the two pairs of wheels during acceleration and braking; greater factor of strength on account of the location of motor suspension in close proximity to the center of truck; less wheel flange pressures against rail heads required to swivel trucks on curves, and also occurring during "nosing" periods; and easier riding qualities. There is a less liability to derail, less flange wear, less tendency to cause rail corrugations, less wear on track, and less maintenance, with the long wheel base truck. Interurban service uses the long wheel base truck, which is best for high speed operation. In a paper before the Central Electric Railway Association, A. C. Vauclain of the Baldwin Locomotive Works stated that the final determination of the wheel base should, if curves permit, be based entirely upon the transom width being sufficient to allow a proper width of bolster and bolster springs, and the fixed length of the motors measured from their axle journals to their supporting noses.

Minimum Curve for Given Truck. Fig. 27 by Graham Bright, *Electric Journal*, 1911, shows the relation between wheel size, wheel base and minimum curve. These curves are plotted according to the expression

$$R = \frac{W}{2 \sin a}$$ (published by the Baldwin Locomotive Works)

in which R = radius of sharpest curve that can be passed, feet.
W = wheel base, feet.
a = angle which flanged wheels make with rail

With diameter of wheel	20 in.	to 24 in	$\sin a = 0.117$
	25	30	= 0.107
	31	40	= 0.090
	41	50	= 0.080
	51	60	= 0.075

Ball Bearing Center Plates. The principal advantages of ball bearing center plates over smooth plate bearings are that their use is accompanied by a minimum of flange wear and energy consumption on curves. They bring about less liability to derailment and require less lubrication.

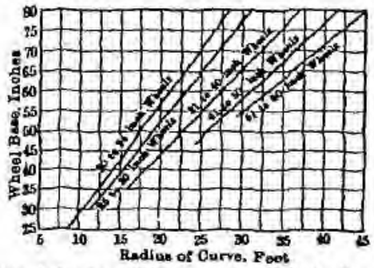
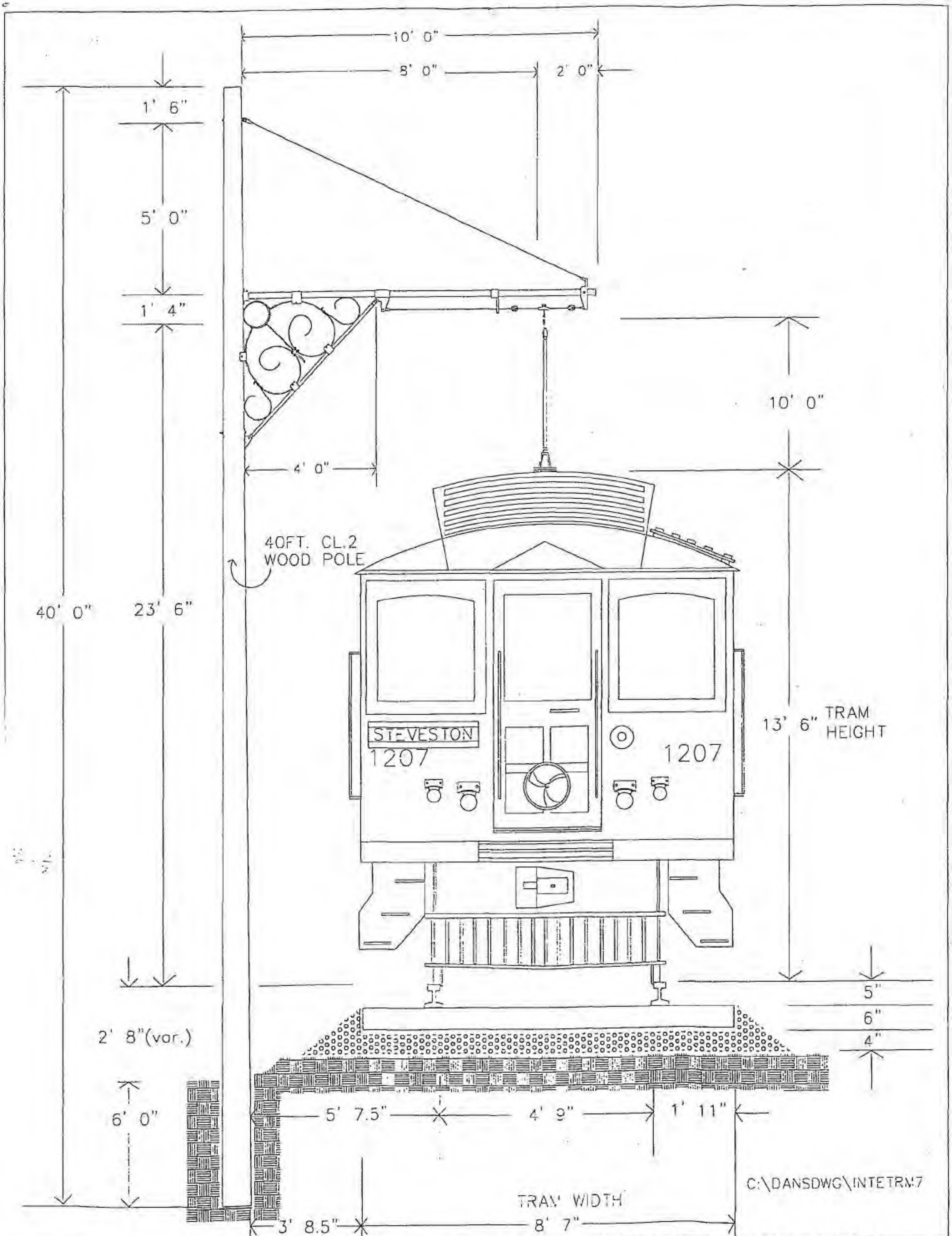


FIG. 27.—Relation between minimum curve, wheel diameter and truck wheel base.


10' 0"
8' 0"
2' 0"
1' 6"
5' 0"
1' 4"
10' 0"
4' 0"
40FT. CL.2
WOOD POLE
40' 0"
23' 6"
STEVESTON
1207
1207
13' 6" TRAM
HEIGHT
5"
6"
4"
2' 8"(var.)
6' 0"
5' 7.5"
4' 9"
1' 11"
C:\DANSDWG\INTETRM7
TRAM WIDTH
3' 8.5"
8' 7"

Appendix B DHR DKE Calculations

Project
Vancouver Streetcar

Calculations for
DHR Vehicle 1207

Mott MacDonald

Divn/Dept	HMM-VAN	Job Nr/File Nr	237388	/	4.1.1
Calculated By	TRMS	Date	2007/10/12	Sheet Nr	
Checked By	DSW	Date	2007/10/13	of	

Track Details

Effective gauge (mm) = 1502
Clearance between rail and wheel flange (excluding tolerances) (mm) = 5

Tram Details

Distance between bogie king pin centres (mm) = 8261
Bogie axle spacing (mm) = 1981
Lateral primary suspension deflection (mm) = 10
Lateral secondary suspension deflection (mm) = 60
Lateral wheel suspension deflection (mm) = 5
Height of body roll centre above top of rail (mm) = 420
Body roll angle - Normal Operating Conditions (degrees) = 3.0
Body roll angle - Failed Suspension (degrees) = 4

Construction and Maintenance Tolerances

Tolerance on lateral tram body dimensions (mm) = 50
Maximum lateral deviation from designed horizontal track position (mm) = 10
Maximum rate of change of lateral deviation from designed horizontal track position (mm / m) = 3
Deviation from designed applied cant (mm) = 6
Lateral wheel flange wear (mm) = 8
Lateral rail wear (mm) = 13

Specification of DKE Calculation Points

Point reference	Longitudinal distance from centre bogie c/l to calculation point (mm)	Width of tram at calculation point (mm)	Height of calculation point above top of rail (mm)	Point description
P1	11786	0	1270	Front of tram at CL excluding coupler
P2	11074	2617	1270	Start of nose curve
P3	11074	2617	3442	Roof line at start of nose curve
P4	10784	2770	1688	Door Handle and roof steps
P5	8230	2617	3442	Roof line at CL front bogie
P6	4115	2617	3442	Roof line at CL vehicle
P7				
P8				
P9				
P10				
P11				
P12				
P13				
P14				
P15				
P16				
P17				
P18				
P19				
P20				

Project	Vancouver Streetcar
Calculations for	DHR Vehicle 1207

Mott MacDonald

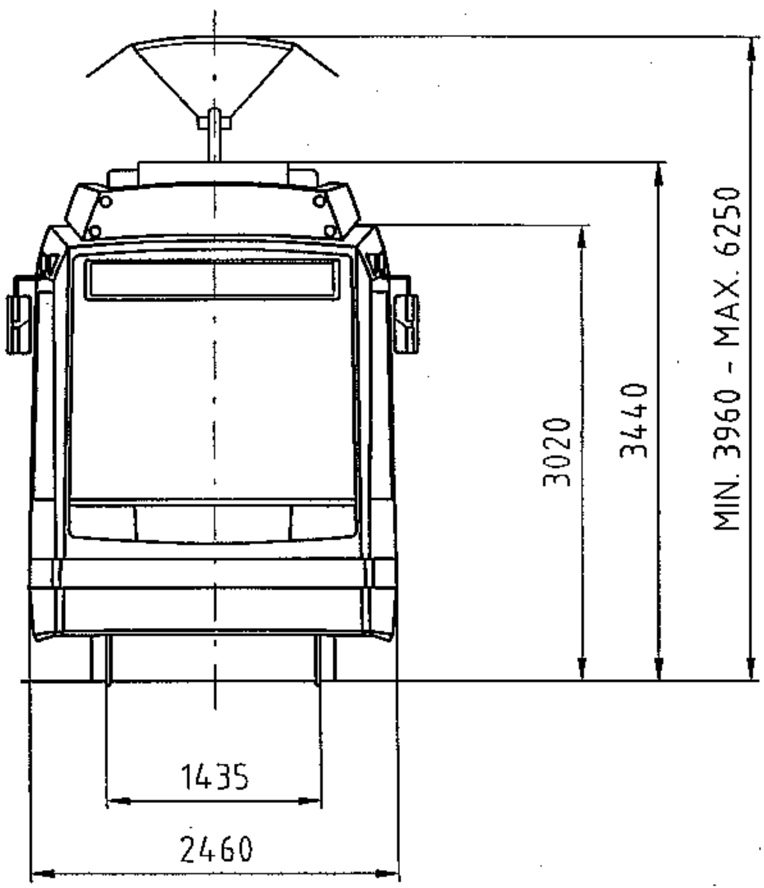
Divn/Dept	HMM-VAN	JobNr/FileNr	237388	/	4.1.1
Calculated By	TRMS	Date	2007/10/12	Sheet Nr	
Checked By		Date		of	

Track Geometry		Envelope ignoring tolerances etc.					DKE - Normal Operating Conditions							DKE - Credible Degraded Mode (Failed Suspension)						
		End Throw		Centre Throw		Overall	End Throw			Centre Throw			Overall	End Throw			Centre Throw			Overall
Track C/L radius (m)	Applied cant (mm)	Offset to track C/L (m)	Critical Point	Offset to track C/L (mm)	Critical Point	Width (m)	Offset to track C/L (m)	Critical Point	Extra over envelope ignoring tolerances etc. (mm)	Offset to track C/L (mm)	Critical Point	Extra over envelope ignoring tolerances etc. (mm)	Width (m)	Offset to track C/L (m)	Critical Point	Extra over DKE - Normal Operating Conditions (mm)	Offset to track C/L (mm)	Critical Point	Extra over DKE - Normal Operating Conditions (mm)	Width (m)
47.5	**25**	1.645	P4	1.557	P6	3.202	2.010	P3	366	1.891	P6	334	3.901	2.063	P3	53	1.943	P6	53	4.007
25	25	1.855	P4	1.731	P6	3.586	2.248	P3	394	2.066	P6	335	4.314	2.301	P3	53	2.119	P6	53	4.420
30	25	1.783	P4	1.669	P6	3.453	2.168	P3	384	2.004	P6	334	4.171	2.220	P3	53	2.057	P6	53	4.277
35	25	1.731	P4	1.626	P6	3.357	2.108	P3	377	1.960	P6	334	4.067	2.161	P3	53	2.013	P6	53	4.173
40	25	1.691	P4	1.593	P6	3.284	2.062	P3	372	1.927	P6	334	3.989	2.115	P3	53	1.980	P6	53	4.095
45	25	1.659	P4	1.568	P6	3.226	2.026	P3	367	1.901	P6	334	3.927	2.079	P3	53	1.954	P6	53	4.033
50	25	1.633	P4	1.547	P6	3.180	1.996	P3	364	1.881	P6	334	3.877	2.049	P3	53	1.934	P6	53	3.983
55	25	1.611	P4	1.531	P6	3.142	1.972	P3	361	1.864	P6	333	3.836	2.025	P3	53	1.917	P6	53	3.942
60	25	1.593	P4	1.517	P6	3.110	1.952	P3	359	1.850	P6	333	3.802	2.005	P3	53	1.903	P6	53	3.908
65	25	1.578	P4	1.505	P6	3.083	1.934	P3	357	1.839	P6	333	3.773	1.987	P3	53	1.892	P6	53	3.879
70	25	1.564	P4	1.495	P6	3.060	1.919	P3	355	1.829	P6	333	3.748	1.972	P3	53	1.882	P6	53	3.854
75	25	1.553	P4	1.487	P6	3.040	1.906	P3	353	1.820	P6	333	3.726	1.959	P3	53	1.873	P6	53	3.832
80	25	1.543	P4	1.479	P6	3.022	1.895	P3	352	1.812	P6	333	3.707	1.948	P3	53	1.865	P6	53	3.813
85	25	1.534	P4	1.472	P6	3.006	1.884	P3	351	1.806	P6	333	3.690	1.937	P3	53	1.859	P6	53	3.796
90	25	1.526	P4	1.467	P6	2.992	1.875	P3	350	1.800	P6	333	3.675	1.928	P3	53	1.853	P6	53	3.781
95	25	1.518	P4	1.461	P6	2.980	1.867	P3	349	1.794	P6	333	3.662	1.920	P3	53	1.847	P6	53	3.768
100	25	1.512	P4	1.456	P6	2.968	1.860	P3	348	1.790	P6	333	3.649	1.913	P3	53	1.843	P6	53	3.755
110	25	1.501	P4	1.448	P6	2.949	1.847	P3	346	1.781	P6	333	3.628	1.900	P3	53	1.834	P6	53	3.734
120	25	1.491	P4	1.441	P6	2.933	1.836	P3	345	1.775	P6	333	3.611	1.889	P3	53	1.827	P6	53	3.717
130	25	1.483	P4	1.436	P6	2.919	1.827	P3	344	1.769	P6	333	3.596	1.880	P3	53	1.822	P6	53	3.702
140	25	1.476	P4	1.431	P6	2.907	1.819	P3	343	1.764	P6	333	3.583	1.872	P3	53	1.817	P6	53	3.689
150	25	1.470	P4	1.426	P6	2.897	1.813	P3	342	1.759	P6	333	3.572	1.866	P3	53	1.812	P6	53	3.678
160	25	1.465	P4	1.422	P6	2.888	1.807	P3	342	1.756	P6	333	3.562	1.860	P3	53	1.809	P6	53	3.668
170	25	1.460	P4	1.419	P6	2.880	1.801	P3	341	1.752	P6	333	3.554	1.854	P3	53	1.805	P6	53	3.660
180	25	1.456	P4	1.416	P6	2.872	1.797	P3	340	1.749	P6	333	3.546	1.850	P3	53	1.802	P6	53	3.652
190	25	1.453	P4	1.413	P6	2.866	1.793	P3	340	1.747	P6	333	3.539	1.846	P3	53	1.800	P6	53	3.645
200	25	1.449	P4	1.411	P6	2.860	1.789	P3	340	1.744	P6	333	3.533	1.842	P3	53	1.797	P6	53	3.639
250	25	1.437	P4	1.402	P6	2.839	1.774	P3	338	1.735	P6	333	3.510	1.827	P3	53	1.788	P6	53	3.615
300	25	1.428	P4	1.396	P6	2.824	1.765	P3	337	1.729	P6	333	3.494	1.818	P3	53	1.782	P6	53	3.600
350	25	1.422	P4	1.392	P6	2.814	1.758	P3	336	1.731	P3	339	3.489	1.811	P3	53	1.784	P3	53	3.595
400	25	1.417	P4	1.388	P6	2.806	1.753	P3	335	1.736	P3	348	3.489	1.806	P3	53	1.789	P3	53	3.595
450	25	1.414	P4	1.386	P6	2.800	1.749	P3	335	1.740	P3	355	3.489	1.802	P3	53	1.793	P3	53	3.595
500	25	1.411	P4	1.387	P4	2.798	1.745	P3	334	1.744	P3	357	3.489	1.798	P3	53	1.797	P3	53	3.595
600	25	1.407	P4	1.391	P4	2.798	1.740	P3	334	1.749	P3	357	3.489	1.793	P3	53	1.802	P3	53	3.595
700	25	1.404	P4	1.394	P4	2.798	1.737	P3	333	1.752	P3	358	3.489	1.790	P3	53	1.805	P3	53	3.595
800	25	1.401	P4	1.397	P4	2.798	1.734	P3	333	1.755	P3	358	3.489	1.787	P3	53	1.808	P3	53	3.595
900	25	1.399	P4	1.399	P4	2.798	1.732	P3	333	1.757	P3	358	3.489	1.785	P3	53	1.810	P3	53	3.595
1000	25	1.398	P4	1.400	P4	2.798	1.731	P3	333	1.759	P3	359	3.489	1.784	P3	53	1.812	P3	53	3.595
1500	25	1.394	P4	1.404	P4	2.798	1.726	P3	332	1.763	P3	359	3.489	1.779	P3	53	1.816	P3	53	3.595
2000	25	1.391	P4	1.407	P4	2.798	1.723	P3	332	1.766	P3	359	3.489	1.776	P3	53	1.819	P3	53	3.595
2500	25	1.390	P4	1.408	P4	2.798	1.722	P3	332	1.767	P3	360	3.489	1.775	P3	53	1.820	P3	53	3.595
3000	25	1.389	P4	1.409	P4	2.798	1.721	P3	332	1.768	P3	360	3.489	1.774	P3	53	1.821	P3	53	3.595
3500	25	1.389	P4	1.409	P4	2.798	1.720	P3	332	1.769	P3	360	3.489	1.773	P3	53	1.822	P3	53	3.595
4000	25	1.388	P4	1.410	P4	2.798	1.720	P3	331	1.770	P3	360	3.489	1.773	P3	53	1.823	P3	53	3.595
4500	25	1.388	P4	1.410	P4	2.798	1.719	P3	331	1.770	P3	360	3.489	1.772	P3	53	1.823	P3	53	3.595
5000	25	1.388	P4	1.410	P4	2.798	1.719	P3	331	1.770	P3	360	3.489	1.772	P3	53	1.823	P3	53	3.595
9999999	25	1.385	P4	1.413	P4	2.798	1.716	P3	331	1.773	P3	360	3.489	1.769	P3	53	1.826	P3	53	3.595

Appendix C   Modern Streetcar DKE Calculations

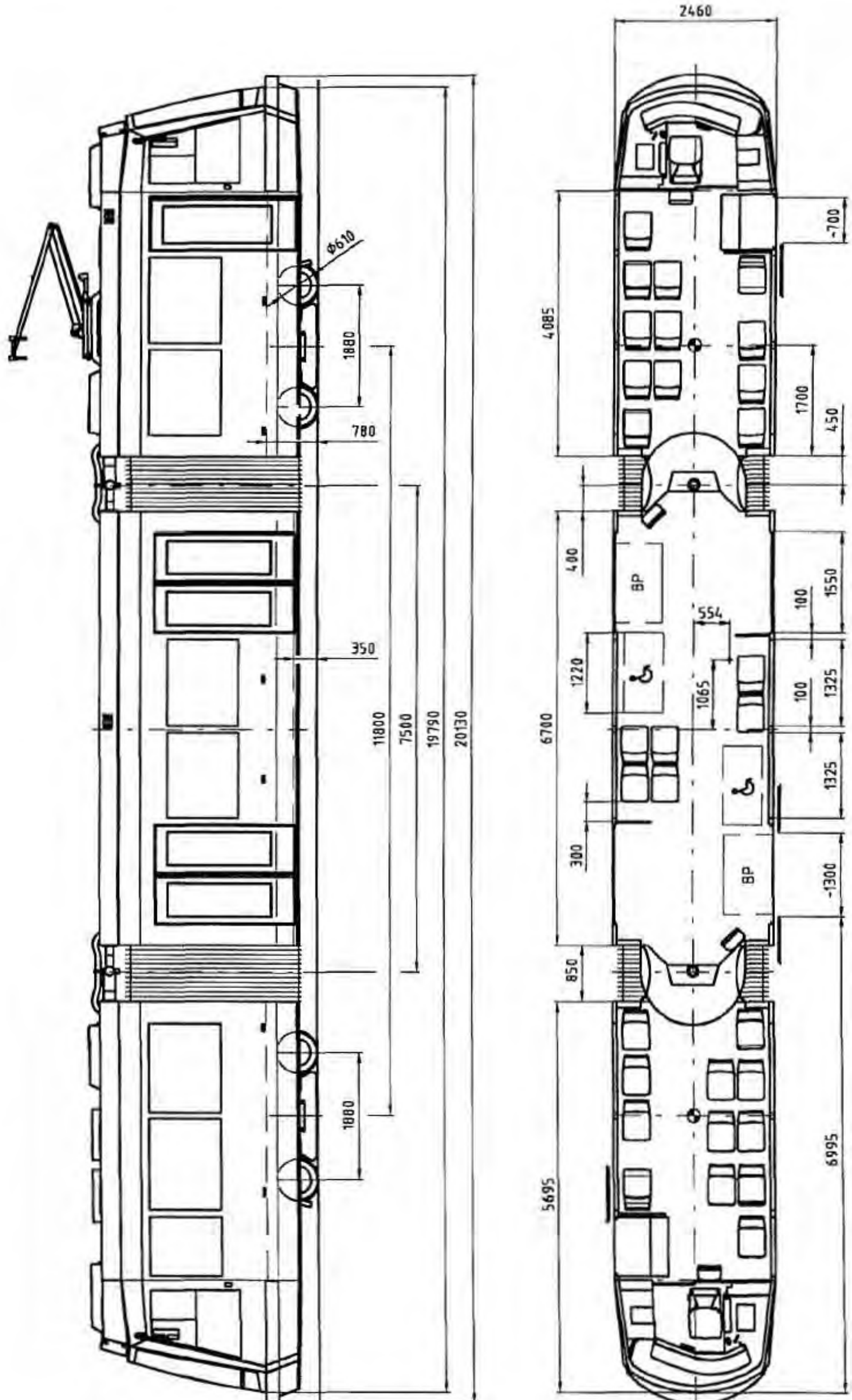
ŠKODA

Layout and Curve Offsets
Typový náčrtek a přesahy tramvajového vozidla



ŠKODA

Layout and Curve Offsets
Typový náčrtek a přesahy tramvajového vozidla



Total pages:28

Page No.1

VEHICLE DYNAMIC ENVELOPE CLEARANCE PROGRAM - HORIZONTAL OFFSETS & DISPLACEMENTS

DATA INPUT — ZADANÉ HODNOTY

	Front End Truck Axel Spacing	1 880	[mm]	- rozvor předního podvozku
	Back End Truck Axel Spacing	1 880	[mm]	- rozvor zadního podvozku
L1	- Pivot Centers Length	7 500	[mm]	- vzdálenost otočných kloubů skříně
L1A	- Articulation Centers	2 150	[mm]	- vzdálenost otočných kloubů skříně od osy podvozku
L2	- Body Corner Length	2 385	[mm]	- vzdálenost zlomu skříně
L3	- Front End Length	3 810	[mm]	- rozvor podvozku (pro potřeby výpočtu)
L4	- Mirror Length	3 155	[mm]	- vzdálenost zrcátek
L5	- Roof Eguipment Length	2 385	[mm]	- vzdálenost střešní nadstavby
L6	- Roof Shroud	2 385	[mm]	- nosná střecha
W2	- Body Corner Width	2 460	[mm]	- šířka zlomu skříně
W3	- Front End Width	2 176	[mm]	- šířka čela
W4	- Mirror Width	2 830	[mm]	- šířka zrcátek
W5	- Roof Eguipment Width	2 009	[mm]	- šířka střešní nadstavby
W6	- Roof Shroud	2 180	[mm]	- nosná střecha
	Pantograph Sway	76	[mm]	- boční výkyv pantografu (celkem)

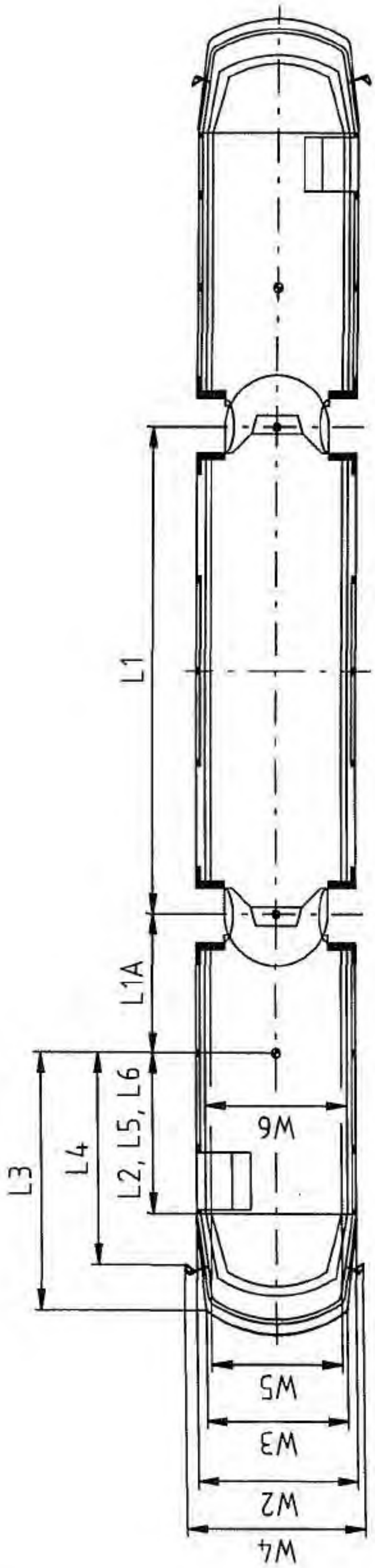
LATERAL MOTION — PŘÍČNÉ POSUVY

Wheel flange wear	8	[mm]	- opotřebení okolku
Rail wear	16	[mm]	- opotřebení kolejnice
Rail gauge tolerance (half)	3	[mm]	- tolerance rozchodu koleje (polovina)
Wheel gauge tolerance (half)	2	[mm]	- tolerance rozchodu dvojkolí (polovina)
Nominal sideplay	19	[mm]	- jmenovitá vůle (polovina)
Lateral suspension motion	20	[mm]	- příčný posuv vypružení
Total	68	[mm]	

SKEW — VYBOČENÍ

	Lateral motion	68	[mm]	- příčný posuv
D2	- Body Corner Skew	68	[mm]	- vybočení zlomu skříně
D3	- Front End Skew	68	[mm]	- vybočení čela
D4	- Mirror Skew	68	[mm]	- vybočení zrcátek
D5	- Roof Eguipment Skew	68	[mm]	- vybočení střešní nadstavby
D6	- Roof Shroud	68	[mm]	- oplechování střechy

ŠKODA	Layout and Curve Offsets Typový náčrtek a přesahy tramvajového vozila	



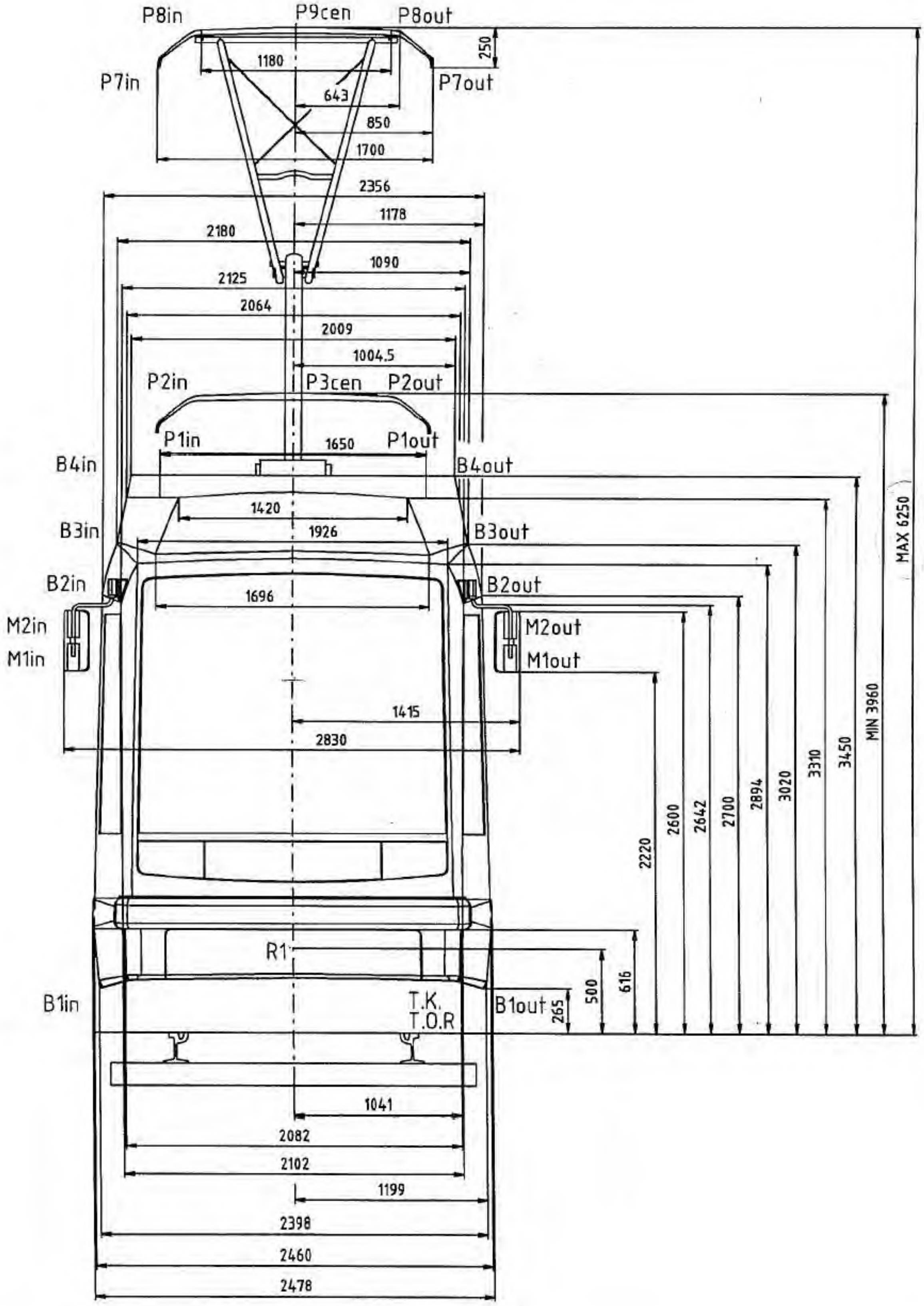
HORIZONTAL OFFSETS & DISPLACEMENTS

Radius [mm]	d1 F End Truck	d2 B End Truck	d3 Center	d Mid	D1	D15	D16	Body Corner		Front End		Mirror		Roof Equip		Roof Shroud	
								D2in	D2out	D3in	D3out	D4in	D4out	D5in	D5out	D6in	D6out
20 000	22,1	22,1	93,3	259,8	1 557,8	1 332,3	1 417,8	1 169	1 409,6	797,7	1 475,7	1 238,9	1 692,3	945,3	1 185,5	1 030,1	1 270,5
25 000	17,7	17,7	74,7	207,3	1 505,3	1 279,8	1 365,3	1 196,2	1 388,6	871,8	1 415,3	1 290,4	1 653,2	971,9	1 164	1 056,9	1 249,2
30 000	14,7	14,7	62,3	172,6	1 470,6	1 245,1	1 330,6	1 214	1 374,2	920,6	1 374	1 324,1	1 626,4	989,3	1 149,4	1 074,5	1 234,7
35 000	12,6	12,6	53,4	147,8	1 445,8	1 220,3	1 305,8	1 226,5	1 363,8	955,2	1 344	1 347,7	1 606,8	1 001,5	1 138,8	1 086,8	1 224,1
40 000	11	11	46,7	129,3	1 427,3	1 201,8	1 287,3	1 235,7	1 355,9	980,9	1 321,3	1 365,2	1 592	1 010,7	1 130,8	1 096	1 216,1
45 000	9,8	9,8	41,5	114,9	1 412,9	1 187,4	1 272,9	1 242,9	1 349,7	1 000,8	1 303,4	1 378,8	1 580,3	1 017,7	1 124,5	1 103,1	1 209,9
50 000	8,8	8,8	37,4	103,3	1 401,3	1 175,8	1 261,3	1 248,5	1 344,7	1 016,6	1 289,1	1 389,5	1 570,9	1 023,3	1 119,4	1 108,7	1 204,8
75 000	5,9	5,9	24,9	68,9	1 366,9	1 141,4	1 226,9	1 265,3	1 329,4	1 063,7	1 245,4	1 421,3	1 542,2	1 040	1 104	1 125,4	1 189,5
100 000	4,4	4,4	18,7	51,6	1 349,6	1 124,1	1 209,6	1 273,6	1 321,7	1 087,1	1 223,4	1 436,9	1 527,6	1 048,2	1 096,2	1 133,7	1 181,7
150 000	2,9	2,9	12,5	34,4	1 332,4	1 106,9	1 192,4	1 281,8	1 313,9	1 110,2	1 201,1	1 452,5	1 512,9	1 056,4	1 088,4	1 141,8	1 173,9
200 000	2,2	2,2	9,3	25,8	1 323,8	1 098,3	1 183,8	1 285,9	1 309,9	1 121,7	1 189,9	1 460,1	1 505,5	1 060,4	1 084,4	1 145,9	1 169,9
250 000	1,8	1,8	7,5	20,6	1 318,6	1 093,1	1 178,6	1 288,3	1 307,6	1 128,6	1 183,1	1 464,7	1 501	1 062,8	1 082,1	1 148,3	1 167,6
400 000	1,1	1,1	4,7	12,9	1 310,9	1 085,4	1 170,9	1 292	1 304	1 138,9	1 173	1 471,6	1 494,3	1 066,5	1 078,5	1 152	1 164
600 000	0,7	0,7	3,1	8,6	1 306,6	1 081,1	1 166,6	1 294	1 302	1 144,6	1 167,3	1 475,4	1 490,5	1 068,5	1 076,5	1 154	1 162
800 000	0,6	0,6	2,3	6,5	1 304,5	1 079	1 164,5	1 295	1 301	1 147,5	1 164,5	1 477,3	1 488,7	1 069,5	1 075,5	1 155	1 161
1 000 000	0,4	0,4	1,9	5,2	1 303,2	1 077,7	1 163,2	1 295,6	1 300,4	1 149,2	1 162,8	1 478,5	1 487,5	1 070,1	1 074,9	1 155,6	1 160,4
2 500 000	0,2	0,2	0,7	2,1	1 300,1	1 074,6	1 160,1	1 297	1 299	1 153,3	1 158,7	1 481,2	1 484,8	1 071,5	1 073,5	1 157	1 159
5 000 000	0,1	0,1	0,4	1	1 299	1 073,5	1 159	1 297,5	1 298,5	1 154,6	1 157,4	1 482,1	1 483,9	1 072	1 073	1 157,5	1 158,5
Tangent	0	0	0	0	1 298	1 072,5	1 158	1 298	1 298	1 156	1 156	1 483	1 483	1 072,5	1 072,5	1 158	1 158

HORIZONTAL OFFSETS & DISPLACEMENTS

Radius [mm]	MAXin	MAXout	MAXin Mirror	MAXout Mirror	MAXin Roof Equip	MAXout Roof Equip	MAXin Roof Shroud	MAXout Roof Shroud
20 000	-1 557,8	1 475,7	-1 557,8	1 692,3	-1 332,3	1 185,5	-1 417,8	1 270,5
25 000	-1 505,3	1 415,3	-1 505,3	1 653,2	-1 279,8	1 164	-1 365,3	1 249,2
30 000	-1 470,6	1 374,2	-1 470,6	1 626,4	-1 245,1	1 149,4	-1 330,6	1 234,7
35 000	-1 445,8	1 363,8	-1 445,8	1 606,8	-1 220,3	1 138,8	-1 305,8	1 224,1
40 000	-1 427,3	1 355,9	-1 427,3	1 592	-1 201,8	1 130,8	-1 287,3	1 216,1
45 000	-1 412,9	1 349,7	-1 412,9	1 580,3	-1 187,4	1 124,5	-1 272,9	1 209,9
50 000	-1 401,3	1 344,7	-1 401,3	1 570,9	-1 175,8	1 119,4	-1 261,3	1 204,8
75 000	-1 366,9	1 329,4	-1 421,3	1 542,2	-1 141,4	1 104	-1 226,9	1 189,5
100 000	-1 349,6	1 321,7	-1 436,9	1 527,6	-1 124,1	1 096,2	-1 209,6	1 181,7
150 000	-1 332,4	1 313,9	-1 452,5	1 512,9	-1 106,9	1 088,4	-1 192,4	1 173,9
200 000	-1 323,8	1 309,9	-1 460,1	1 505,5	-1 098,3	1 084,4	-1 183,8	1 169,9
250 000	-1 318,6	1 307,6	-1 464,7	1 501	-1 093,1	1 082,1	-1 178,6	1 167,6
400 000	-1 310,9	1 304	-1 471,6	1 494,3	-1 085,4	1 078,5	-1 170,9	1 164
600 000	-1 306,6	1 302	-1 475,4	1 490,5	-1 081,1	1 076,5	-1 166,6	1 162
800 000	-1 304,5	1 301	-1 477,3	1 488,7	-1 079	1 075,5	-1 164,5	1 161
1 000 000	-1 303,2	1 300,4	-1 478,5	1 487,5	-1 077,7	1 074,9	-1 163,2	1 160,4
2 500 000	-1 300,1	1 299	-1 481,2	1 484,8	-1 074,6	1 073,5	-1 160,1	1 159
5 000 000	-1 299	1 298,5	-1 482,1	1 483,9	-1 073,5	1 073	-1 159	1 158,5
Tangent	-1 298	1 298	-1 483	1 483	-1 072,5	1 072,5	-1 158	1 158

ŠKODA	**Layout and Curve Offsets** **Typový náčrtek a přesahy tramvajového vozila**	



STATIC LRV ROLL CENTER

	X	Y
	mm	mm
R1	0	500

STATIC LRV BODY POINTS

	X	Y			X	Y
	mm	mm			mm	mm
B1out	1 199	265		B1in	-1 199	265
B2out	1 178	2 700		B2in	-1 178	2 700
B3out	1 090	3 020		B3in	-1 090	3 020
B4out	1 004,5	3 450		B4in	-1 004,5	3 450

STATIC LRV MIRRORS POINTS

	X	Y			X	Y
	mm	mm			mm	mm
M1out	1 415	2 200		M1in	-1 415	2 200
M2out	1 415	2 600		M2in	-1 415	2 600

STATIC LRV PANTOGRAPH POINTS

	X	Y			X	Y
	mm	mm			mm	mm
P1out	850	3 710		P1in	-850	3 710
P2out	643	3 960		P2in	-643	3 960
P3cen	0	3 960				
P4out	850	4 855		P4in	-850	4 855
P5out	643	5 105		P5in	-643	5 105
P6cen	0	5 105				
P7out	850	6 000		P7in	-850	6 000
P8out	643	6 250		P8in	-643	6 250
P9cen	0	6 250				

SUPERELEVATION & CROSS LEVEL FOR EACH TABLE

Table Number	Super Elevation	Cross Level		Table Number	Super Elevation	Cross Level
1	0	0		4	0	21,5
2	0	7,2		5	0	28,7 2%
3	0	14,4				

Track Gauge:	1 435	mm	Rol Angle:	3	Degrees
Rail Head Width	69	mm	Mirror Roll Angle:	3	Degrees

ŠKODA

Layout and Curve Offsets

Typový náčrtek a přesahy tramvajového vozidla

TABLE 5A - VEHICLE DYNAMIC ENVELOPE - OUTSIDE OF CURVE

Cross Level Variation = 28,7 mm (2,0% Slope)

Superelevation = 0,0 mm

Radius	R1 CEN		B1 OUT		M1 OUT		M2 OUT		B2 OUT		B3 OUT		B4 OUT	
[m]	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
20	-9,7	514,3	1 492,2	160,3	1 819,4	2 074,9	1 847,9	2 715,2	1 639	2 798,4	1 456,9	3 109,1	1 402,9	3 531,9
25	-9,7	514,3	1 431,8	161,5	1 780,3	2 075,7	1 808,8	2 714,4	1 578,6	2 797,3	1 435,6	3 108,7	1 381,4	3 531,5
30	-9,7	514,3	1 390,8	162,2	1 753,5	2 076,2	1 782	2 713,9	1 537,6	2 796,5	1 421,1	3 108,4	1 366,8	3 531,4
35	-9,7	514,3	1 380,3	162,4	1 733,9	2 076,6	1 762,5	2 713,6	1 527,2	2 796,3	1 410,6	3 108,2	1 356,2	3 531,4
40	-9,7	514,3	1 372,4	162,6	1 719,1	2 076,8	1 747,6	2 713,3	1 519,3	2 796,1	1 402,6	3 108,2	1 348,2	3 531,4
45	-9,7	514,3	1 366,2	162,7	1 707,4	2 077,1	1 736	2 713,1	1 513,1	2 796	1 396,3	3 108,2	1 341,9	3 531,4
50	-9,7	514,3	1 361,2	162,8	1 698	2 077,2	1 726,6	2 712,9	1 508,1	2 795,9	1 391,3	3 108,2	1 336,8	3 531,4
75	-9,7	514,3	1 345,9	163,1	1 669,3	2 077,8	1 697,9	2 712,3	1 492,8	2 795,6	1 376	3 108,2	1 321,4	3 531,4
100	-9,7	514,3	1 338,2	163,2	1 654,8	2 078,1	1 683,3	2 712,1	1 485,1	2 795,5	1 368,2	3 108,2	1 313,6	3 531,4
150	-9,7	514,3	1 330,4	163,4	1 640	2 078,4	1 668,6	2 712	1 477,3	2 795,3	1 360,4	3 108,2	1 305,8	3 531,4
200	-9,7	514,3	1 326,5	163,5	1 632,6	2 078,5	1 661,2	2 712	1 473,3	2 795,2	1 356,4	3 108,2	1 301,8	3 531,4
250	-9,7	514,3	1 324,1	163,5	1 628,2	2 078,6	1 656,7	2 712	1 471	2 795,2	1 354	3 108,2	1 299,5	3 531,4
400	-9,7	514,3	1 320,5	163,6	1 621,4	2 078,7	1 650	2 712	1 467,4	2 795,1	1 350,5	3 108,2	1 295,9	3 531,4
600	-9,7	514,3	1 318,5	163,6	1 617,7	2 078,8	1 646,2	2 712	1 465,4	2 795,1	1 348,5	3 108,2	1 293,9	3 531,4
800	-9,7	514,3	1 317,5	163,6	1 615,8	2 078,8	1 644,3	2 712	1 464,4	2 795,1	1 347,5	3 108,2	1 292,9	3 531,4
1 000	-9,7	514,3	1 316,9	163,6	1 614,7	2 078,8	1 643,2	2 712	1 463,8	2 795,1	1 346,9	3 108,2	1 292,3	3 531,4
2 500	-9,7	514,3	1 315,5	163,7	1 611,9	2 078,9	1 640,5	2 712	1 462,4	2 795	1 345,4	3 108,2	1 290,9	3 531,4
5 000	-9,7	514,3	1 315	163,7	1 611	2 078,9	1 639,6	2 712	1 461,9	2 795	1 345	3 108,2	1 290,4	3 531,4
Tangent	-9,7	514,3	1 314,5	163,7	1 610,1	2 078,9	1 638,7	2 712	1 461,4	2 795	1 344,5	3 108,2	1 289,9	3 531,4

TABLE 5A - VEHICLE DYNAMIC ENVELOPE - OUTSIDE OF CURVE

Cross Level Variation = 28,7 mm (2,0% Slope)
Superelevation = 0,0 mm

Radius	P3 CEN		P1 OUT		P2 OUT		P4 OUT		P5 OUT		P7 OUT		P8 OUT	
[m]	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
20	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
25	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
30	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
35	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
40	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
45	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
50	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
75	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
100	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
150	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
200	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
250	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
400	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
600	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
800	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
1 000	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
2 500	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
5 000	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5
Tangent	-362,6	3 973,6	1 192,3	3 778,8	1 003,7	4 013,4	1 274,1	4 920,8	1 085,4	5 155,4	1 355,8	6 062,9	1 167,2	6 297,5

TABLE 5B - VEHICLE DYNAMIC ENVELOPE - INSIDE OF CURVE

Cross Level Variation = 28,7 mm (2,0% Slope)
Superelevation = 0,0 mm

Radius	P6 CEN		B1 IN		M1 IN		M2 IN		B2 IN		B3 IN		B4 IN	
[m]	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
20	-434,5	5 118,4	-1 574,3	158,7	-1 684,9	2 077,5	-1 713,4	2 712,6	-1 721,1	2 800	-1 604,2	3 111,9	-1 549,6	3 534,7
25	-434,5	5 118,4	-1 521,8	159,7	-1 632,5	2 078,5	-1 661	2 711,6	-1 668,7	2 799	-1 551,8	3 110,9	-1 497,2	3 533,7
30	-434,5	5 118,4	-1 487,1	160,4	-1 597,7	2 079,2	-1 626,2	2 711	-1 633,9	2 798,3	-1 517	3 110,2	-1 462,4	3 533
35	-434,5	5 118,4	-1 462,3	160,9	-1 572,9	2 079,6	-1 601,5	2 710,5	-1 609,2	2 797,8	-1 492,3	3 109,7	-1 437,7	3 532,5
40	-434,5	5 118,4	-1 443,8	161,2	-1 554,4	2 080	-1 582,9	2 710,1	-1 590,6	2 797,5	-1 473,7	3 109,4	-1 419,1	3 532,2
45	-434,5	5 118,4	-1 429,4	161,5	-1 540	2 080,3	-1 568,5	2 709,9	-1 576,2	2 797,2	-1 459,3	3 109,1	-1 404,7	3 531,9
50	-434,5	5 118,4	-1 417,9	161,7	-1 528,5	2 080,5	-1 557	2 709,6	-1 564,7	2 797	-1 447,8	3 108,9	-1 393,2	3 531,7
75	-434,5	5 118,4	-1 383,4	162,4	-1 548,4	2 080,1	-1 577	2 710	-1 530,3	2 796,3	-1 413,3	3 108,2	-1 358,7	3 531
100	-434,5	5 118,4	-1 366,2	162,7	-1 564,1	2 079,8	-1 592,6	2 710,3	-1 513	2 796	-1 396,1	3 107,9	-1 341,5	3 530,7
150	-434,5	5 118,4	-1 348,9	163	-1 579,6	2 079,5	-1 608,1	2 710,6	-1 495,8	2 795,7	-1 378,9	3 107,6	-1 324,3	3 530,4
200	-434,5	5 118,4	-1 340,3	163,2	-1 587,3	2 079,4	-1 615,8	2 710,8	-1 487,2	2 795,5	-1 370,3	3 107,4	-1 315,7	3 530,2
250	-434,5	5 118,4	-1 335,2	163,3	-1 591,9	2 079,3	-1 620,4	2 710,9	-1 482,1	2 795,4	-1 365,1	3 107,3	-1 310,5	3 530,1
400	-434,5	5 118,4	-1 327,4	163,4	-1 598,7	2 079,1	-1 627,3	2 711	-1 474,3	2 795,3	-1 357,4	3 107,2	-1 302,8	3 530
600	-434,5	5 118,4	-1 323,1	163,5	-1 602,5	2 079,1	-1 631,1	2 711,1	-1 470	2 795,2	-1 353,1	3 107,1	-1 298,5	3 529,9
800	-434,5	5 118,4	-1 321	163,6	-1 604,4	2 079	-1 633	2 711,1	-1 467,9	2 795,1	-1 350,9	3 107,1	-1 296,3	3 529,9
1 000	-434,5	5 118,4	-1 319,7	163,6	-1 605,6	2 079	-1 634,1	2 711,1	-1 466,6	2 795,1	-1 349,6	3 107	-1 295,1	3 529,8
2 500	-434,5	5 118,4	-1 316,6	163,6	-1 608,3	2 079	-1 636,9	2 711,2	-1 463,5	2 795,1	-1 346,5	3 107	-1 292	3 529,8
5 000	-434,5	5 118,4	-1 315,6	163,7	-1 609,2	2 078,9	-1 637,8	2 711,2	-1 462,4	2 795	-1 345,5	3 106,9	-1 290,9	3 529,7
Tangent	-434,5	5 118,4	-1 314,5	163,7	-1 610,1	2 078,9	-1 638,7	2 711,2	-1 461,4	2 795	-1 344,5	3 106,9	-1 289,9	3 529,7

TABLE 5B - VEHICLE DYNAMIC ENVELOPE - INSIDE OF CURVE

Cross Level Variation = 28,7 mm (2,0% Slope)
Superelevation = 0,0 mm

Radius	P9 CEN		P1 IN		P2 IN		P4 IN		P5 IN		P7 IN		P8 IN	
[m]	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
20	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
25	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
30	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
35	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
40	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
45	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
50	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
75	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
100	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
150	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
200	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
250	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
400	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
600	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
800	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
1 000	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
2 500	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
5 000	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5
Tangent	-516,3	6 263,2	-1 192,3	3 778,8	-1 003,7	4 013,4	-1 274,1	4 920,8	-1 085,4	5 155,4	-1 355,8	6 062,9	-1 167,2	6 297,5

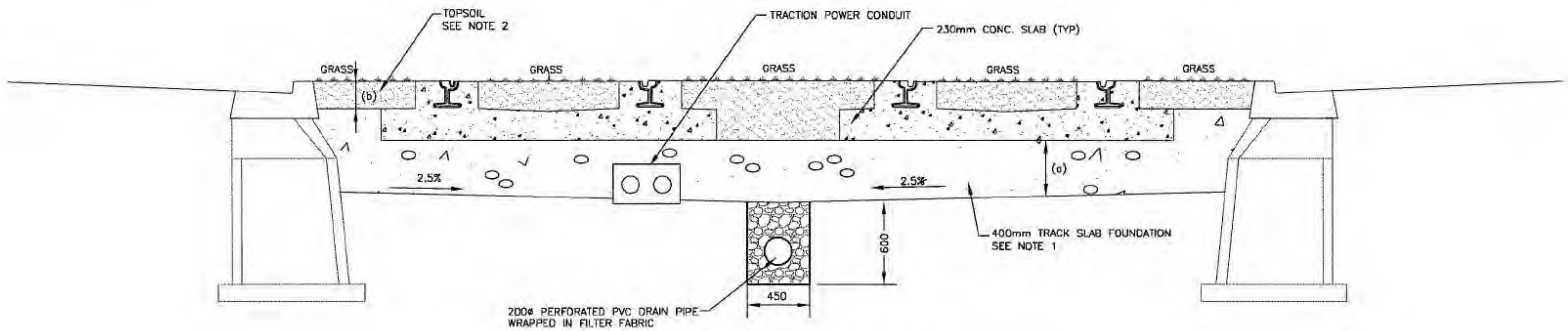
Project	Vancouver Streetcar
Calculations for	DHR Vehicle 1207

Mott MacDonald

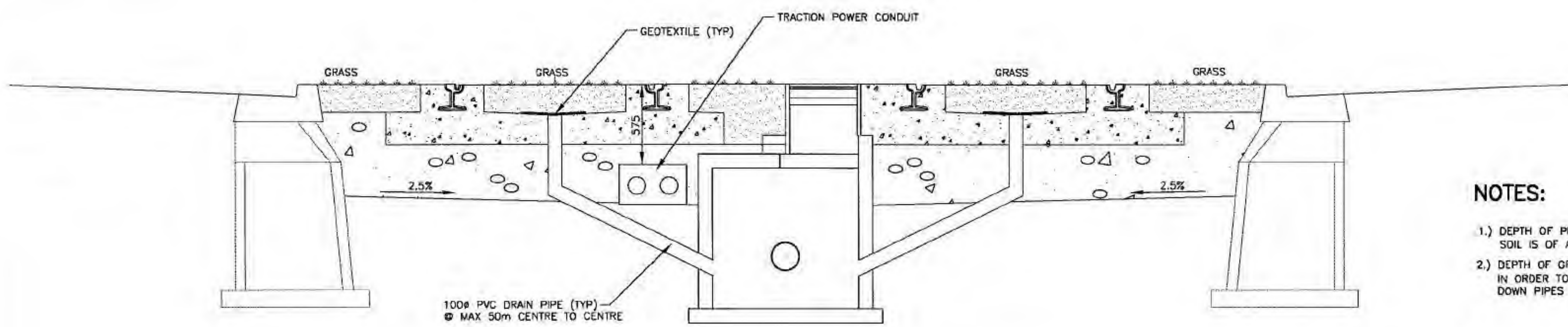
Divn/Dept	HMM-VAN	JobNr/FileNr	237388 / 4.1.1
Calculated By	TRMS	Date	2007/10/12
Checked By		Date	
Sheet Nr	of		

Track Geometry		Envelope ignoring tolerances etc.					DKE - Normal Operating Conditions							DKE - Credible Degraded Mode (Failed Suspension)						
		End Throw		Centre Throw		Overall	End Throw			Centre Throw			Overall	End Throw			Centre Throw			Overall
Track C/L radius (m)	Applied cant (mm)	Offset to track C/L (m)	Critical Point	Offset to track C/L (mm)	Critical Point	Width (m)	Offset to track C/L (m)	Critical Point	Extra over envelope ignoring tolerances etc. (mm)	Offset to track C/L (mm)	Critical Point	Extra over envelope ignoring tolerances etc. (mm)	Width (m)	Offset to track C/L (m)	Critical Point	Extra over DKE - Normal Operating Conditions (mm)	Offset to track C/L (mm)	Critical Point	Extra over DKE - Normal Operating Conditions (mm)	Width (m)
47.5	25	1.645	P4	1.557	P6	3.202	2.010	P3	366	1.891	P6	334	3.901	2.063	P3	53	1.943	P6	53	4.007
25	25	1.855	P4	1.731	P6	3.586	2.248	P3	394	2.066	P6	335	4.314	2.301	P3	53	2.119	P6	53	4.420
30	25	1.783	P4	1.669	P6	3.453	2.168	P3	384	2.004	P6	334	4.171	2.220	P3	53	2.057	P6	53	4.277
35	25	1.731	P4	1.626	P6	3.357	2.108	P3	377	1.960	P6	334	4.067	2.161	P3	53	2.013	P6	53	4.173
40	25	1.691	P4	1.593	P6	3.284	2.062	P3	372	1.927	P6	334	3.989	2.115	P3	53	1.980	P6	53	4.095
45	25	1.659	P4	1.568	P6	3.226	2.026	P3	367	1.901	P6	334	3.927	2.079	P3	53	1.954	P6	53	4.033
50	25	1.633	P4	1.547	P6	3.180	1.996	P3	364	1.881	P6	334	3.877	2.049	P3	53	1.934	P6	53	3.983
55	25	1.611	P4	1.531	P6	3.142	1.972	P3	361	1.864	P6	333	3.836	2.025	P3	53	1.917	P6	53	3.942
60	25	1.593	P4	1.517	P6	3.110	1.952	P3	359	1.850	P6	333	3.802	2.005	P3	53	1.903	P6	53	3.908
65	25	1.578	P4	1.505	P6	3.083	1.934	P3	357	1.839	P6	333	3.773	1.987	P3	53	1.892	P6	53	3.879
70	25	1.564	P4	1.495	P6	3.060	1.919	P3	355	1.829	P6	333	3.748	1.972	P3	53	1.882	P6	53	3.854
75	25	1.553	P4	1.487	P6	3.040	1.906	P3	353	1.820	P6	333	3.726	1.959	P3	53	1.873	P6	53	3.832
80	25	1.543	P4	1.479	P6	3.022	1.895	P3	352	1.812	P6	333	3.707	1.948	P3	53	1.865	P6	53	3.813
85	25	1.534	P4	1.472	P6	3.006	1.884	P3	351	1.806	P6	333	3.690	1.937	P3	53	1.859	P6	53	3.796
90	25	1.526	P4	1.467	P6	2.992	1.875	P3	350	1.800	P6	333	3.675	1.928	P3	53	1.853	P6	53	3.781
95	25	1.518	P4	1.461	P6	2.980	1.867	P3	349	1.794	P6	333	3.662	1.920	P3	53	1.847	P6	53	3.768
100	25	1.512	P4	1.456	P6	2.968	1.860	P3	348	1.790	P6	333	3.649	1.913	P3	53	1.843	P6	53	3.755
110	25	1.501	P4	1.448	P6	2.949	1.847	P3	346	1.781	P6	333	3.628	1.900	P3	53	1.834	P6	53	3.734
120	25	1.491	P4	1.441	P6	2.933	1.836	P3	345	1.775	P6	333	3.611	1.889	P3	53	1.827	P6	53	3.717
130	25	1.483	P4	1.436	P6	2.919	1.827	P3	344	1.769	P6	333	3.596	1.880	P3	53	1.822	P6	53	3.702
140	25	1.476	P4	1.431	P6	2.907	1.819	P3	343	1.764	P6	333	3.583	1.872	P3	53	1.817	P6	53	3.689
150	25	1.470	P4	1.426	P6	2.897	1.813	P3	342	1.759	P6	333	3.572	1.866	P3	53	1.812	P6	53	3.678
160	25	1.465	P4	1.422	P6	2.888	1.807	P3	342	1.756	P6	333	3.562	1.860	P3	53	1.809	P6	53	3.668
170	25	1.460	P4	1.419	P6	2.880	1.801	P3	341	1.752	P6	333	3.554	1.854	P3	53	1.805	P6	53	3.660
180	25	1.456	P4	1.416	P6	2.872	1.797	P3	340	1.749	P6	333	3.546	1.850	P3	53	1.802	P6	53	3.652
190	25	1.453	P4	1.413	P6	2.866	1.793	P3	340	1.747	P6	333	3.539	1.846	P3	53	1.800	P6	53	3.645
200	25	1.449	P4	1.411	P6	2.860	1.789	P3	340	1.744	P6	333	3.533	1.842	P3	53	1.797	P6	53	3.639
250	25	1.437	P4	1.402	P6	2.839	1.774	P3	338	1.735	P6	333	3.510	1.827	P3	53	1.788	P6	53	3.615
300	25	1.428	P4	1.396	P6	2.824	1.765	P3	337	1.729	P6	333	3.494	1.818	P3	53	1.782	P6	53	3.600
350	25	1.422	P4	1.392	P6	2.814	1.758	P3	336	1.731	P3	339	3.489	1.811	P3	53	1.784	P3	53	3.595
400	25	1.417	P4	1.388	P6	2.806	1.753	P3	335	1.736	P3	348	3.489	1.806	P3	53	1.789	P3	53	3.595
450	25	1.414	P4	1.386	P6	2.800	1.749	P3	335	1.740	P3	355	3.489	1.802	P3	53	1.793	P3	53	3.595
500	25	1.411	P4	1.387	P4	2.798	1.745	P3	334	1.744	P3	357	3.489	1.798	P3	53	1.797	P3	53	3.595
600	25	1.407	P4	1.391	P4	2.798	1.740	P3	334	1.749	P3	357	3.489	1.793	P3	53	1.802	P3	53	3.595
700	25	1.404	P4	1.394	P4	2.798	1.737	P3	333	1.752	P3	358	3.489	1.790	P3	53	1.805	P3	53	3.595
800	25	1.401	P4	1.397	P4	2.798	1.734	P3	333	1.755	P3	358	3.489	1.787	P3	53	1.808	P3	53	3.595
900	25	1.399	P4	1.399	P4	2.798	1.732	P3	333	1.757	P3	358	3.489	1.785	P3	53	1.810	P3	53	3.595
1000	25	1.398	P4	1.400	P4	2.798	1.731	P3	333	1.759	P3	359	3.489	1.784	P3	53	1.812	P3	53	3.595
1500	25	1.394	P4	1.404	P4	2.798	1.726	P3	332	1.763	P3	359	3.489	1.779	P3	53	1.816	P3	53	3.595
2000	25	1.391	P4	1.407	P4	2.798	1.723	P3	332	1.766	P3	359	3.489	1.776	P3	53	1.819	P3	53	3.595
2500	25	1.390	P4	1.408	P4	2.798	1.722	P3	332	1.767	P3	360	3.489	1.775	P3	53	1.820	P3	53	3.595
3000	25	1.389	P4	1.409	P4	2.798	1.721	P3	332	1.768	P3	360	3.489	1.774	P3	53	1.821	P3	53	3.595
3500	25	1.389	P4	1.409	P4	2.798	1.720	P3	332	1.769	P3	360	3.489	1.773	P3	53	1.822	P3	53	3.595
4000	25	1.388	P4	1.410	P4	2.798	1.720	P3	331	1.770	P3	360	3.489	1.773	P3	53	1.823	P3	53	3.595
4500	25	1.388	P4	1.410	P4	2.798	1.719	P3	331	1.770	P3	360	3.489	1.772	P3	53	1.823	P3	53	3.595
5000	25	1.388	P4	1.410	P4	2.798	1.719	P3	331	1.770	P3	360	3.489	1.772	P3	53	1.823	P3	53	3.595
9999999	25	1.385	P4	1.413	P4	2.798	1.716	P3	331	1.773	P3	360	3.489	1.769	P3	53	1.826	P3	53	3.595

Appendix D Typical Traction Longitudinal Power Conduit Arrangement



TYPICAL GRASS TRACK DETAILS

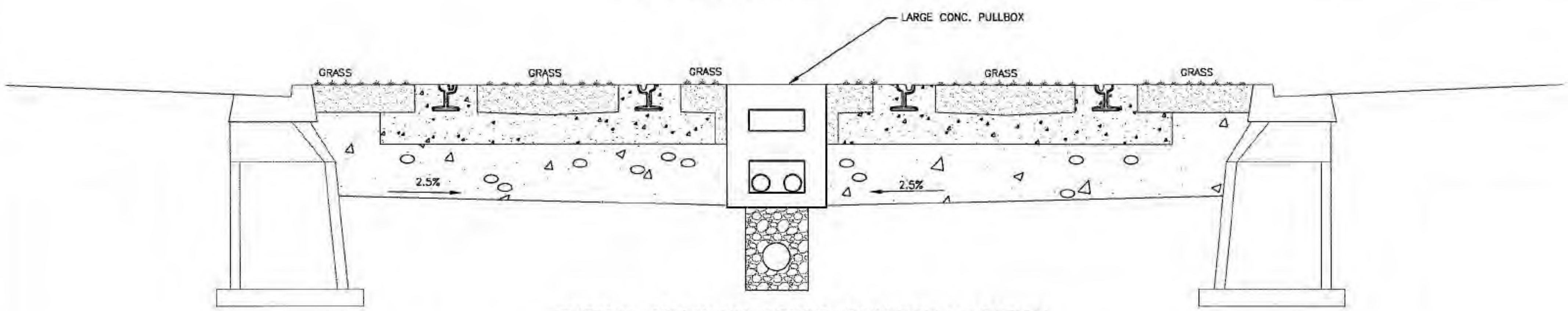


TYPICAL SECTION WITH MANHOLE

NOTES:

1.) DEPTH OF PROPOSED SLAB TRACK FOUNDATION (a) ASSUMES SUB GRADE SOIL IS OF AVERAGE STIFFNESS.

2.) DEPTH OF GROWING MEDIA (b) WILL VARY FROM 150mm TO 200mm IN ORDER TO FACILITATE LONGITUDINAL DRAINAGE OF SOIL MEDIA AT 1.0–1.5%. DOWN PIPES ARE PROPOSED AT 50m MAXIMUM SPACING.



TYPICAL TRACTION POWER PULLBOX LOCATION

PRELIMINARY

DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

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NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

ENGINEER STAMP:

REV.	ISSUED FOR	AUTH. BY	DATE
0	ISSUED FOR CoV REVIEW	DSW	11/02/07
ISSUE AUTHORIZATION			

Hatch Mott MacDonald

DESIGNED BY: TS DATE:
DRAWN BY: SM DATE:
CHECKED BY: DSW DATE:
PROJECT MANAGER: DSW DATE:

HMM PROJECT No: 237388
DWG SCALE FULL SIZE: 1:20 HALF SIZE: 1:40

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

DETAILS

DWG No: 237388-T-174 | SHT No | REV No 0

LAST SAVED BY: ---- - 11/2/2007 4:00 PM

PLOT PAGE SETUP: PAGE_SETUP_NAME
PLOT PAPER SIZE: PAPER_SIZE
PLOT SCALE FACTOR: SCALE_FACTOR
PLOT STYLE TABLE: PLOT_STYLE_TBL
PLOT PRINTER: PRINTER

CAD FILE: P:\237388-Vancouver_Downtown_Streetcar\03_CAD\3.4_Civil\Road\Drawings\237388_T-170-175.dwg (LAYOUT: T-174)

PRINTED: November 9, 2007 - 8:12 AM

XREFs and images Attached: 237388-Title-D.dwg | TYPICAL_SECTIONS.dwg

Appendix E Traction Power Lateral Conduit Arrangement

Skutezky, Trevor

From: Wright, David
Sent: Monday, October 22, 2007 4:08 PM
To: Coupland, Max
Cc: Romanetz, Garry; Konowalchuk, Wally; Skutezky, Trevor; 237388 Downtown Streetcar; Singer, Barry; Stuart.Riddick; Bracewell, Dale
Subject: RE: SEFC First Avenue DHR GCOMM - URGENT
Attachments: 20070717_1742 Trolley Pole Standards.pdf; 20071022_1654 Mark up of TP126-128.pdf

Our ref: 237388/2.5
Max

Attached you will find copies of our draft Traction Power plans which we have annotated by hand to identify where we require conduits to be installed from the median to the north sidewalk. Formal issues of these drawings will be made when we complete our preliminary design at the end of October. There are two types of conduit feed required:

- Traction power feeds to street lighting poles; each has 2no. 100mm dia ducts as per the standard details from Coast Mountain use (also attached for reference, although please confirm that these details are applicable for the poles being procured for the SEFC Project). On the attached plans you should find connections annotated for the lighting columns with HMM reference numbers - 14, 26, 40,68 and 81. The feeds should extend to the middle of the median and be stop ended (we will not be recommending the installation of draw pits in the median at this time given that the final detail for modern streetcar has not been finalised).
- Connections from the GCOMM; 6no. 100mm ducts in the same configuration as positioned in the GCOMM. We have identified 4 lateral crossings, each with the 6no. 100mm dia. ducts. The exact location will depend upon where you have GCOMM manholes. Our proposal has a preference of creating a duct loop from the north side walk to the median, through the streetcar stops and back to the north sidewalk. At Manitoba we believe that we can tie into to two manholes. However, at Cook this may not be the case; can you advise what options we may have based upon your current design. Again, the ducts can be stop ended in the centre of the median.

We hope that the attached is sufficient for you current needs.

Yours sincerely
David Wright CEng MICE
Associate

Hatch Mott MacDonald
Suite 1010 Oceanic Plaza
1066 West Hastings Street
Vancouver BC V6E 3X2
T 604.629.1736 ext.359
F 604.639.1191
david.wright@hatchmott.com
<<http://www.hatchmott.com/>>

From: Bracewell, Dale [mailto:dale.bracewell@vancouver.ca]
Sent: Monday, October 22, 2007 1:20 PM
To: Coupland, Max; Skutezky, Trevor; Wright, David
Cc: Romanetz, Garry; Konowalchuk, Wally

Subject: RE: SEFC First Avenue DHR GCOMM - URGENT

Max,

I spoke with David today and they are working on this and should have something to you by tomorrow...

Cheers,
Dale

Dale Bracewell, MASc, PEng
Manager, Olympic Transportation

"To be leaders in providing communities and individuals with opportunities to adopt a sustainable transportation lifestyle"

453 West 12th Avenue, Vancouver, BC, V5Y 1V4
tel: 604-871-6440 e-mail: dale.bracewell@vancouver.ca

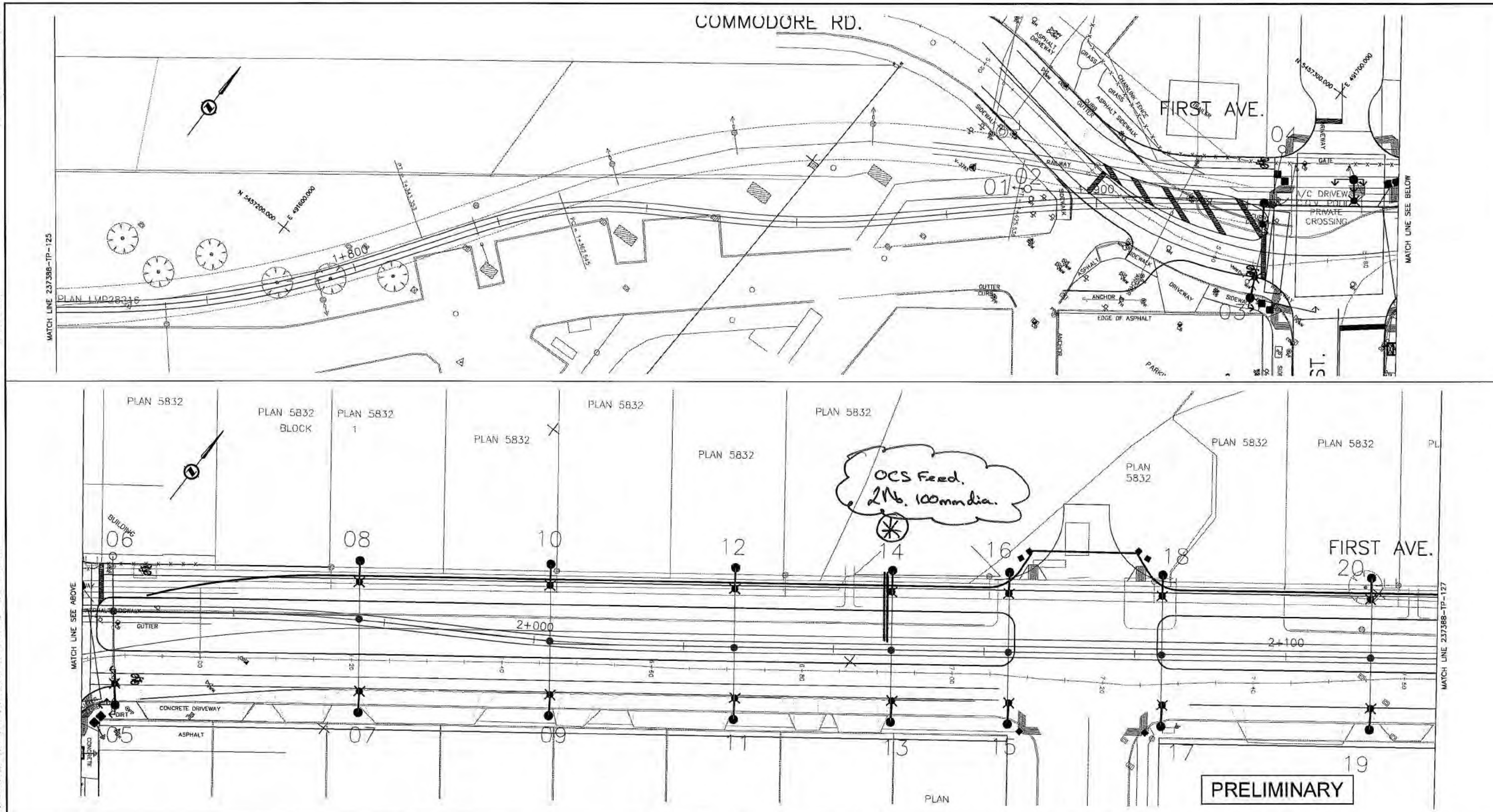
From: Coupland, Max [mailto:max.coupland@stantec.com]
Sent: Thursday, October 18, 2007 6:44 PM
To: Bracewell, Dale; Skutezky, Trevor; Wright, David
Cc: Romanetz, Garry; Konowalchuk, Wally
Subject: SEFC First Avenue DHR GCOMM - URGENT

Dale / David,

To complete the updated SEFC C111 GCOMM designs, as previously requested we required the locations of crossings and any termination requirements. Similarly, the traction power locations and termination requirements are also needed.

This information is needed by October 23 to meet our design / C111 timeframes.

Max Coupland, AScT
Senior Project Manager - Associate
Stantec
10th Floor 13401 - 108th Avenue
Surrey BC V3T 5T3
Ph: (604) 587-8408
Fx: (604) 587-8489
Cell: (778) 772-5424
max.coupland@stantec.com
stantec.com



DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

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DESIGNED BY: – DATE:
DRAWN BY: – DATE:
CHECKED BY: DATE:
PROJECT MANAGER: DSW DATE:

HMM PROJECT No: 237388

DWG SCALE: FULL SIZE: 1:250, HALF SIZE: 1:500

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

DHR TRACTION POWER POLE LOCATION PLAN

FROM STA. 1+760 TO STA 2+120

DWG No: 237388-TP-126

SHT No | REV No

LAST SAVED BY: ---- - 9/19/2007 4:12 PM

PLOT PAGE SETUP: PAGE_SETUP_NAME
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PLOT SCALE FACTOR: SCALE_FACTOR
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PLOT PRINTER: PRINTER

CAD FILE: P:\237388-Vancouver_Downtown_Streetcar\03_CAD\3.4_CIVIL\Road\Drawings\237388_TP-101-TP-130.dwg (LAYOUT: TP-126)

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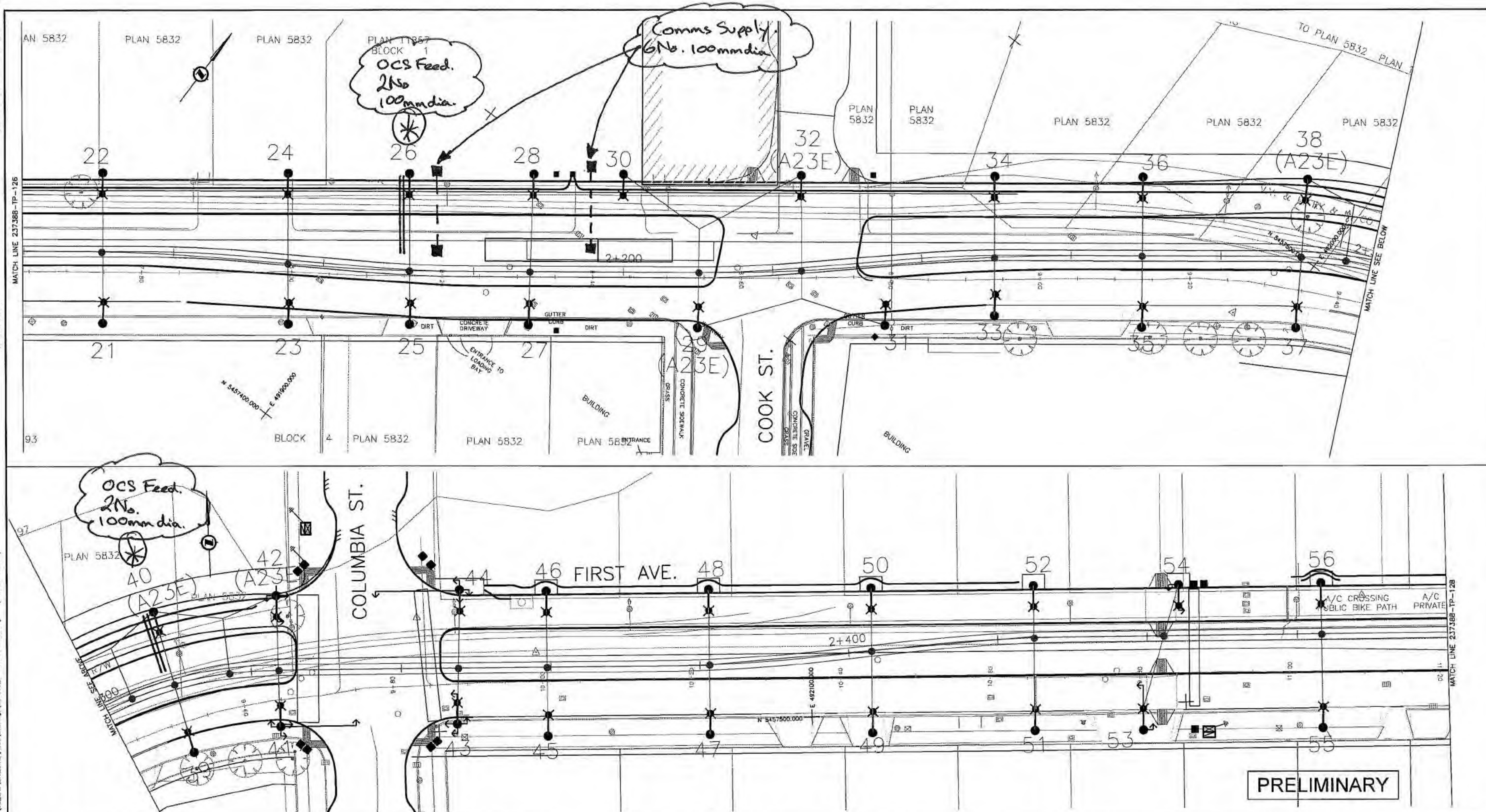

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REFERENCE DRAWINGS

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DRAWN BY: – DATE: PROJECT MANAGER: DSW DATE:

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

STREETCAR TRACTION POWER POLE LOCATION PLAN

FROM STA. 2+120 TO STA. 2+480

HMM PROJECT No: 237388
DWG SCALE FULL SIZE: 1:250 HALF SIZE: 1:500
DWG No: 237388-TP-127
SHT No | REV No

CAD FILE: P:\237388-Vancouver_Downtown_Streetcar\03_CAD\3.4_CIVIL\Root\Drawings\237388_TP-101-TP-130.dwg (LAYOUT: TP-127)

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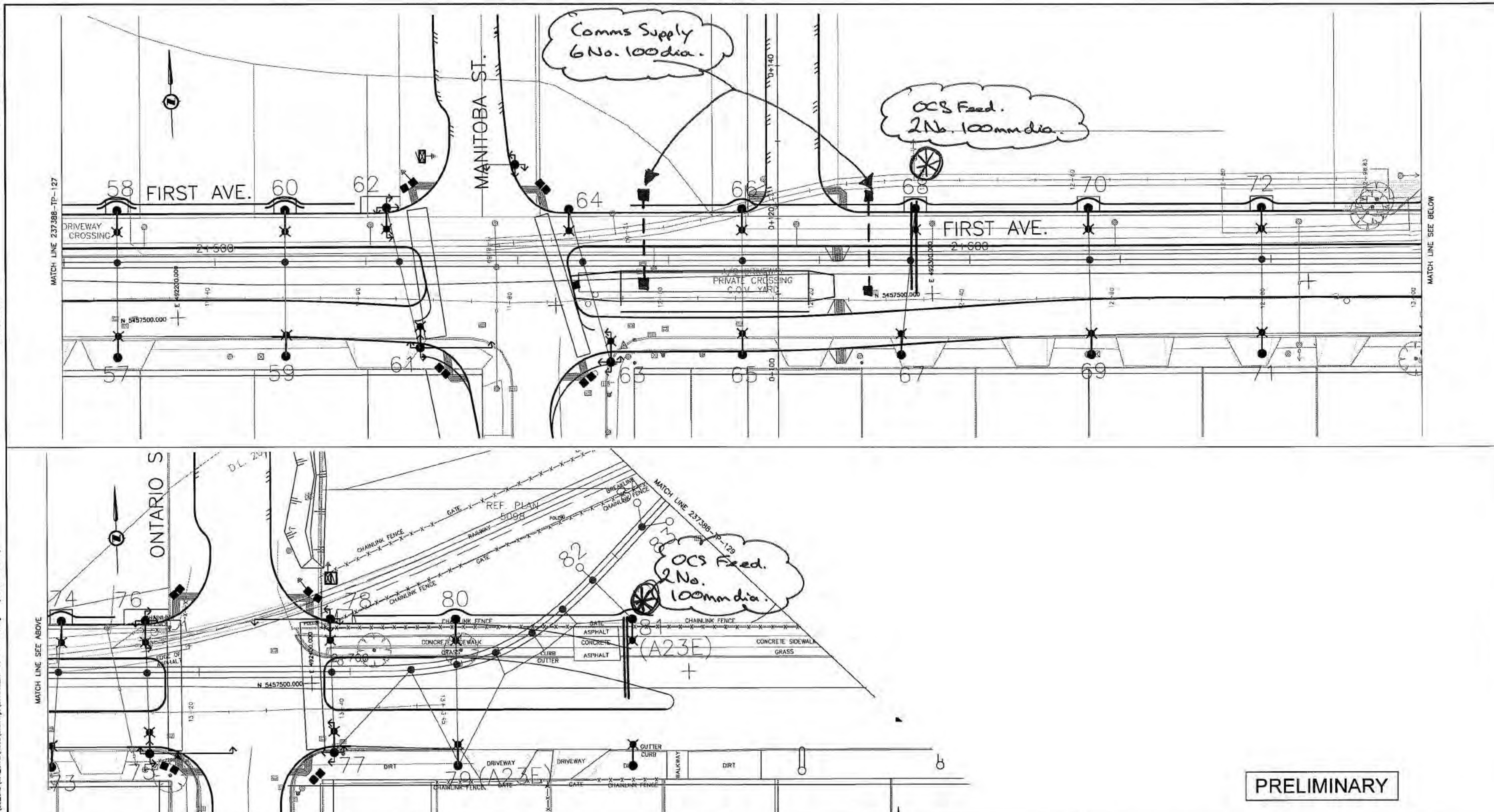

PRELIMINARY

DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

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NO.	DESCRIPTION	CHK'D	APP'D	DATE
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CHECKED BY: DATE:
PROJECT MANAGER: DSW DATE:

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

DHR TRACTION POWER POLE LOCATION PLAN

FROM STA. 2+480 TO STA. 2+750

HMM PROJECT No: 237388
DWG SCALE: FULL SIZE: 1:250 HALF SIZE: 1:500
DWG No: 237388-TP-128
SHT No | REV No

CAD FILE: P:\237388-Vancouver_Downtown_Streetcar\03_CAD\3.4_CIVIL\Road\Drawings\237388_TP-101-TP-130.dwg (LAYOUT: TP-128)

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PRINTED: September 19, 2007 - 4:32 PM

Appendix F HMM Memo: Rail Reuse Recommendations

Our ref 237388/2.1
Your ref

SEFC Project Office
1800 Spyglass Place
Vancouver, BC, Canada
V5Z4K8

30 January 2008

Attention: Wally Konowalchuk

Dear Mr. Konowalchuk, P. Eng.:

Re: Reimplementation of Downtown Historic Railway

Further to your request of 9 January 2008, a review has been conducted to assess the feasibility of re-using the existing rail equipment for the reinstatement of Downtown Historic Railway (DHR) service along the 1st Avenue median.

On the morning of January 18 2008, HMM attended the construction yard near Crowe Street and was met by Ozzie Lepore, Construction Inspector for the City of Vancouver.

The stockpile of track materials was inspected and our findings are as follows:

Not all of the material made it into the stockpile. Scrap rail and track material has been pushed to one side in piles within the right of way near Cook Street (see Photo 1). It is difficult from the piles to ascertain the precise amount, but it is in the order of several hundred track feet.
The ties, tie plates, spikes, rail anchors, joint bars have been neatly segregated (see photos 2 and 3). A section of rubber flangeway for a road crossing was salvaged in good condition. See photo 4.

The rail has been improperly stockpiled. Rail should be stored in tiers with the rail base on wooden dunnage and out of the water. At minimum, all rail anchors should have been removed to avoid gouging the adjacent rails (see photos 5 and 6).

Our discussion and recommendation regarding the re-use of this material is:

Ties

The tie condition varies from poor to good. A poor tie is one that is soft, excessively split or rotted and is generally 25+ years old. A good condition tie is solid and has sound wood in the tie plate area so as to be able to bear the rail loadings.

Second hand ties are not economic to be re-used unless a remaining life of 15-20 years is achieved. Some of the ties in the stockpile would be re-usable. The quantity of re-useable ties could not be determined because they are piled and banded. Normally a sorting process would have been done prior to banding. Nearly all of the ties would be suitable for sale into the landscaping market. If it is intended to "patch" the section from Granville Island to Cambie Street, it is recommended that the stockpiles be sorted by an experienced tie contractor; he would pay for and haul away the non-recoverable ties and band the re-useable remainder for future use. BC Rail, CN and CPR have often used 440 Services from Squamish for this type of work.

Other Track Material (OTM)

Other Track Material is the joint bars, tie plates, spikes and rail anchors. There is a mix of tie plate types and weights of joint bars. They are corroded and in fair to poor condition. The spikes are bent and corroded and in generally poor condition, the Fair rail anchors are likely "sprung" or cold-worked and should not be re-used. Some joint bars could be salvaged for maintenance between Granville and Cambie, if the existing track section there is to be re-used.

Rail

None of this rail would meet current Class 1 Railway Industrial Standards for siding construction because of the small section sizes; although there is a fair amount of wear life left on some of the rail. Rail contractors may pay a price above scrap for this rail as it could be used to service a few of their customers with older track for broken or worn rail change-out. Also, some of this rail could be used as maintenance rail on the Granville Island to Cambie section, if the existing track is going to be retained. Retaining this rail to rebuild the 1st Avenue section is not recommended.

In brief, if maintenance in kind will be done on the section between Granville and Cambie, some of this material may be useful and save costs; the remainder should be disposed of for best scrap value.

Pacific Northern Rail and A&B Rail Services Ltd. could provide a salvage estimate on the steel track materials; OTM and rail.

I trust this meets your needs and please do not hesitate to contact us should you have any questions.

Sincerely yours,
Hatch Mott MacDonald

Stuart Riddick, BEng (Hons)
Project Manager

6046291736
stuart.riddick@seatoskydbfo.ca

Encl: Six Inspection Photos

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Appendix G iTrans Road Safety Review

iTRANS Consulting Inc.
100 York Blvd., Suite 300
Richmond Hill, ON L4B 1J8
Tel: (905) 882-4100
Fax: (905) 882-1557
www.itransconsulting.com

Distribution:
File:
Project # 3981

Memorandum

To: David Wright, Hatch Mott MacDonald (HMM)
Cc: Trevor Skutezky, HMM
From: Geni Bahar – iTRANS
Donna Howes – iTRANS
Michelle Mascarenhas - iTRANS
Date: December 11, 2007
Re: **Vancouver Downtown Streetcar Project – Preliminary Safety Audit - DRAFT**

1. INTRODUCTION

A preliminary safety audit was undertaken to identify safety issues that may arise with the implementation of the proposed Vancouver Downtown Streetcar project. The audit comprised a brief description of related topics found in published literature, with respect to the safety of Light Rail Transit (LRT) operations, and a review of the projects' preliminary design drawings. The topics, as part of the brief literature review, include safety conflicts between Light Rail Vehicles (LRV) and motorists, and between LRV and pedestrians; pedestrian and driver expectancy; cross-sections and access management. The review of the preliminary design examined drawings (Dated November 2007) for the proposed Downtown Heritage Railway (DHR) alignment and drawings for the proposed Phase 0 alignment (Streetcar), on a section-by-section basis. Reference was also made to the Draft Report (005 RevA) prepared by HMM as at Oct 31, 2007.

The documented issues found in the published literature and the review of the preliminary design drawings were applied to highlight potential safety conflicts along segments of the alignment as well as for the overall system under design for the Vancouver Downtown Streetcar project. Our findings are limited in their scope due the many undefined project parameters and thus, the safety audit is constrained by the depth of information available at this time. Therefore, it is our intent that the safety concerns addressed in this memorandum be considered as a preliminary / initial step in assisting the next stage of the planning and design process of the Vancouver Downtown Streetcar project. As the project progresses and more information become available, additional safety reviews/audits are recommended.

2. LITERATURE REVIEW

The literature review includes findings from several transportations studies, which are found at the end of this memorandum (References), and much of iTRANS current research project being undertaken for the U.S. Transit Corporate Research Program, for Project A-30, "Improving Pedestrian and Motorist Safety Along Light Rail Transit Alignments," on-going, iTRANS Consulting Ltd., October 2006 – August 2008.

2.1 LRT Operations

Collisions

Light rail accidents at any given crossing are rare events. Analysis of the frequency of accidents at higher speed LRT crossings reveals that LRT systems in North America are generally safe [(3)]. When, however, collisions do occur at higher speed LRT crossings, the collisions are often severe [(2)]. While the number of collisions has been a traditional safety indicator for LRT systems, TCRP Reports 17 and 69 showed that, because vehicle and pedestrian collisions at grade crossings are relatively infrequent, the number of collisions is often too small to be amenable to standard statistical testing [(1, 2)]. A survey of 11 LRT systems in North America showed that light rail accidents at any given location are very rare: 80 % of the 30 highest-accident locations averaged fewer than four accidents per year [(1)].

Priority

Based on standard LRT industry practice and an 1877 Supreme Court ruling (Continental Improvement Company v. Stead) regarding highway-rail crossings, the rail mode has right-of-way over other users (motorists, pedestrians, and bicyclists) at higher speed crossings because of the "character," "momentum," and "requirements of public travel by means thereof," but the rail operation is required to give timely warning of approaching trains [(2)].

Emergency Services

According to the US MUTCD, Section 8C-6, "Where multiple or successive pre-emption may occur from differing modes, train actuation should receive first priority and emergency vehicles second priority." This recommendation applies at higher speed LRT crossings [LRVs operating at speeds greater than 55 km/h (35mph)] where the LRV detection system is interconnected with the traffic signals at a nearby intersection [(2)].

2.2 Single vs Double-Track LRT Systems

Studies have found that LRT systems with double track operations generally have more crossing accidents than those with single track operations. For example, a survey of eight LRT systems in the U.S. found that two of the systems with single track operations had experienced no accidents since initiation of their LRT services [4]. At LRT crossings with dual tracks, motorists and pedestrians may act in a manner they believe to be safe, such as crossing the tracks when there is an LRT train stopped at a nearby station, or traversing the tracks ahead of slow moving freight trains when they do not have the right of way, but such behaviour has resulted in collisions with second trains [5]. It is unclear from existing research how much of this finding whether the greater frequency of accidents at crossings on LRT systems with double track operations is due to the nature of double track operations and a different level of exposure to the risk of collisions at crossings with dual tracks, or whether it is due to higher volumes of trains at these types of crossings. [3]

2.3 <u>Motor Vehicles and LRV</u>

Accident Types

In some LRT systems, accidents between motor vehicles and LRVs account for more than 80% of all LRV-related accidents [3]. The single most frequent ***accident type*** between a motor vehicle and a LRV occurs when a motor vehicle makes a left-turn movement in front of a LRV travelling in the same direction [3]. Four possible traffic conflicts between a left-turning motor vehicle and a LRV are shown in **Exhibit 1** presented below. Previous TCRP research [1] has found that the conflict type a) in **Exhibit 1**, where the vehicle overtakes the LRV by turning left in front of the LRV, is a risky manoeuvre [3].

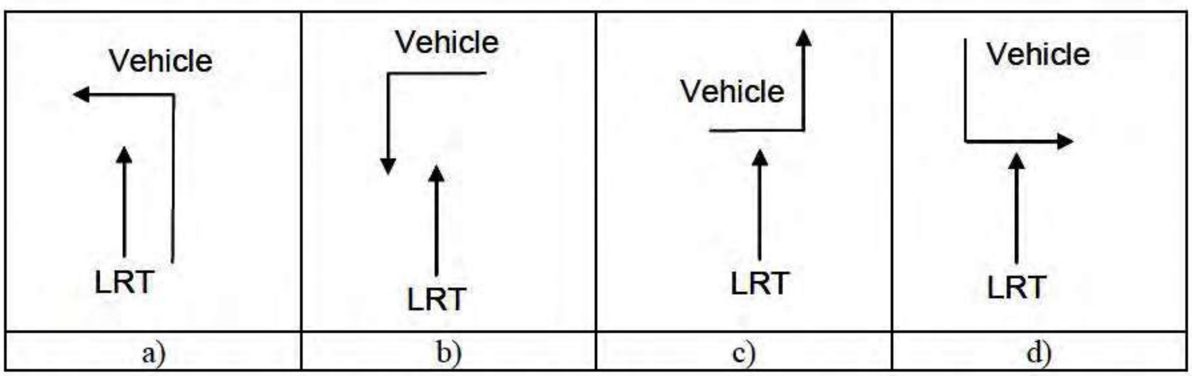


Exhibit 1 Possible vehicle-LRT traffic conflicts for left turning vehicle manoeuvres

Additional ***accident types*** between motor vehicles and LRVs, as identified in TRCP Report 17, are listed below:

1. Two-way side-aligned LRT operations (2 trains moving in opposite directions on adjacent track alignments), on one-way or two-way streets confuse motorists and result in high accident frequencies. Typical problems include the following:
    i. Motorists are confused as to which way the LRV is approaching.

ii. Driveway access across LRT tracks conflicts with LRV operations
iii. Two *two-way* street couplets are effectively formed when a two-way LRT is side aligned on a two-way street. This type of geometry, especially when turning traffic is involved, forces the motorist to make complicated decisions. Motorists may be especially confused at night, when the headlights of an approaching LRV appear on the right-hand side of the road.

2. Motorists make illegal left turns across the LRT right-of-way immediately after termination of their green left-turn arrow. They know it will take a few seconds for the parallel through traffic to enter the intersection from a stopped position; however, they might not be aware that an LRV is approaching the intersection at a higher speed.
3. Motorists often violate the red left-turn arrow when leading left-turn arrow indications are pre-empted by LRVs. Usually, this illegal movement is not a conscious choice on the part of the motorist, who has simply learned to expect the green arrow indication before the through movement. Motorist expectancy is violated when the LRV pre-empts the leading left-turn phase at a signal.
4. Red time extensions resulting from multiple LRV pre-emptions cause motorists waiting to turn left across the LRT tracks to become impatient. This impatience develops further when the signals do not recover to the left-turn movements. (Typically, signal pre-emption strategies are designed to return to the cross-street traffic movement.) Often, motorists will assume that the traffic signal has malfunctioned and will then violate the signal.
5. Differences between standard and pre-empted traffic signal phase sequences violate motorist expectancy. For example, pre-emption of coordinated traffic signals in a grid network violates what motorists expect as they progress along cross-street arterials.
6. Motorists violate active and passive NO LEFT / RIGHT TURN signs, especially where left turns were previously allowed before the LRT system was constructed. Permanently prohibiting a traffic movement that was previously allowed disrupts normal, expected travel patterns.
7. Motorists confuse LRT signals with traffic signals, especially left-turn signals.
8. Motorists confuse LRT switch signals (coloured ball aspects) with traffic signals.
9. Motorists drive on LRT rights-of-way that are delineated only by solid double yellow striping.
10. Motorists violate traffic signals at perpendicular grade crossings. Motorists often try to beat LRVs to the crossing, especially where they know LRVs are operating at slow speeds.
11. Complex intersection geometry complicates motorist decisions.

Risky Behaviour Patterns

TRCP Report 17 also identifies ***risky behaviour patterns*** between motorists and LRV, and are listed below for left-turn collisions, right-angle collisions, and right-turn accidents:

Left-turn Collisions

1. At signalized intersections, motorists stopped at an exclusive left-turn lane initiate their left turns against the red turn arrow as soon as the traffic signal for the cross-street traffic turns red while an LRV approaches from behind. This risky behaviour is particularly common at locations with traffic signals with a leading left-turn phase.
2. At signalized intersections, motorists violate the red left-turn signal at the end of the left-turn phase as they proceed to turn left without stopping while an LRV approaches from behind. This risky behaviour is also common at locations with traffic signals with a leading left-turn phase.
3. At signalized and unsignalized intersections, motorists make illegal left turns across light rail tracks, against passive NO LEFT TURN signs while an LRV approaches from behind.
4. At signalized and unsignalized intersections, left-turning motorists stop on the light rail tracks, waiting for gaps in the opposing traffic stream while an LRV approaches the intersection.

Right-Angle Collisions

1. At signalized intersections, motorists on the cross street violate the red signal light and enter the intersection without stopping, unaware an LRV is approaching.
2. At signalized intersections, motorists on the cross-street violate the red signal light and speed through the intersections in an attempt to beat out an approaching LRV.
3. At signalized intersections, motorists on the cross-street initially follow another vehicle approaching the intersection. The leading vehicle stops for the red signal indication as an LRV approaches the intersection. However, the following motorist overtakes and passes the stopped vehicle, and enters the intersection.
4. At unsignalized intersections on side-running alignments, motorists on the cross street stop on the light rail tracks, waiting for gaps in the major street traffic stream as an LRV approaches the intersection.

Right-turn Accidents – These typically involve LRV and motor vehicles travelling in the same direction and occur during an attempt to turn right at intersections along right-side-running alignments.

1. Motorists attempt right turns at intersections or driveways, violating passive NO RIGHT TURN signs and unaware that an LRV is approaching from behind.

2. Motorists attempt right turns, violating passive or active NO RIGHT TURN signs and speeding up to beat out an LRV approaching from behind.
3. At signalized intersections, on right-side-running alignments, motorists on cross streets attempt right turns on red, and then stop on the light rail tracks as an LRV approaches

In addition to the ***risky behaviour patterns*** identified in TCRP Report 17, the following ***risky behaviour*** is noted:

1. Lack of left-turn lanes / storage will create pressure on motorists making left-turn movements as they will be aware of vehicles queuing behind them. In addition, this may encourage queued drivers trying to make through movements to encroach into bicycle lanes in an attempt to pass the stopped left-turn vehicle.

2.4 Pedestrians and LRV

The most severe LRV-related accident type occurs between left-turning LRV and pedestrians. Although this accident type only accounts for approximately 10% of all LRV-related accidents, 50% of these accidents result in fatalities (1).

Accident Types

Accident types between pedestrians and LRV, as identified in TRCP Report 17, are listed below:

1. Pedestrians trespass on side-aligned LRT tracks where no sidewalk exists. This design disrupts the normal, pedestrian travel pattern.
2. Pedestrians jaywalk across LRT rights-of-way, having received mixed messages about relative crossing ease from block to block.
3. Clearly designed *safe* locations for pedestrians are lacking. In many instances, pedestrians do not have adequate, safe queuing areas. Additionally, LRV dynamic envelopes are not marked clearly, are marked improperly at LRV turns, or are implied to be smaller then they are by de facto pavement delineation, such as concrete paving above the railroad ties or just between the rails that are installed in an asphalt roadway.
4. Two-way side-aligned LRT operations on one-way or two-way streets confuse pedestrians and result in high accident frequencies. Typical problems include the following:
    i. Pedestrian are confused as to which way the LRV is approaching.
    ii. Driveway access across LRT tracks conflicts with LRV operations.
5. Complex intersection geometry complicates pedestrian decisions.

Risky Behaviour Patterns

TRCP Report 17 also identifies ***risky behaviour patterns*** between pedestrians and LRV, and are listed below:

1. In a semi-exclusive, median-running alignment, pedestrians queue on the light rail track and in the street after they have alighted from the LRV and are waiting to cross the street. Such actions put them at risk when LRVs approach or depart the station, or as motor vehicles approach in the traffic lanes where the pedestrians are queuing.
2. At median-aligned LRT stations, pedestrians alighting from one LRV and seeking to board another form of transportation (e.g. a bus) attempt to cross the light rail track behind the stopped LRV but in front of the another LRV that is approaching or departing the station from the other direction.
3. For reasons similar to those stated above, pedestrians run in front of an LRV in a LRV/pedestrian mall as the LRV departs from a station.
4. Despite signs posted to warn pedestrians that trespassing on the light rail tracks is illegal, pedestrians walk on the left-side-aligned light rail tracks on a one-way street because there is no left-side pedestrian walk-way.
5. Pedestrians cross a transit mall at midblock locations despite signs warning that jaywalking is illegal. Pedestrians dart behind an LRV or a bus that has just passed and cross in front of a second LRV that is approaching from the opposite direction.
6. On pedestrian transit malls, young children dart out of stores along the mall onto the light rail track as LRVs approach at low speeds
7. On pedestrian transit malls where LRVs turn, pedestrians walk (in the same direction as the LRV) close to the tracks. Such pedestrians run the risk of being hit by the rear unit of the train because of the end overhang and/or the middle ordinate of the LRV.
8. At intersections along semi-exclusive, median-running rights-of-way, pedestrians cross travel lanes (parallel to light rail tracks) against the pedestrian signal as an LRV approaches the intersection. These pedestrians either stop in the middle of the roadway to let the train pass or try to beat out the train.

2.5 Motorist / Pedestrian Expectancy and LRT

This section outlines the impact to motorists expectancy followed by pedestrian expectancy in a later paragraph.

When motorist expectancy is violated, the motorist's perception of the situation is compromised. Certain ***accident types***, which may be a result of violations to motorist expectancy, have been identified for motorist-LRV conflicts. These ***accident types***, which have been previously identified above and taken from TRCP Report 17, are listed below:

1. Two-way side-aligned LRT operations on one-way or two-way streets confuse motorists and result in high accident frequencies. Typical problems include the following:
    i. Motorists are confused as to which way the LRV is approaching.
2. Motorists often violate the red left-turn traffic arrow when the leading left-turn traffic arrow indications are pre-empted by LRVs. Usually, this illegal movement is not a conscious choice on part of the motorist, who has simply learned to expect the green arrow indication before the through movement. Motorist expectancy is violated when the LRV pre-empts the leading left-turn phase at a signal.
3. Red time extensions resulting from multiple LRV pre-emptions cause motorists waiting to turn left across the LRT tracks to become impatient. This impatience develops further when the signals do not recover to the left-turn movements. (Typically, signal pre-emption strategies are designed to return to the cross-street traffic movement.) Often, motorists will assume that the traffic signal has malfunctioned and will then violate the signal.
4. Differences between standard and pre-empted traffic signal phase sequences violate motorist expectancy. For example, pre-emption of coordinated traffic signals in a grid network violates what motorists expect as they progress along cross-street arterials.
5. Motorists violate active and passive NO LEFT / RIGHT TURN signs, especially where left turns were previously allowed before the LRT system was constructed. Permanently prohibiting a traffic movement that was previously allowed disrupts normal, expected travel patterns.
6. Motorists confuse LRT signals with traffic signals, especially left-turn signals.
7. Motorists confuse LRT switch signals (coloured ball aspects) with traffic signals.

Similarly when pedestrian expectancy is violated, the pedestrian's perception of the situation is also compromised. Certain ***accident types*** may be a result of violations to pedestrian expectancy. These ***accident types***, which have been previously identified above and taken from TRCP Report 17, are listed below:

1. Pedestrians jaywalk across LRT rights-of-way, having received mixed messages about relative crossing ease from block to block.
2. Two-way side-aligned LRT operations on one-way or two-way streets confuse pedestrians and result in high accident frequencies. Pedestrians are confused as to which way the LRV is approaching.

2.6 Access Management

Each access point along the corridor should be reviewed to address potential safety conflicts at these locations. In particular special attention should be made to transition locations where the streetcar track alignment shifts from off-road (dedicated right-of-way) to on-street with vehicular and cyclist traffic. It should also be considered at busy driveways where left-turn movements may not be prohibited or protected by a signal.

TRCP Report 17 identifies ***risky behaviour patterns*** between motorists and LRV associated with mid-block accidents, and are listed below:

Mid-block Accidents:

1. On right-side running alignments, motorists (who travel left of the light rail track) turn right into driveways, crossing the LRT tracks as an LRV approaches from behind. This may occur despite active NO RIGHT TURN signs.
2. On side-running alignments, motorists exit unsignalized driveways and cross the light rail tracks as an LRV approaches.
3. As an LRV approaches a gated crossing, motorists violate flashing red lights and enter the crossing before the railroad gate arm physically blocks the crossing in semi-exclusive alignments.
4. At signalized intersections along transit mall cross-street motorists violate the red traffic signal indication in an attempt to beat out an LRV moving at low speed.

3. REVIEW OF PRELIMINARY DESIGN DRAWINGS

The preliminary safety audit of the preliminary design drawings for the proposed DHR alignment and the proposed Phase 0 alignment (Streetcar) are discussed on a section-by-section basis as well as for the overall system. The findings of the Literature Review were used as the basis to review the preliminary design drawings. Where possible, areas of concern where there may be future collision conflict have been identified.

3.1 Considerations for the Proposed DHR

The existing DHR alignment primarily operates as a single line track but with two sections of double track which operate as passing loops. The DHR alignment is to be relocated to a new central median as part of the redevelopment of South East False Creek. The segment along 1st Avenue from Cambie Street Bridge to Ontario Street is of primary concern for the design. (6)

The following table, **Table 3-1**, identifies potential safety concerns associated with the proposed DHR preliminary designs, and references the drawings supplied to iTRANS on November 5, 2007. In addition, specific comments have been marked up on drawings and attached (Attachment A). As mentioned in the introduction, it should be noted that the safety audit was limited to the information provided to iTRANS, and that there may be additional issues which we were not able to review at this time. We expect that in future phases of the project, we would be able to provide more in-depth review of the design characteristics of the Streetcar System.

Table 3-1: Proposed DHR Safety Considerations

Drawing No. & Name	Issue/Concern
Granville Island to Ash Street	
237388-T-101-DHR Base Alignment Plan	▪ Is trespassing an issue today? How is it prevented or deterred? Are there fences? ▪ With increasing frequency of LRVs, how will pedestrians or users be notified of increased service during weekday periods? ▪ What is the provision of pedestrian facilities at the Hemlock Street pedestrian overpass? Where is the access provided?
237388-T-102-DHR Base Alignment Plan & 237388T-103-DHR Base Alignment Plan	▪ How is trespassing prevented? Are there fences?
237388-T-104 - DHR Base Alignment Plan	▪ At-grade crossing at Moberly Street. Any warning / signals for motorists, pedestrians and cyclists for approaching streetcar? How are pedestrians prevented from crossing tracks when streetcar is approaching the station? ▪ With the surrounding vegetation, are pedestrian, cyclists and motorists' sight lines compromised? ▪ Are motorists turning right out of Moberly Street prevented from turning on red? What traffic control device is planned for Moberly Street and Lamey's Mill Road intersection: Stop-controlled or signalized?
Ash Street to 1st Avenue (Wylie Street)	
237388-T-105 - DHR Base Alignment Plan	▪ There is a pubic pedestrian crossing as noted in the plans: how are pedestrians warned of approaching streetcar? ▪ With increased frequency of the LRT service, how are pedestrians protected while crossing the tracks? Will there be alternate access points to the recreational facilities (tennis courts on the north side of the tracks)? ▪ Do existing trees compromise the conductor or pedestrians' sight lines?
1st Avenue from Wylie Street to Ontario Street	
237388-T-106 - DHR Base Alignment Plan	▪ How are pedestrians prevented or directed from crossing the tracks? ▪ With increased frequency of LRT service, how are cyclists, pedestrians and motorists accommodated? ▪ If median track is green/grass, what left-turn storage is provided for motorists or cyclists? ▪ Will left-turns be restricted for vehicles or cyclists crossing streetcar tracks? Without a protected left-turn phase, how are left-turn movements accommodated? ▪ There is concern that bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection? ▪ How are cyclists warned of approaching streetcars from behind? ▪ Motorists / on-road cyclists turning left will queue at median and possibly sit on tracks. What type of visibility would a conductor have of a cyclist sitting on the tracks?

Drawing No. & Name	Issue/Concern
	▪ How will the emergency vehicle (police) be pre-empted at this intersection and/or coordinated with the increased frequency of the LRT service? Will they have an exemption from the left-turning restriction? ▪ There is a serious concern with the lack of DHR signals for these locations; signals must be provided. ▪ Please refer to a marked up drawing for additional comments at intersection of 1st Avenue, Wylie Street and Commodore Road
237388-T-107 - DHR Base Alignment Plan	▪ How are pedestrians directed to / from the Cook Street Station? Are there barriers to restrict crossing at crosswalk? ▪ If median track is green/grass, what left-turn storage is provided for motorists or cyclists? ▪ Will left-turns be restricted outside of protected phase for vehicle or cyclists crossing streetcar tracks? ▪ Which locations have proposed dedicated signals to hold left-turn vehicles on 1st Avenue from crossing the streetcar? ▪ There is concern with bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection? ▪ How are cyclists warned of approaching streetcars from behind? ▪ What are the access points to the surrounding developments? Access points should be minimized. ▪ How are cyclists protected from right-turning vehicles? How are cyclists protected from vehicles encroaching into bike lanes? ▪ There is a serious concern with the lack of DHR signals for these locations; signals must be provided.
Ontario Street Intersection	
237388-T-108 - DHR Base Alignment Plan	▪ How are left-turning motorists and cyclists prevented from sitting on the streetcar track while waiting to make turns? ▪ With a stopped streetcar at Manitoba Street Station and potential left-turning motorist from 1st Avenue heading south queued in the median, what type of sight lines are available for left-turning motorist turning northbound onto Manitoba Street? ▪ There is a serious concern with the lack of DHR signals for these locations; signals must be provided. ▪ At entrance / road east of Manitoba Street is there a pedestrian crosswalk across 1st Avenue? Are pedestrians forced to cross at the crosswalk at the intersection? No details of the station are provided to show how pedestrian movements are directed. ▪ How do you prevent westbound traffic on First Avenue, east of Ontario Street, from sitting on the tracks past the stop bar east of the new DHR alignment? ▪ Please refer to a marked up drawing for additional comments
Ontario Street Intersection to Science World	
237388-T-110 - DHR Base Alignment Plan	▪ At the driveway entrance / exit to Science World; are motorists, pedestrians and cyclists warned of an approaching streetcar vehicle?
237388-E-141 - DHR Alignment Electrical Plan	▪ DHR Pre-emption signal display: Motorists travelling westbound on 1st Avenue turning south on Wylie Street. During the DHR pre-emption stage, how are these

Drawing No. & Name	Issue/Concern
	motorists informed if DHR is approaching from behind? Are left-turn movements prohibited during this phase?
237388-E-146 - DHR Alignment Electrical Plan	▪ DHR Pre-emption signal display: Motorists travelling eastbound on 1st Avenue turning north on Ontario Street. During the DHR pre-emption stage, how are these motorists informed if DHR is approaching from behind? Are left-turn movements prohibited during this phase?

3.2 Consideration for the Proposed Phase 0

The proposed phase 0 of the Vancouver Streetcar design is double-tracked for its entire length. The 1st Avenue median is to be constructed as a grass/green track. The majority of the track alignment follows that of the proposed DHR track alignment up until the Ontario intersection leading to Science World. At this location, for the proposed Phase 0, the track extends beyond the DHR alignment, up to the future maintenance yard.

The following table, **Table 3-2**, identifies potential safety concerns associated with the proposed Phase 0 preliminary designs, and references the drawings supplied to iTRANS on November 5, 2007. Comments that are still relevant from the DHR **Table 3-1** have been repeated for completeness. As mentioned in the introduction, it should be noted that the safety audit was limited to the information provided to iTRANS, and that there may be additional issues which we were not able to review at this time. We expect that in future phases of the project, we would be able to provide more in-depth review of the design characteristics of the Streetcar System.

Table 3-2: Proposed Phase 0 Safety Considerations

Drawing No. & Name	Issue/Concern
Granville Island to Ash Street	
237388-T-151 - Streetcar Base Alignment Plan	▪ How are pedestrians prevented from trespassing? Any existing fences? ▪ Is there any warning device (signage/signals/bells) to be used to warn pedestrians of the reverse movement of the streetcar upon departure? ▪ How are pedestrians made aware of which track is in use? How are they informed if the train crosses over to the other track? ▪ Where is the access to the pedestrian overpass by Hemlock Street? ▪ Are there any sidewalks or bike lanes provided on Lamey's Mill Road?
237388-T-152- Streetcar Base Alignment Plan	▪ How is trespassing prevented? ▪ With higher speeds and increased frequency of the LRT service, how are pedestrians protected from crossing the double tracks?
237388-T-153 - Streetcar Base Alignment Plan	▪ Access to Station to be reviewed. Are two side platforms being considered? ▪ How are pedestrians prevented from trespassing? Any existing fences? ▪ What pedestrian access is provided from the station to Lamey's Mill Road? How are pedestrians directed to cross the tracks to the north side?

Drawing No. & Name	Issue/Concern
	▪ Is there any warning for the second approaching streetcar?
237388-T-154 - Streetcar Base Alignment Plan	▪ At-grade crossing at Moberly Street. Any warning / signals for motorists, pedestrians and cyclists for approaching streetcar? How are pedestrians prevented from crossing the tracks when a streetcar is approaching the station? ▪ With the surrounding vegetation are pedestrian, cyclists and motorists' sight lines compromised? ▪ Are motorists turning right out of Moberly Street prevented from turning on red? Is Moberly Street and Lamey's Mill Road intersection stop-controlled or signalized? ▪ How are pedestrians prevented from crossing over the tracks from one platform to the other? How are pedestrians informed of a second approaching streetcar?
Ash Street to 1st Avenue (Wylie Street)	
237388-T-155 - Streetcar Base Alignment Plan	▪ At the public pedestrian crossing; how are pedestrians warned of approaching streetcars? How are pedestrians warned of approaching streetcar from the opposite direction? ▪ With the increased frequency of the LRT, how are pedestrians protected from crossing the tracks? Will there be alternate access points to the recreational facilities (tennis courts on the north side of the tracks)? ▪ Do existing trees compromise the conductor or pedestrians' sight lines?
1st Avenue from Wylie Street to Ontario Street	
237388-T-156 - Streetcar Base Alignment Plan	▪ What accommodations are made at the Cambie Street Station to provide warnings for approaching streetcars and to differentiate for the second approaching streetcar? ▪ How are pedestrians prevented or directed from crossing the tracks? ▪ Are LRT signals and / or LRT switch signals discernable from traffic signals? ▪ With increased frequency of LRT service, how are cyclists, pedestrians and motorists accommodated? ▪ What are cyclists' sight lines for approaching streetcars? ▪ If median track is green/grass, what left-turn storage is provided for motorists or cyclists? ▪ Will left-turns be restricted outside of a protected phase for vehicles or cyclists crossing over the streetcar tracks? ▪ Which locations have proposed dedicated signals to hold left-turn vehicles on 1st Avenue from crossing the streetcar? ▪ There is concern with bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection? ▪ How are cyclists warned of approaching streetcars from behind? ▪ How will the emergency vehicle (police) be pre-empted at this intersection and/or coordinated with the increased frequency of the LRT service? Will they have an exemption from the left-turning restriction? ▪ Please refer to a marked up drawing for additional comments at intersection of 1st Avenue, Wylie Street and Commodore Road:
237388-T-157 - Streetcar Base Alignment Plan	▪ How are pedestrians directed to / from the Cook Street Station? Are there barriers to restrict crossing at the crosswalk? ▪ If median track is green/grass, what left-turn storage is provided for motorists or

Drawing No. & Name	Issue/Concern
	cyclists? ▪ Will left-turns be restricted outside of protected phase for vehicle or cyclists crossing streetcar tracks? ▪ Which locations have proposed dedicated signals to hold left-turn vehicles on 1st Avenue from crossing the streetcar tracks? ▪ There is concern with bike's tires may get caught in the track; what is the surface of the tracks at the crossing to ensure traversibility at the intersection? ▪ How are cyclists warned of approaching streetcars from behind? ▪ How are cyclists protected from right-turning vehicles? How are cyclists protected from vehicles encroaching into bike lanes? ▪ What are the access points to the surrounding parking lots? Access points should be minimized.
237388-T-158 - Streetcar Base Alignment Plan	▪ How are pedestrians exiting at Manitoba Street Station prevented / directed from crossing the roadway or across the tracks? At entrance / road east of Manitoba Street is there a pedestrian crosswalk? Are pedestrians forced to cross at the crosswalk at the intersection? No details of the station are provided to show how pedestrian movements are directed. ▪ Concrete portion of median created to accommodate delivery vehicles. How are other vehicles, pedestrians or cyclists prevented from using this paved median for making turning movements? How are delivery vehicles controlled from entering / exiting when the streetcar is in operation? ▪ Potential conflicts with left-turning motorists and cyclists. Same concerns as noted for other intersections. ▪ Please refer to a marked up drawing for additional comments
Ontario Street Intersection to Science World	
237388-T-159 - Streetcar Base Alignment Plan	▪ Provision of sidewalk to be reviewed. Are there any barriers to prevent pedestrians / off-road cyclists from crossing over tracks to cross the street? Any warnings? ▪ Is sight distance adequate for the conductor and pedestrians/cyclists at the intersection of 1st Avenue and Quebec Street? ▪ How are pedestrians and off-road cyclists accommodated to cross over the tracks on 1st Avenue? Is there any warning for them during the streetcar-protected phase? ▪ Right turns on red must be prohibited for vehicles turning from Quebec Street onto 1st Avenue. How will drivers react at the intersection during all-red movements? Signalization is still being developed at this location.
237388-T-160 - Streetcar Base Alignment Plan	▪ Science World Entrance: How are vehicles entering Science World from Quebec Street protected / directed during turning movements into entrance? ▪ How are motorists exiting Science World protected from the streetcar? How are they prevented from sitting on the tracks? ▪ There is concern with the counterflow (onto one side of the cross section); what separation is provided to clearly meet the needs of the motorists with respect to glare and flow of traffic? ▪ What are the speeds along Quebec Street? Is there any potential for motorists to sideswipe the streetcar? ▪ What protection is provided for cyclists and pedestrians?

Drawing No. & Name	Issue/Concern
Science World to Quebec Street / Pacific Avenue & Streetcar Yard	
237388-T-161 - Streetcar Base Alignment Plan	▪ Science World station: what provisions are made to accommodate pedestrians crossing over tracks and crossing 1st Avenue to get to Terminal Avenue? ▪ Are sight lines for the conductor or pedestrians compromised because of the location of the Skytrain columns? ▪ What provisions/warnings are given to acknowledge a second oncoming streetcar? ▪ Science World car park or access roads? Limiting pedestrian access may encourage crossing the tracks at locations where crossing is not permitted. ▪ Please refer to a marked up drawing for additional comments
237388-T-162 - Streetcar Base Alignment Plan	▪ Pedestrian walkway: how are pedestrians notified of oncoming streetcars? ▪ Pacific Boulevard Station: How are pedestrians crossing over the streetcar tracks mitigated? ▪ How are pedestrians warned of second approaching streetcar? ▪ Warning should be provided of crossover switch location to pedestrians to inform which track the streetcar may be utilizing when crossing through the pedestrian walkway. ▪ Need to detail how the signal at National Avenue will operate.
237388-T-163 - Streetcar Base Alignment Plan	▪ Potential for serious conflicts with vehicles making turning movements off of or onto Quebec Street. ▪ Signalization should be reviewed to determine how to incorporate mixing the streetcar back into vehicle traffic to arrive at the maintenance facility ▪ Please refer to a marked up drawing for additional comments

3.3 Considerations for the Overall LRT System

In addition to the safety concerns identified above, the following is a list of questions and concerns that should also be considered in the next planning and design stage of the project. These comments are not specific to a particular segment, but instead should be considered for the overall system design. Refer to **Table 3-3** below.

Table 3-3 General Safety Considerations

Issue/Concern
General
▪ Along single DHR track, how will motorists, pedestrians and cyclists know which direction the streetcar is operating? Will they know to look ahead and behind when crossing the tracks?
▪ What type of access management is existing / proposed? Number of crossings should be minimized where possible.
▪ Need to review LRT design with respect to future traffic, pedestrian and cycle volumes with the redevelopment of the area.
▪ What is the design speed of the LRV?
▪ What are the operating speeds of traffic and the LRT on 1st Avenue and Quebec Street?

Issue/Concern
▪ What provisions are made for emergency services? How will coordination efforts between the emergency vehicles and the LRV take place if they are required to travel on the tracks?
▪ Sight distance. Location of platforms and surrounding buildings need to be reviewed with respect to sight distance.
▪ Need to review track surface type at intersections and associated safety for pedestrians and cyclists.
▪ With the variations in the alignment of the track (median, segregated, curb side), will motorist expectancy be violated?
Signals and Signage
▪ "No specific DHR signals provided at Crow, Cook, Columbia or Manitoba. DHR assumed to work with existing road traffic signals. To remove conflict with existing left turns at intersections it is assumed that DHR will approach the intersection 'at caution' – line of sight operation, and only cross when clear. Use of DHR bell/warning sound required."[(6)]
▪ "No specific DHR signals, but consideration will be given to additional signage/warning signals to road traffic. Left turns will have to undertake Stop manoeuvre and give way/yield to DHR." [(6)]
▪ How are pedestrians and cyclists accommodated without adequate signalization or warning of approaching streetcars? What pedestrian signals are being implemented?
▪ Are all pedestrian crossings signalized or unsignalized?
▪ Concern for handicapped, deaf or blind pedestrians. Are there audible pedestrian crossings? Tactile warnings?
▪ How do existing pedestrian signals function at LRT crossings?
▪ General public – how will they perceive the signals? Are LRT signals head discernable from traffic signals heads?
▪ How will the signals be implemented? Flashing lights versus traffic signals?
▪ How will signals be synchronized?
▪ What is the signage plan for motorists, pedestrians and cyclists?
▪ Conflicting messages to motorists from excess/cluttered signals and signage
Motorists
▪ Is there presence of any slow moving or turning truck traffic across tracks?
▪ Vehicles stopping on tracks, or encroaching on tracks?
▪ Are there any physical barriers that separate the streetcar from motor vehicles?
▪ Any on-street parking locations? How will they be maintained?
Pedestrians
▪ What provisions will be made to bring clarity about those locations where LRT transitions from off-road (dedicated right-of-way) to on-road.
▪ What provisions are made for pedestrians with special needs, i.e. blind, handicapped, or deaf
▪ LRT Platforms and channelization of pedestrians. Channelization of the median in the roadway to help direct pedestrians
▪ What is the existing accident rate of this system? Are there key locations/crossings that have a higher number of incidents/accidents?
▪ What are the proposed pedestrian volumes at major crossings?
▪ Pedestrian sight distance needs to be reviewed.
▪ Are pedestrian stopping locations clearly marked?

Issue/Concern
▪ Pedestrians may not be aware of a second approaching LRV when on the platform. They may associate the warning with the first LRV and not the second.
▪ Alignment/geometry of crossings - any angled crossings will be a cause for concern.
▪ What illumination is provided at station locations to assist pedestrians in safe crossings?
Cyclists
▪ Left-turning cyclists at intersections may have difficulty with wheels caught in street car tracks
▪ Cyclists have sometimes used areas to pull off the road to wait for streetcars to go by. Is there anywhere for cyclists to escape if vehicles encroached the bike lane?
▪ What treatments are provided for cyclists to provide advance warning of approaching trains or tracks ahead?

4. NEXT STEPS

Based on the preliminary safety assessment for the Vancouver Streetcar project, it is recommended that each of the potential safety concerns identified be considered in the next stage of planning and design.

References:

1) Korve, H. W., Farran, J. I., Mansel, D. M., Levinson, H. S., Chira-Chavala, T., and Ragland, D. R., "Integration of Light Rail Transit into City Streets." TCRP 17, (1996)

2) Korve, H. W., Ogden, B. D., Siques, J. T., Mansel, D. M., Richards, H. A., Gilbert S., Boni, E., Butchko, M., Stutts, J. C., and Hughes, R. G., "Light Rail Service: Pedestrian and Vehicular Safety." TCRP 69, Transportation Research Board, (2001)

3) TCRP Project A-30, "Improving Pedestrian and Motorist Safety Along Light Rail Transit Alignments.", iTRANS Consulting Ltd. (October 2006 – September 2008)

4) Kelly, R. W., "Are LRT At-grade Crossings Really Safe?" An Analysis of Vehicle/Train Accidents at Gated At-grade Crossings, Institute of Transportation Engineers 65th Annual Meeting, (1995) pp. 504-507.

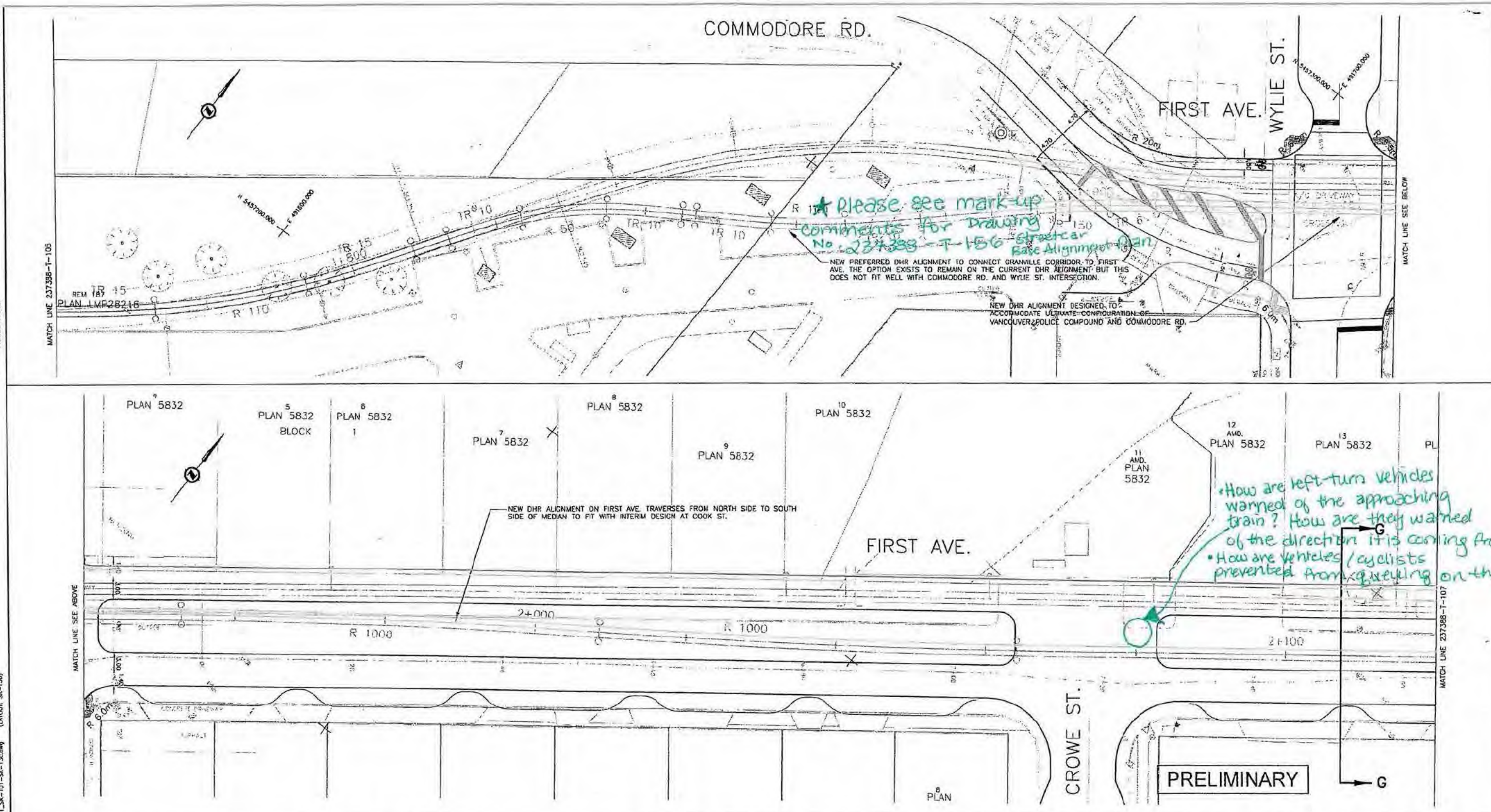
5) Farradyne, P. B., "Final Report for the Second Train Warning Sign Demonstration Project on the Los Angeles Metro Blue Line." FTA-CA-26-7017-01, Los Angeles, CA, US Department of Transportation, Federal Transit Administration, (1-10-2002) pp. 1-69.

6) "Downtown Streetcar Project, Preliminary Draft Design Report." Hatch Mott MacDonald, November 2007

7) "Southeast False Creek Transportation Study, Final Report. IBI Group in association with Ward Consulting and the Boulevard Transportation Group (November 2002)

8) McClintock, H., and Morris, D., "Integration of Cycling & Light Rapid Transit: Realising the Potential." World Transport Policy & Practice, Volume 9, Number 3, pages 9 to 14, (2003)

9) Irwin, D., "Safety Criteria for Light Rail Pedestrian Crossings." Tri-County Metropolitan Transportation District of Oregon, Transportation Research Circular E-C058: 9th National Light Rail Transit Conference. (November 2003)



ATTACHMENT A

DRAWING NUMBER	DRAWING TITLE
	REFERENCE DRAWINGS

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Hatch Mott MacDonald

DESIGNED BY: SM	DRAWN BY: SM
DATE:	DATE:
CHECKED BY: TS	PROJECT MANAGER: DSW
DATE:	DATE:
HMM PROJECT No: 237388	DWG SCALE FULL SIZE: 1:250 HALF SIZE: 1:500

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

DHR BASE ALIGNMENT PLAN

FROM STA. 1+760 TO STA 2+120

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237388-T-106		0

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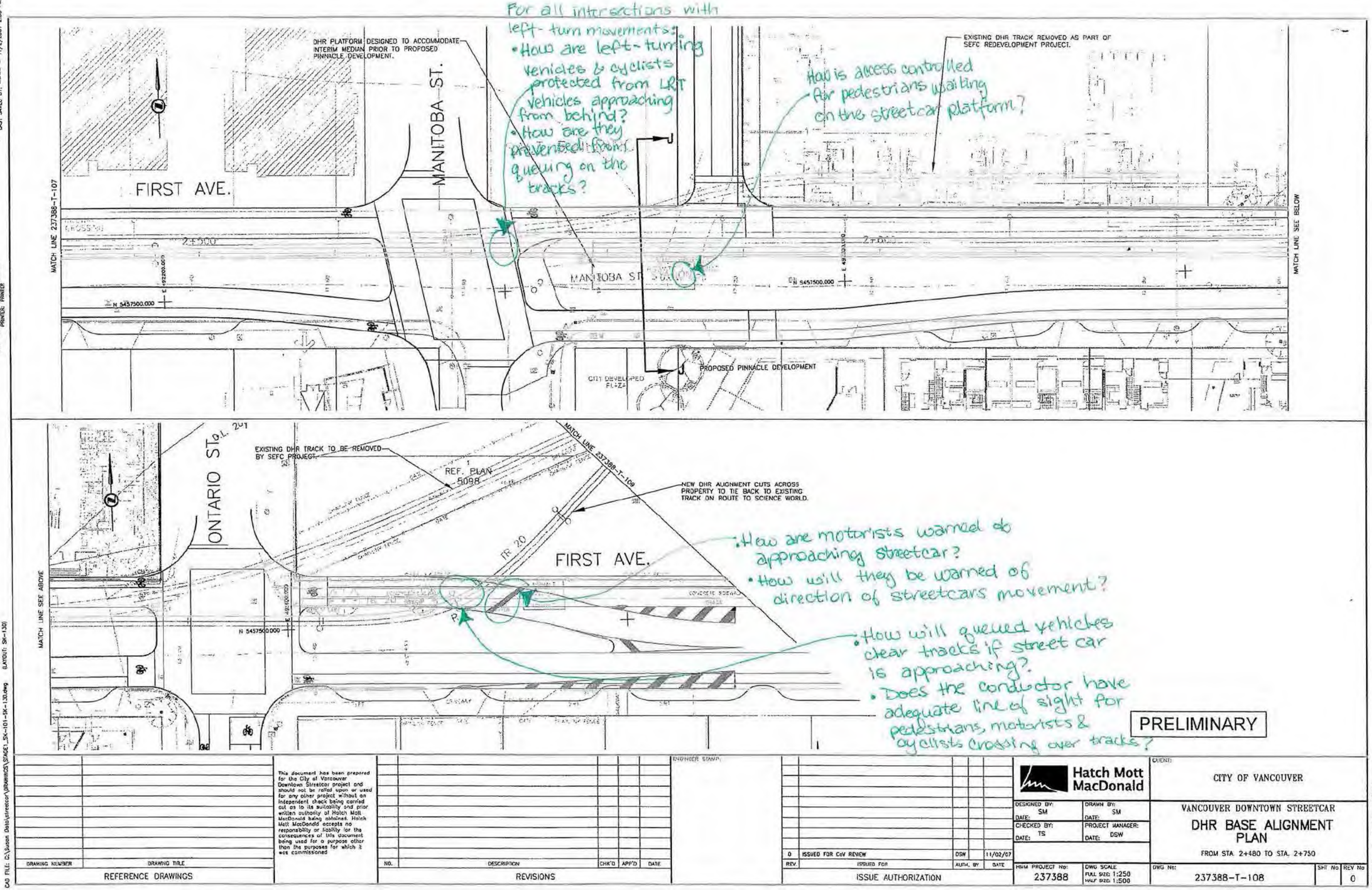

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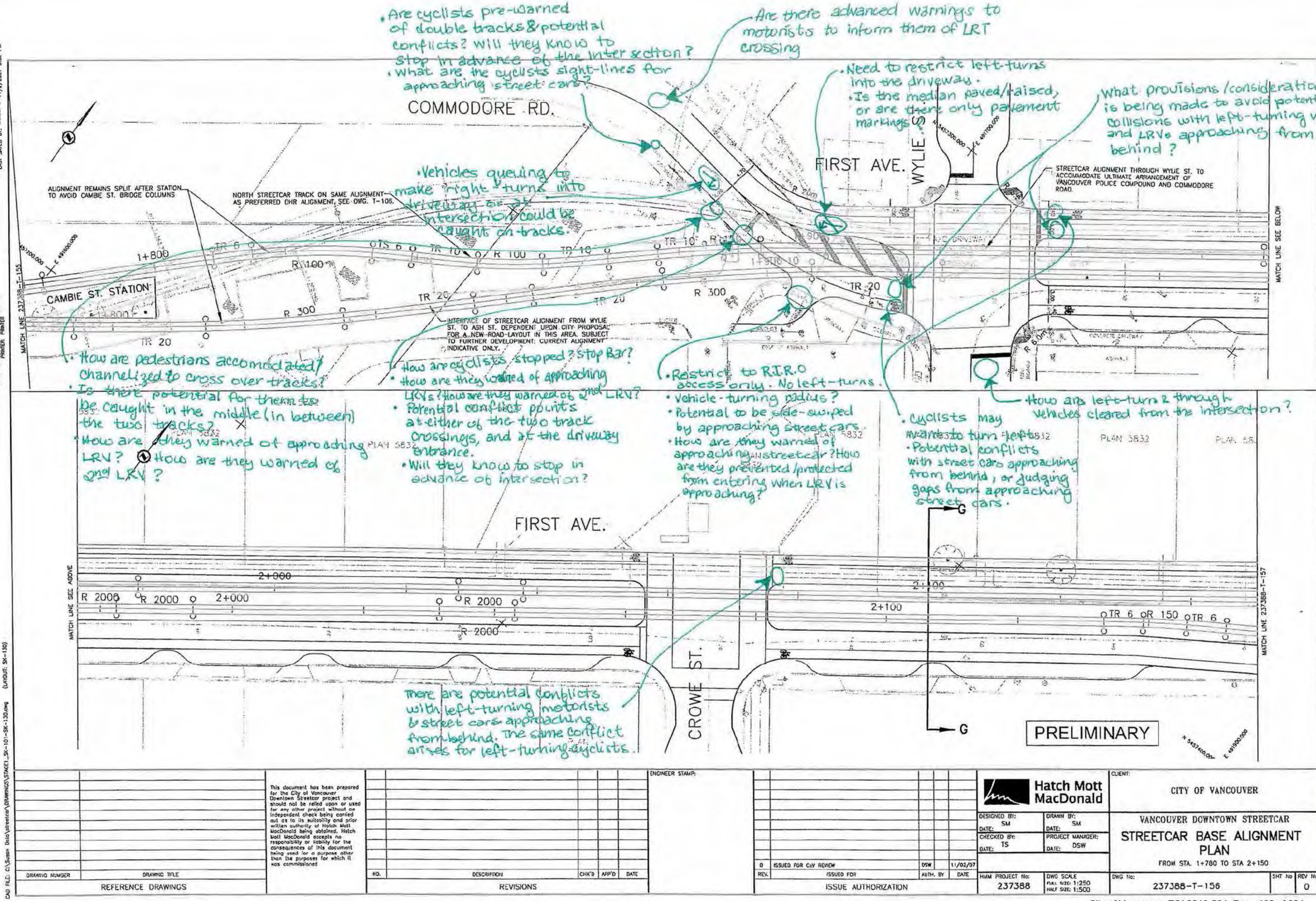

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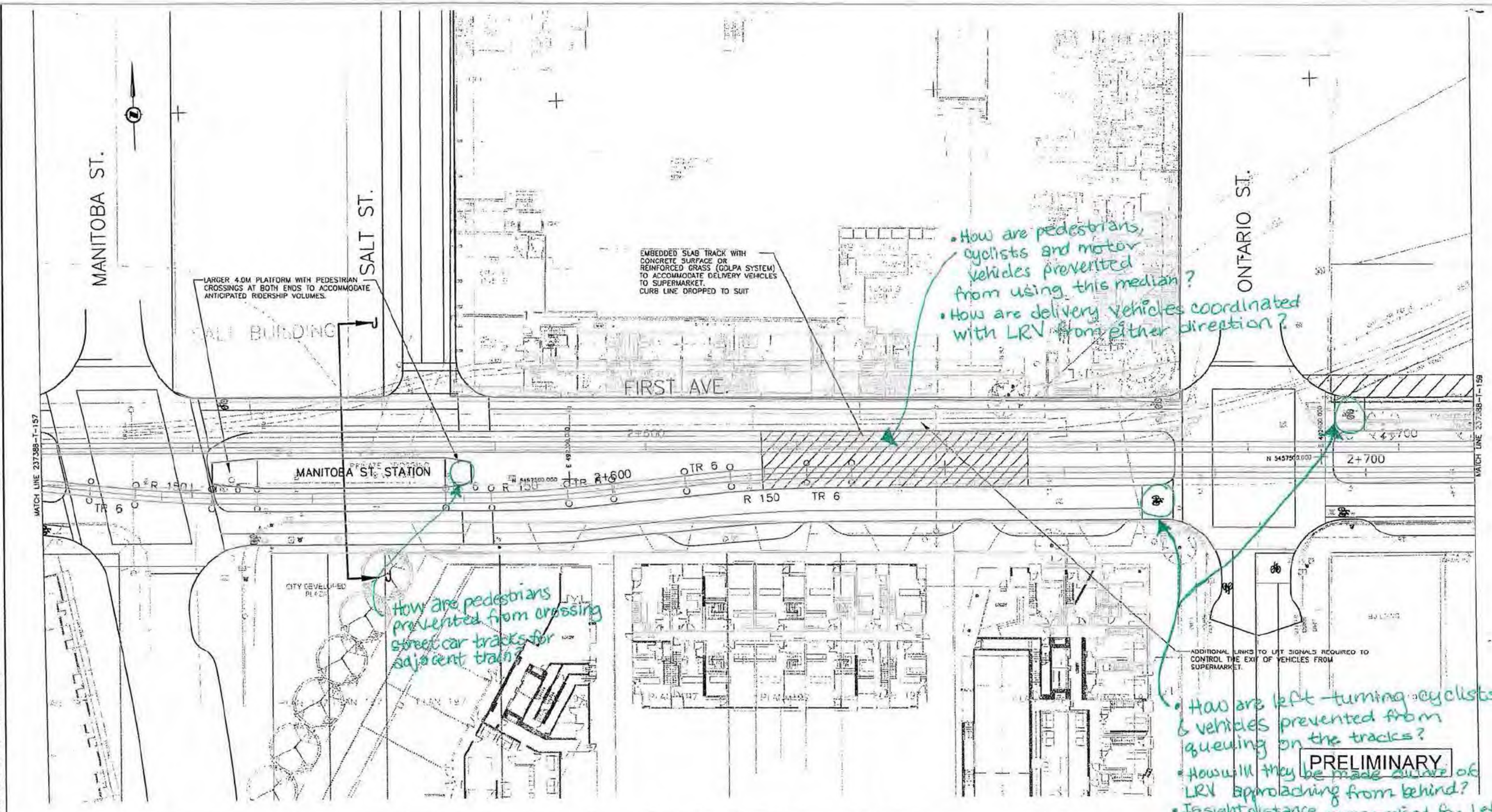

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CHECKED BY: TS DATE:	PROJECT MANAGER: DSW DATE:
HMM PROJECT No: 237388	DWG SCALE FULL SIZE: 1:250 HALF SIZE: 1:500

CLIENT: CITY OF VANCOUVER

VANCOUVER DOWNTOWN STREETCAR

STREETCAR BASE ALIGNMENT PLAN

FROM STA. 2+520 TO STA. 2+710

DWG No:	SHT No	REV No
237388-T-158		0

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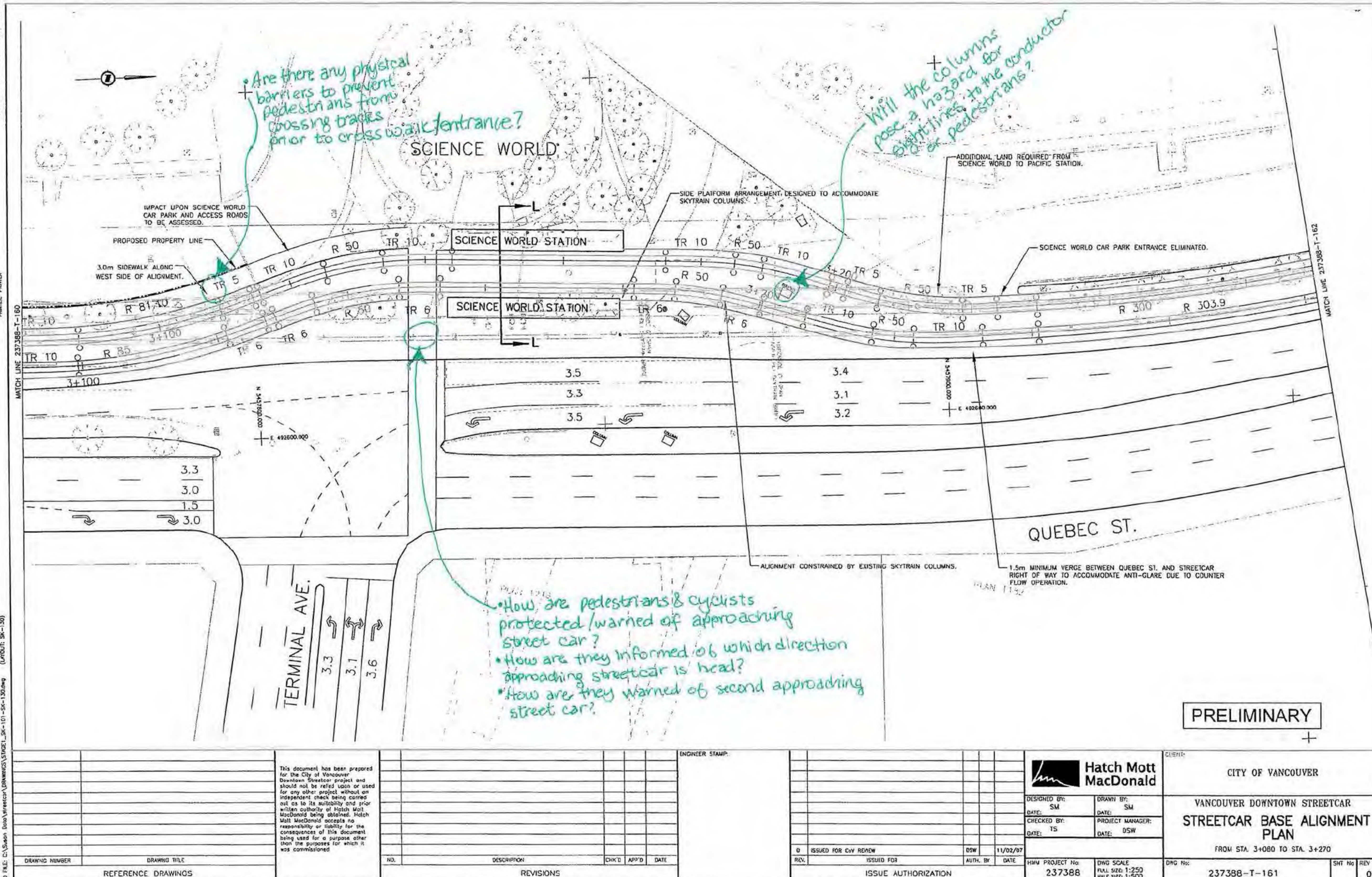

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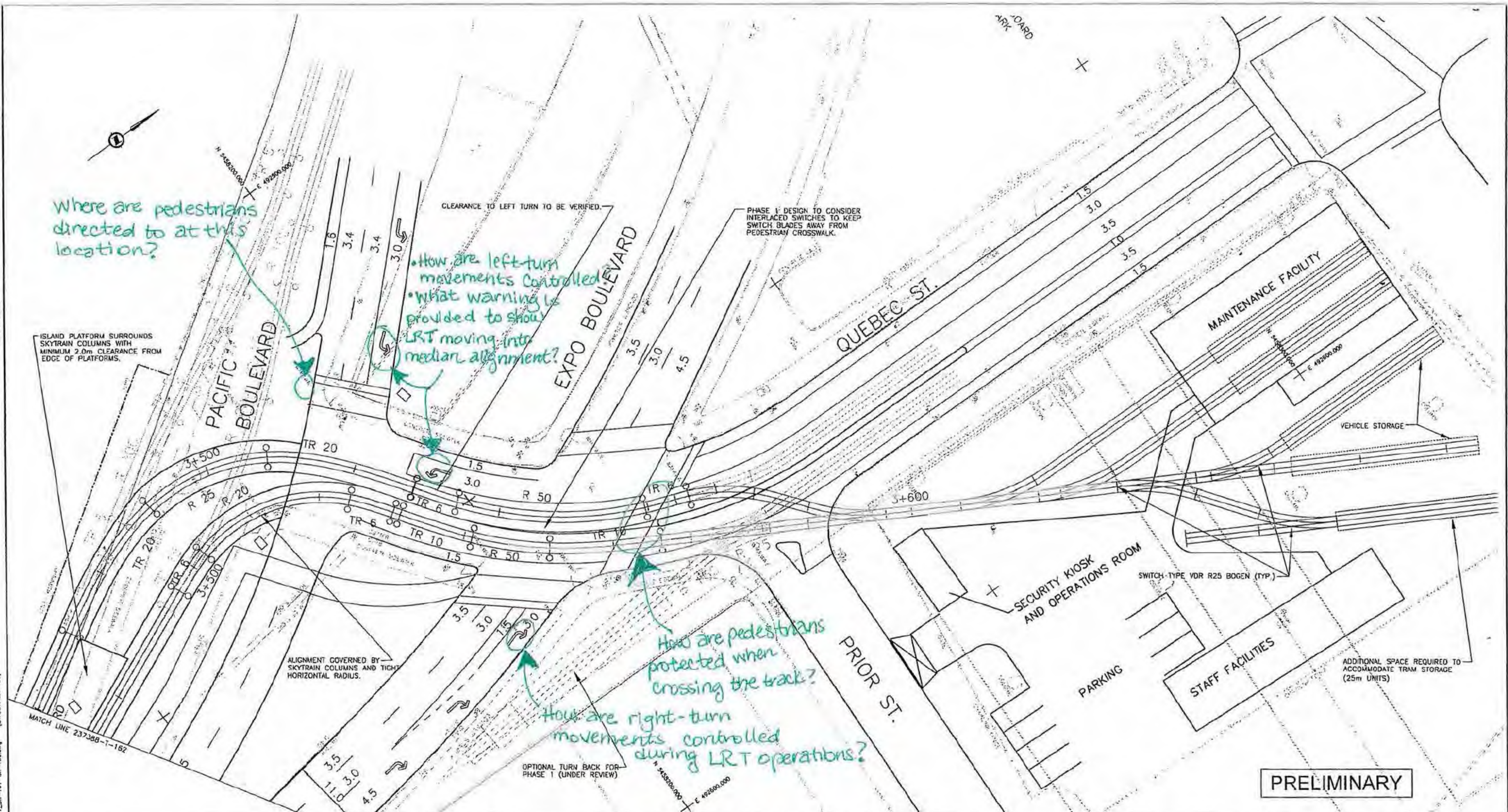

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HMM PROJECT No: 237388	DWG SCALE FULL SIZE: 1:250 HALF SIZE: 1:500

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VANCOUVER DOWNTOWN STREETCAR

STREETCAR BASE ALIGNMENT PLAN

FROM STA. 3+460 TO DEPOT

DWG No: 237388-T-163 | SHT No | REV No: 0

ATTACHMENT A

9

Appendix H Utility Review Summary

Vancouver Downtown Streetcar
Summary of Utility Relocation
2007/08/01
Trevor Skutezky
Hatch Mott MacDonald

Rev.	0

Notes:
1.All utilities without longitudinal profile are marked as possible conflict.
2. Conflicts identified assume that a drainage pipe will be placed between the tracks. See typical cross section in appendix C for details.

1ST AVENUE WORKS								
Cross Street	Service	Details	Cover	Station	Orientation	Existing or Proposed	Conflict (Y/N)	Comments
	BASED ON HMM DESIGN STATIONING FOR NEW ALIGNMENT							
Granville to Wylie	Water	150 diameter CI		0+075	Transverse	Existing	Maybe	Vertical information not provided
	Storm	375 diameter		0+078	Transverse	Existing	Maybe	Vertical information not provided
	Storm	900 diameter		0+220	Transverse	Existing	Maybe	Vertical information not provided
	Hydro	Unknown		0+399	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 diameter CI		0+588	Transverse	Existing	Maybe	Vertical information not provided
	Water	200 diameter CI		0+798	Transverse	Existing	Maybe	Vertical information not provided
	Gas	114 diameter (LIVE)		0+944	Transverse	Existing	Maybe	Vertical information not provided
	Water	200 diameter CI		0+992	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	300 diameter		1+108	Transverse	Existing	Maybe	Vertical information not provided
	Gas	88 diameter (DEAD)		1+110	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	300 diameter		1+111	Transverse	Existing	Maybe	Vertical information not provided
	Storm	1800 diameter		1+113	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	100 diameter		1+115	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 diameter CI		1+205	Transverse	Existing	Maybe	Vertical information not provided
	Hydro	Unknown		1+359	Transverse	Existing	Maybe	Vertical information not provided
	Gas	114 diameter (LIVE)		1+378	Transverse	Existing	Maybe	Vertical information not provided
	Phone	Unknown		1+435	Transverse	Existing	Maybe	Vertical information not provided
	Hydro	Unknown		1+437	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 diameter CI		1+438	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	1350 diameter Combined		1+479	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 Diameter		1+820	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 Diameter DI CL		1+843	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 diameter		1+844	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 diameter		1+855	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 diameter		1+870	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 diameter		1+875	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 diameter assumed		1+890	Transverse	Existing	Maybe	Vertical information not provided
	Water	300 Diameter DI CL		1+892	Transverse	Existing	Maybe	Vertical information not provided
	Storm	200 diameter assumed		1+902	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	375 diameter		1+905	Transverse	Existing	Maybe	Vertical information not provided
	Water	900 diameter CSP		1+915	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	750 diameter Force Main		1+916	Transverse	Existing	Maybe	Vertical information not provided
	STATION BASED ON FIRST AVENUE DESIGN STATIONING							
Wylie	Signals/COMMS	Wylie west signal;	0.6	0+100	Longitudinal	Proposed	Yes	0.6m deep typical PBA
	Sanitary	375 diameter		0+088 - 0+241	Longitudinal	Existing	No	
	Sanitary	450 diameter	1 8	0+101	Diagonal	Proposed	No	
	Water	300 diameter	0 8	0+105	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Heating	150 diameter	0 8	0+108	Zig Zag	Proposed	Maybe	New gradeline is not on drawing. 0.8m cover to existing
	Phone	Unknown	2	0+115	Transverse	Existing	No	
	Hydro	6-100 diameter	2 3	0+118	Transverse	Proposed	No	
	Signals/COMMS	Wylie East signal	0 6	0+118	Transverse	Proposed	Yes	0.6m deep typical PBA
	Storm	Unknown	0.35	0+120	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Water	150 service	0 8	0+135	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Storm	Unknown	0.35	0+148	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Water	150 diameter	1 0	0+163	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Water	100 diameter	1 0	0+173	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Storm	Unknown	0.35	0+183	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Manhole			0+190	Point	Existing	Yes	
	Storm	300 concrete		0+190 - 0+250	Longitudinal	Existing	No	
	Gas	60 diameter (DEAD)		0+222 - 0+242	Zig Zag	Existing	No	DEAD; spec removal
	Hydro	Unknown	Unknown	0+225	Transverse	Existing	Maybe	Invert Unknown.
	Storm	Unknown	0.35	0+239	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
Crowe	Hydro	6-100 diam	2 5	0+242	Transverse	Proposed	No	2.3m cover
	Signals/COMMS	Crowe west signal	0 6	0+242	Transverse	Proposed	Yes	0.6m deep typical PBA
	Heating	150 diameter	1.4	0+243	Transverse	Proposed	Yes	
	Sanitary	375 diameter	3 0	0+241	Transverse	Existing	No	
	Sanitary	525 diameter	4 0	0+244	Transverse	Proposed	No	Crowe Crossing
	Sanitary	600 diameter FORCE MAIN	3 2	0+245	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Sanitary	1500 diameter combined sewer	1 2	0+250	Transverse	Existing	Yes	No longitudinal section provided. Based on invert.
	Water	200 diameter	3	0+255	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Water	200 diameter	1 5	0+256	Transverse	Existing	Maybe	No longitudinal section provided. Based on invert.
	Phone	Unknown		0+259	Transverse	Existing	Maybe	
	Phone	6-100mm	2.1	0+259	Transverse	Proposed	No	

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Hatch Mott MacDonald

Rev. 0

Notes:
1.All utilities without longitudinal profile are marked as possible conflict.
2. Conflicts identified assume that a drainage pipe will be placed between the tracks. See typical cross section in appendix C for details.

1ST AVENUE WORKS									
Cross Street	**Service**	**Details**	**Cover**	**Station**	**Orientation**	**Existing or Proposed**	**Conflict (Y/N)**	**Comments**
	Storm	Unknown	0.35	0+264	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Sanitary	250 diameter	4 5	0+265 - 0+505	Zig Zag	Existing	No	
	Water	100 diameter	Unknown	0+288	Transverse	Existing	Maybe	Invert unknown
	Water	200 diameter	2	0+291	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Storm	Unknown	0.35	0+301	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Water	150 diameter	Unknown	0+307	Transverse	Existing	No	To be abandoned
	Storm	675 diameter		0+320 - 0+440	Longitudinal	Proposed	No	See typical cross section - Wylie to Columbia
	Storm	450 diameter concrete		0+250 - 0+360	Longitudinal	Existing	No	See typical cross section - Wylie to Columbia
	Storm	Unknown	0.35	0+342	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Storm	150 diameter		0+359	Zig Zag	Existing	Maybe	Need depth details
	Gas	168 diameter (DEAD)		0+359-0+485	Zig Zag	Existing	No	DEAD; spec removal
	Manhole			0+361	Point	Existing	Maybe	
Cook	Signals/COMMS	Cook West signal	0 6	0+368	Transverse	Proposed	Yes	0.6m deep typical PBA
	Sanitary	100 diameter	3 0	0+378	Diagonal	Existing	No	No longitudinal section provided. Based on invert.
	Storm	Unknown	0.35	0+388	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Storm	100 diameter storm connector		0+379	Diagonal	Existing	Maybe	Need depth details
	Storm	300 diameter		0+391 - 0+500	Longitudinal	Existing	No	To be abandoned
	Heating	150 diameter	0 9	0+395	Transverse	Proposed	Yes	
	Water	200 diameter	1 8	0+398	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Water	100 diameter	1 5	0+399	Transverse	Existing	No	To be abandoned
	Phone	6-100mm	2	0+403	Transverse	Proposed	No	
	Hydro	6-100 diameter		0+405	Transverse	Proposed	No	2.5m cover
	Sanitary	150 diameter	3 0	0+410	Transverse	Proposed	Maybe	No longitudinal section provided. Based on invert.
	Storm	Unknown	0.35	0+422	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Storm	Unknown	0.35	0+435	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Storm	Unknown	0.35	0+461	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Storm	375mm diameter	0 8	0+474	Transverse	existing	Maybe	No longitudinal section provided. Cover based on invert.
	Storm	375mm diameter	1 2	0+500	Transverse	Existing	Maybe	No longitudinal section provided. Cover based on invert.
	Storm	Unknown	0.35	0+500	Transverse	Proposed	Yes	CB lead, based on CoV standard CB detail
	Signals/COMMS	Columbia west signal	0 6	0+505	Transverse	Proposed	Yes	0.6m deep typical PBA
	Storm	600 diameter		0+505	Transverse	Proposed	No	Adequate depth
	Sanitary	200 diameter		0+505 - 0+805	Longitudinal	Existing	No	Outside of streetcar R.O.W. as per typical section
	Storm	550 diameter concrete storm		0+506 - 0+728	Longitudinal	Existing	No	To be removed
Columbia	Sanitary	900 diameter steel + cover (conc)	1 - varies	0+510 to 0+560	Zig Zag	Existing	Yes	GVRD FORCE MAIN: 150x900 concrete cover
	Signals/COMMS	Columbia east signal	0 6	0+522	Transverse	Proposed	Yes	0.6m deep typical PBA
	Sanitary	900 diameter steel + no cover (conc)	1- varies	0+560 - 0+900	Longitudinal	Existing	Yes	GVRD FORCE MAIN: No cover. Conflict with comm ducts
	Gas	Diameter unknown (DEAD)		0+510	Transverse	Existing	No	DEAD; Invert unknown, remove if conflicting
	Gas	168 diameter (DEAD)		0+511 - 0+712	Longitudinal	Existing	NO	DEAD; specify removal
	Storm	1800 diameter	3 0	0+513	Transverse	Proposed	No	Does not cross centreline
	Storm	200 diameter	2 0	0+515	Transverse	Existing	Maybe	No longitudinal section provided. Cover based on invert.
	Phone	24-100mm	2	0+515	Transverse	Proposed	No	
	Hydro	9-100 diameter ducts		0+519	Transverse	Proposed	No	Columbia crossing
	Water	300 diameter	2	0+519	Transverse	Proposed	No	Columbia crossing
		200 diameter	Unknown	0+522	Transverse	Existing	Maybe	Invert unknown
	Water	150 diameter	1	0+540	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Storm	Unknown	0 9	0+540	Transverse	Proposed	Yes	CB gallery lead
	Storm	Unknown	0 9	0+560	Transverse	Proposed	Yes	CB gallery lead
	Storm	Unknown	0 9	0+572	Transverse	Proposed	Yes	CB gallery lead
	Storm	Unknown	0 9	0+595	Transverse	Proposed	Yes	CB gallery lead
	Water	150 diameter	1 8	0+596	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Storm	Unknown	0 9	0+596	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Storm	100 diameter		0+607	Transverse	Existing	Maybe	No depth information provided.
	Phone	2-100mm	1.7	0+608	Transverse	Proposed	Maybe	Based on dwg.
	Signals/COMMS	Columbia-Manitoba Cross Over	0 6	0+625	Transverse	Proposed	Yes	Based on dwg.
	Water	150 diameter	Unknown	0+631	Transverse	Existing	Maybe	Invert unknown
	Storm	Unknown	0 9	0+632	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Phone	2-100mm	1.7	0+645	Transverse	Proposed	Maybe	Based on dwg.
	Storm	Unknown	0 9	0+659	Transverse	Proposed	Yes	Based on dwg.
	Hydro	Unknown		0+672	Transverse	Existing	Maybe	Invert unknown
	Sanitary	100 diameter	1 8	0+684	Transverse	Existing	No	To be abandoned
	Storm	100 diameter		0+685	Transverse	Existing	Maybe	No depth information provided.
	Storm	Unknown	0 9	0+701	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
Manitoba	Hydro	6-100 diameter	3	0+703	Transverse	Proposed	No	Manitoba crossing
	Heating	150 diameter	0 9	0+720	Transverse	Proposed	Yes	
	Signals/COMMS	Manitoba east signal	0 6	0+725	Transverse	Proposed	Yes	0.6m deep typical PBA
	Storm	Unknown	0 9	0+712	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Gas	168 diameter (DEAD)		0+712 - 0+875	Longitudinal	Existing	NO	Dead
	Phone	6-100mm	1 5	0+715	Transverse	Proposed	No	Manitoba Crossing
	Gas		1-1.2	0+718	Transverse	Proposed	Maybe	No longitudinal section provided. Cover based on invert.
	Gas	114 diameter	0.5-1.2	0+719 - 0+900	Longitudinal	Existing	Yes	
	Gas	114 diameter (DEAD)		0+720 - 0+900	Longitudinal	Existing	No	DEAD
	Water	300 diameter	0 8	0+725	Transverse	Proposed	Yes	Manitoba crossing
	Sanitary	200 diameter	2 5	0+726	Transverse	Existing	No	To be abandoned
	Storm	375 diameter	2	0+727	Transverse	Existing	Maybe	No longitudinal information proivded. Cover based on invert.

Vancouver Downtown Streetcar
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Trevor Skutezky
Hatch Mott MacDonald

Rev. **0**

Notes:
1.All utilities without longitudinal profile are marked as possible conflict.
2. Conflicts identified assume that a drainage pipe will be placed between the tracks. See typical cross section in appendix C for details.

1ST AVENUE WORKS								
Cross Street	**Service**	**Details**	**Cover**	**Station**	**Orientation**	**Existing or Proposed**	**Conflict (Y/N)**	**Comments**
	Storm	Unknown	0 9	0+740	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Water	150 diameter	Unknown	0+748	Transverse	Existing	Maybe	Invert unknown
	Storm	unknown	0 9	0+753	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Storm	Unknown	0 9	0+768	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Phone	2-100	1 8	0+773	Transverse	Proposed	Maybe	Based on dwg.
	Storm	Unknown	0 9	0+782	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Storm	Unknown	0 9	0+808	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Storm	Unknown	0 9	0+825	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
	Storm	Unknown	0 9	0+849	Transverse	Proposed	Yes	CB gallery lead, cover based on cross section
Ontario	Signals/COMMS	Ontario west signal	0 6	0+855	Transverse	Proposed	Yes	0.6m deep typical PBA
	Hydro	6-100 diameter ducts + cover		0+857	Transverse	Proposed	No	Ontario crossing
	Gas	Unknown		0+858	Transverse	Proposed	Maybe	No detals on depth of gas line
	Sanitary	200 diameter	2 5	0+861	Transverse	Proposed	No	Ontario crossing
	Heating	150 diameter	0 9	0+865	Transverse	Proposed	Yes	
	Phone	8-100mm	3	0+866	Transverse	Proposed	No	Ontario crossing
	Water	300 diameter	2 8	0+870	Transverse	Proposed	No	Ontario crossing
	Gas	168 diameter		0+871	Transverse	Existing	No	DEAD. Remove if conflict
	Signals/COMMS	Ontario east signal	0 6	0+872	Transverse	Proposed	Yes	0.6m deep typical PBA
	Storm	Unknown		0+873	Diagonal	Proposed	Yes	Inadequate information provided
	Storm	300 diameter		0+876 - Quebec	Transverse	Existing	Yes	
	Sanitary	900 diameter FORCE MA N	1 0	0+900 - 3+110	Longitudinal	Existing	Yes	Continuation of FM noted above - separated for notation only
	Sanitary	200 diameter	2 5	0+877	Diagonal	Proposed	Maybe	No longitudinal section provided. Based on invert.

Vancouver Downtown Streetcar

Summary of Utility Relocation

2007/08/01

Trevor Skutezky

Hatch Mott MacDonald

Rev. **0**

Notes:

1.All utilities without longitudinal profile are marked as possible conflict.

2. Conflicts identified assume that a drainage pipe will be placed between the tracks. See typical cross section in appendix C for details.

1ST AVENUE WORKS								
Cross Street	**Service**	**Details**	**Cover**	**Station**	**Orientation**	**Existing or Proposed**	**Conflict (Y/N)**	**Comments**
	BASED ON HMM DESIGN STATIONING FOR NEW ALIGNMENT - SOUTH TRACK							
1st Ave. to Maintenance Yard	Storm	300 diameter	2 5	2+700 - Quebec	Longitudinal	Existing	No	
	Sanitary	200 diameter	2	2+700 - Quebec	Longitudinal	Existing	No	
	Storm	100 diameter	0.25	2+720	Transverse	Existing	Yes	
	Sanitary	150 diameter	2 2	2+720	Transverse	Existing	No	
	Storm	100 diameter	2 2	2+748	Transverse	Existing	No	
	Sanitary	150 diameter	2 2	2+749	Transverse	Existing	No	
	Storm	100 diameter	2 2	2+762	Transverse	Existing	No	
	Sanitary	150 diameter	2 2	2+763	Transverse	Existing	No	
	Storm	100 diameter	1 5	2+795	Transverse	Existing	No	
	Sanitary	200 diameter	1 5	2+796	Transverse	Existing	No	
	Gas	26 diameter (DEAD)		2+820 - 2+840	Longitudinal	Existing	Maybe	Vertical information not provided
	Gas	88 diameter (LIVE)		2+820 - 2+840	Longitudinal	Existing	Maybe	Vertical information not provided
	Storm	600 diameter concrete	3	2+730 - 2+890	Longitudinal	Existing	No	
	Hydro			2+840 - 3+440	Longitudinal	Existing	Maybe	
	Gas	88 diameter (LIVE)		3+121 - 3+ 123	Longitudinal	Existing	Maybe	
	Gas	88 diameter (LIVE)		3+220 - 3+400	Longitudinal	Existing	Maybe	
	Sanitary	600 diameter FORCE MA N		3+110 - 3+125	Longitudinal	Existing	No	Assumed CoV Thorton Park Tie in
	Water	200 diameter DI CL		3+128	Transverse	Existing	Maybe	Vertical information not provided
	Hydro			3+142	Transverse	Existing	Maybe	No stationing from here to end; #s for now, add stations later
	Storm	2.7x3.4 concrete box	2	3+130	Transverse	Existing	No	
	Water	300 diameter		3+155	Transverse	Existing	Maybe	Vertical information not provided
	Sanitary	Unknown		3+162	Transverse	Existing	Maybe	Vertical information not provided
	Phone		1	3+175	Transverse	Existing	Yes	
	Hydro		0.75	3+185	Transverse	Existing	Yes	
	Gas	60 diameter	0.65	3+195	Transverse	Existing	Yes	
	Gas		0.19	3+215	Transverse	Existing	Yes	
	Gas	60 diameter	0 5	3+224	Transverse	Existing	Yes	
	Hydro		1	3+260	Transverse	Existing	Yes	
	Gas	42 diameter	0.75	3+310	Transverse	Existing	Yes	
	Storm	Unknown		3+315	Transverse	Existing	Maybe	Invert unknown
	Hydro		1 2	3+350	Transverse	Existing	yes	
	Gas	60 diameter	0.75	3+395	Transverse	Existing	Yes	
	Storm	Unknown		3+430	Transverse	Existing	Maybe	Invert unknown
	Storm	900 diameter concrete	3 5	3+559	Transverse	Existing	No	
	Sanitary	250 diameter	2 2	3+559	Longitudinal	Existing	No	Relocate to get out from under tracks
	Sanitary	600 diameter FORCE MA N	0.6 - 1.2	3+575	Longitudinal	Existing	Maybe	Relocate to get out from under tracks
	Phone	3-75 diameter PVC	1 2	3+570	Transverse	Existing	yes	
	Phone		1 2	3+575	Transverse	Existing	yes	
	Storm			3+538	Transverse	Existing	Maybe	Assume ties to 900 storm; conflict unlikely
	Sanitary	Unknown	2.1	3+538	Transverse	Existing	No	
	Water	Unknown	1		Transverse	Existing	Yes	Chainage unknown
	Hydro	streetlighting conduit		3+555	Transverse	Existing	Maybe	Vertical information not provided
	Phone			3+578	Transverse	Existing	Maybe	Vertical information not provided
	Phone			3+587	Transverse	Existing	Maybe	Vertical information not provided
	Water			3+580	Transverse	Existing	Maybe	Vertical information not provided
	Storm			3+573	Transverse	Existing	Maybe	Invert unknown
	Water			3+600	Transverse	Existing	Maybe	Invert unknown
Beyond Phase 0	Storm	600 diameter	1	No station	Transverse	Existing	Maybe	Confirm depth
	Signals/COMMS	METRONET COMM 3		No station	Transverse	Existing	Maybe	Invert Unknown
	Signals/COMMS	COMM		No station	Transverse	Existing	Maybe	Invert Unknown
	Storm		1 3	No station	Transverse	Existing	yes	
	Storm		1 3	No station	Transverse	Existing	yes	
	Storm			No station	Transverse	Existing	Maybe	Invert Unknown
	Hydro	Transmission conduits	1 5	No station	Transverse	Existing	No	
	Water	300 diameter DI (relcoated?)	1	No station	Transverse	Existing	Maybe	GVRD dwgs indicate WM to be relocated.
	Sanitary	200 diameter concrete encased	2 5	No station	Transverse	Existing	No	
	Storm	450 diameter concrete encased	3	No station	Transverse	Existing	No	
	Water		2 5	No station	Transverse	Existing	No	

Appendix I HMM Utility Conflict Memo

Hatch Mott MacDonald

1066 W. Hastings Street
Suite 1010
Vancouver, BC V6E 3X2
T 604.629.1736 www.hatchmott.com

Our ref 237388/2.1
Your ref

City of Vancouver
453 West 12th Avenue
Vancouver, BC, Canada
V5Y1V4

27 August 2007

Attention: Dale Bracewell

Dear Mr. Bracewell P. Eng.:

Re: Downtown Streetcar Project
DHR Baseline Design
1st Avenue – Wylie St. to Ontario St.

Further to our meeting on August 20th, we write to respond to some of the points raised. The comments are primarily addressed to the SEFC Project Team and require their comment.

Interface with Existing and Proposed 1st Avenue Utilities

HMM has reviewed the tender drawings for the proposed 1st Avenue works and has identified a number of potential utility conflicts. Two types of conflicts with existing or proposed utilities were identified: (a) conflict with proposed DHR/streetcar track bed, and, (b) conflict with the power and or communication ducting for a future streetcar.

In order to resolve these issues prior to the commencement of construction on 1st Avenue, HMM wishes to poses the following questions for SEFC Project Team's consideration and response:

1. HMM's preliminary design anticipates that in the order of 6 communication ducts and 2 traction power ducts will be required for the modern streetcar system. The ducts would typically be a 100-150mm diameter size, arranged 3x2 or 2x3 for the communication set, and 2x1 for the traction power. We have considered placing some of these in a dedicated duct bank along the centre of the median between the streetcar tracks. However, because of a number of existing and proposed utility and drainage crossings along 1st Avenue, this

would introduce a number of conflicts, resulting in a deeper and more complex duct bank configuration, which would ideally be installed during the forth coming 1st Avenue works.

To mitigate this conflict we would like to consider if it is possible to include the streetcar ducts in the duct banks proposed along the new sidewalks of 1st Avenue? (i.e. Communication ducts in the north sidewalk and traction power in the south sidewalk).

2. Additional information on some utilities is required in order for HMM to complete its assessment. The exact information required is attached to this letter as Appendix A.
3. Cover to some utilities was found to be as low as 0.35m. Has the SEFC design considered loading of the DHR and/or modern streetcar when designing utility cover and protection requirements? From our meetings we understand this to be a 'No', but would appreciate any comment that their design team may have on this matter.
4. Proposed and/or existing utilities may need to be relocated to simplify installation of streetcar infrastructure in the future. What stage is SEFC Project design at in negotiations with utility companies and award of contracts? Are changes to the utility design still possible at this stage?
5. The SEFC Project design proposes storm water infiltration galleries between Columbia Street and Ontario Street. Detail 1 on DWG SW-003 shows an impermeable liner around the upper part of the gallery, and a permeable area around the perforated pipe. HMM has been told this detail may have been modified. Please confirm.

Reinstatement of DHR Track

It was noted in the meeting of August 20th that the existing DHR track infrastructure is considered to be in a poor condition. Consequently, it is anticipated that when the DHR is reinstalled as part of the 1st Avenue work that the extent of track renewal will extend beyond the limits of the 1st Avenue corridor (where the track leaves Commodore Rd), in order to tie in with sound track. Acknowledgement from the SEFC Project Team of this issue is required.

Truck Turning Movements

HMM has proposed a number of curb modifications to the SEFC Project design along 1st Avenue in order to accommodate the future modern streetcar. At our meeting of August 20th, HMM was asked to confirm that WB15 truck turning movements were maintained, specifically at Manitoba. However, it appears that the SEFC Project design does not meet the WB15 turning criteria, and that the changes proposed by HMM does not alter (improve or worsen) that position significantly. Appendix B contains figures with the turning movements annotated for your consideration.

We look forward to your comments on the above issues and do not hesitate to call should you wish to discuss any of the points in greater detail.

Sincerely yours,
Hatch Mott MacDonald

David Wright, CEng MICE
Associate

6046291736
david.wright@hatchmott.com

Appendix A: Potential Utility Conflicts

Existing Utilities		
Utility	**Details**	**Issue**
Water	Transverse pipes (11) at station: 0+105, 0+135, 0+163, 0+173, 0+255, 0+256, 0+288, 0+291, 0+398, 0+631, 0+748	Slope or second invert required to determine cover. Based on inverts as low as 0.8m, some conflicts are anticipated.
Sanitary	GVRD force main	Inverts and/or cover required along the length of the pipe.
Sanitary	600 diameter transverse pipe at Crowe (1), station 0+245.	Slope or second invert required to determine cover.
Storm	Transverse pipes (8) at station: 0+359, 0+379, 0+474, 0+500, 0+515, 0+607, 0+685, 0+727, 0+876	Slope or second invert required to determine cover. Based on inverts as high as 0.8m, some conflicts are anticipated.
Hydro	Transverse (2) at Crowe St. (0+225) and Manitoba St. (0+672)	Inverts required to determine cover.
Telephone	Transverse (1) at Cook St. (0+259)	Inverts required to determine cover.
Gas	Longitudinal between Manitoba St. and Ontario St. (1)	Additional inverts required to determine cover along length. Based on inverts as high as 0.5m, some conflicts are anticipated.

Proposed Utilities		
Utility	**Details**	**Issue**
Water	Transverse water main (1) at Manitoba St. (0+725):	0.8m cover.
Water	Transverse service pipes (5) at station: 0+255, 0+291, 0+398, 0+540, 0+596	Slope or second invert required to determine cover. Based on inverts as high as 1.0m, some conflicts are anticipated.
Sanitary	Transverse (2) pipes, 0+410, 0+877	Slope or second invert required to determine cover. Based on inverts of 2.5m and 3.0m, no conflicts are anticipated.
Storm	Proposed CB leads (14), Wylie to Columbia.	Based on CoV standard CB detail and tender drawings, anticipated cover expected at 0.35m. This appears low.
Storm	Proposed Infiltration Gallery Leads (16), Columbia to Ontario.	Based on tender drawings, anticipated cover at about 0.8m – 1.0m.
Telephone	Transverse (1) at Manitoba St. (0+715)	Anticipated cover 0.75m.
Telephone	Transverse (3) at station. 0+608, 0+645, 0+773	Slope or second invert required to determine cover. Based on inverts as high as 1.7m, no conflicts are anticipated.
Signals	Transverse (10)	Typical cover 0.6m. Please confirm depth.
Gas	Transverse at Manitoba St. and Ontario St.	Additional information required.

Appendix J GVRD Force Main Relocation Options

Memo

Stantec Consulting Ltd.
10th Floor 13401 - 108th Avenue
Surrey BC V3T 5T3
Tel: (604) 587-8400
Fax: (604) 587-8489

Stantec

To:	Wally Konowalchuk, P.Eng. SEFC Project Office	From:	Garry Romanetz, P.Eng., Max Coupland, AScT Stantec Consulting Ltd.
cc:	Dale Bracewell, P.Eng. City of Vancouver	Date:	January 22, 2008
File:	111700218-C111-C		

Subject: **Southeast False Creek and Olympic Village**
Contract No. C111 – First Avenue Reconstruction
Forcemain Relocation – Functional Design Memorandum
Updated January 22, 2008 – Final Report

1.0 Introduction

Stantec Consulting has been retained to prepare a Functional Design Memorandum outlining options for potential relocation of a 900 mm ϕ ductile iron forcemain along First Avenue in the City of Vancouver.

2.0 Existing Conditions

2.1 Existing Forcemain

A 900 mm ϕ forcemain currently extends along First Avenue from Quebec Street westward to Columbia Street. This is detailed in **Figure 1.0** in **Appendix A**. This forcemain continues south along Columbia Street to Second Avenue. The characteristics of forcemain are as follows:

i) 900 mm ϕ

ii) Pipe material = Ductile Iron

iii) Unrestrained Joints, excepting at bends

iv) Depth with cover = ± 1.0 m from existing ground

v) Concrete encasement at the First Avenue / Columbia Street Intersection

vi) Location = + 8.60 m South of existing North Property line of First Avenue

vii) Year of Construction = 1999

2.2 Geotechnical

A predesign geotechnical investigation has been completed by Levelton Consultants. A copy of this report is included in **Appendix B**.

The main findings of this report are as follows.

i) Over excavation is required and will generally be 0.8 m to 1.5 m depth to remove existing unsuitable materials, except in the vicinity of Manitoba to Ontario Streets along the old foreshore, where the depth could extend to 4.5 m.

ii) Backfill materials should consist of clean free draining sand compacted to 95% Modified Proctor.

iii) Settlement of the GVRD forcemain, and DHR railway is estimated at 25-30 mm within most areas. An exception is the Manitoba to Ontario Streets area along the old foreshore where settlement is estimated at 50-100 mm without alternative means.

3.0 Proposed Works / Utility Corridors / Construction Methodology

3.1 Proposed Works

First Avenue is to be reconstructed as part of Contract No. C111. This Contract has recently been awarded to BEL Contracting. Construction started December 04, 2007 . The existing 900 mm ϕ forcemain is currently located beneath an existing asphalt roadway. The ultimate cross-section along First Avenue is detailed on **Figure 2.0**. Key component of this ultimate roadways are as follows.

i) 20.6 mm ROW plus 4.0 m setback along the North Property line and a 0.80 m setback (future right-of-way) along the South Property line.

ii) A 4.40 m wide west bound roadway.

iii) A 4.40 m wide east bound roadway plus a 2.50 m parking bay.

iv) A 7.10 m street car corridor.

v) An existing gas, watermain, sanitary sewer, storm sewer and GVRD forcemain (offsets vary).

New street lightings, a GCOM duct bank, watermain and DHS (District Heating System) have been proposed in the north half of the proposed First Avenue RoW. New storm and sanitary sewers, street lighting and a hydro duct bank have been proposed for the south half of the proposed First Avenue RoW. The existing 900 mm ϕ forcemain was to remain beneath the ultimate 6.90 m wide street car corridor.

The current construction methodology for Contract No. C111 is based upon the ability to install new utilities and replace existing utilities within a limited right of way while maintaining both utility services to existing buildings and both pedestrian and vehicle traffic. This generally includes construction of the northern half of the First Avenue roadway with new utilities. This will allow the existing watermain on the southern half of First Avenue to be abandoned. Installation of storm / sanitary sewers are also required.

4.0 Forcemain Replacement Options

4.1 General

This functional design memorandum addresses options for the potential relocation of the existing 900 mm ϕ forcemain.

The three areas being considered are as follows:

i) **Area A - Manitoba Street to Ontario Street**

ii) **Area B - Columbia Street to Manitoba Street**

iii) **Area C - Ontario Street to Quebec Street**

The forcemain area limits are detailed on **Figure 3.0.** Four (4) options are provided within this report for Area A. This is due to the existing wood waste/ unsuitable fill material zone located between Manitoba and Ontario Streets. There is also a settlement concern to both the DHR and forcemain.

The forcemain replacement within Area B and C, does not involve over excavation or removal of unsuitable materials below the GVRD forcemain.

4.2 Forcemain Design Criteria

In keeping with the original design, the forcemain replacement materials will be 900 mm ϕ Ductile Iron Pressure Class PC 150 cement mortar and lined pipe with polyethylene encasement. Joint restraints will be used along the pipe where the forcemain is installed on imported fill and where required for bends and tie-in points.

Flow requirements for the bypass have been provided by the City of Vancouver as outlined in the September 24, 2007 email to Stantec. A bypass system is expected to handle 12,000 USGPM based upon the GVRD being able to re-direct flows from the Columbia Pump Station. In addition this email requests that the bypass pipe be of the same diameter or multiple pipes with equivalent capacity as the existing 900 mm ϕ forcemain.

Bypass of the existing forcemain or abandonment of the existing forcemain will require the utilization of stopple devices via "hot taps" at either end of the section of pipe to stop the flows. Adjacent to the stopple, secondary hot tap connections with isolation valves to connect the bypass or ultimate pipe to the existing forcemain will also be installed. Pricing for the hop tap connections have been based upon installation of 600 mm ϕ hot tap valves and reducers to connect to the pipe.

4.3 Area A – Option 1: Original Concept

The original scope of work tendered in Contract No. C111 included protecting the existing GVRD forcemain in its current location which would be located in the ultimate First Avenue median. The work also includes provisions for protecting the existing Pinnacle building along the south property line. No excavation of the wood waste / unsuitable below the track area and forcemain area was planned within this contract. Mitigation of potential settlement was to be reviewed and alternates such as lightweight fill and flexible joints for utilities were to be further evaluated. The conceptual plan for this work along First Avenue is detailed on **Figure 4.0**. The scope of work for this option is as follows:

i) Install Sheetpile Walls #1, #2 and #3.

ii) Excavate entire road right of way to remove wood waste / unsuitable fill materials, "<u>except</u>" the area adjacent to the existing 900 mm ϕ forcemain area between Sheetpile Wall #1 and #2.

iii) Construct new utilities and roadway.

Please note, the scope of work for Option 1 was not accepted by the various approving authorities.

4.4 Area A – Option 2: Reinstatement at Existing Alignment

With this option, the existing 900 mm ϕ forcemain is to be removed and re-instated at its current location with the ultimate First Avenue roadway median. The proposed works generally include removal of existing wood waste/ unsuitable materials to mitigate settlement of the existing forcemain or the proposed DHR above. The conceptual plan for this work along First Avenue is detailed on **Figure 5.0**. The scope of work for this option is summarized as follows:

i) Install Sheetpile Walls #1 and #3 only.

ii) Remove wood waste / unsuitable fill materials from the north side of right of way only.

iii) Construct new utilities and roadway (north side).

iv) Install stopple and hot tap valve connection at either end of Area A. Install temporary 900mm ϕ HDPE forcemain on top of north roadway surface. Roadway traffic will be shut down during this work.

v) Bypass flows to temporary forcemain, remove and salvage existing D.I. forcemain.

vi) Excavate southern roadway to remove wood waste / unsuitable fill materials. Backfill area within GVRD corridor.

vii) Re-install salvaged D.I. forcemain. Remove stopples and re-introduce flows to forcemain. Remove temporary forcemain and blind flange hot tap valve locations.

viii) Construct remaining new south side utilities and roadway.

A similar option of reinstatement at the existing alignment utilizing limited sections of open cut excavation with support of existing utilities from overhead beams was not evaluated. Preliminary discussions with contractors regarding the site interferences, location of existing utilities and staging requirement of the project suggested this construction methodology is not viable.

Please note, Option 2 does not optimize reinstatement of the forcemain in the south boulevard, which may minimize future access issues along the street car corridor.

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4.5 Area A – Option 3: South Boulevard Alignment - Pinnacle Stays

This option involves installation of a new 900 mm ϕ forcemain along the south boulevard between Station 0+735 to 0+855 and abandonment of the existing 900 mm ϕ forcemain under the roadway median. The option also considers that the existing Pinnacle buildings located along the southern property line will remain in place and be protected (with the installation of a sheet pile wall to accommodate removal of existing wood waste). The conceptual plan for this work along First Avenue is detailed on **Figure 6.0**. The scope of this option is summarized as follows:

i) Install Sheetpile Walls #1 and #3 only.

ii) Remove wood waste / unsuitable fill materials from the north side of right of way only.

iii) Construct new utilities and roadway (north side).

iv) Excavate limited southern portion of roadway adjacent to the building to remove wood waste / unsuitable fill materials and allow installation of BC Hydro duct bank and new 900 mm ϕ forcemain. Install Sheetpile Wall #2 only if required by the geotechnical engineer to protect the existing GVRD forcemain / City of Vancouver utilities, if 2:1 cut slope is not achievable.

v) Install BC Hydro duct bank and new 900 mm ϕ forcemain. Backfill southern portion of roadway adjacent to building.

vi) Install stopple and hot tap valve connection at either end of Area A. Tie new forcemain to existing pipe at hot taps and divert flows. Install caps on abandoned section and removal stopples.

vii) Complete remainder of south side wood waste / unsuitable material excavation and construct remaining new south side utilities and roadway.

4.6 Area A – Option 4: South Boulevard Alignment - Pinnacle Goes

This option involves installation of a new 900 mm ϕ forcemain along the south boulevard between Station 0+735 to 0+855 and abandonment of the existing 900 mm ϕ forcemain under the roadway median. The option also assumes that the existing Pinnacle buildings located along the southern property line will be demolished and the contractor is able to back slope the excavation onto private property. The conceptual plan for this work along First Avenue is detailed on

Figure 7.0. The excavation (backslope) concept onto private property is detailed on **Figure 8.0**. The scope of this option is summarized as follows;

i) Install Sheetpile Wall #1 only.

ii) Remove wood waste / unsuitable fill materials from the north side of right of way only.

iii) Construct new utilities and roadway (north side).

iv) Excavate limited southern portion of roadway sloping onto adjacent Pinnacle site to remove wood waste / unsuitable fill materials and allow installation of BC Hydro duct bank and new 900 mm ϕ forcemain. Install Sheetpile Wall #2 only if required by the geotechnical engineer to protect the existing GVRD forcemain / City of Vancouver utilities, if 2:1 cut slope is not achievable.

v) Install BC Hydro duct bank and new 900 mm ϕ forcemain. Backfill southern portion of roadway.

vi) Install stopple and hot tap valve connection at either end of Area A. Tie new forcemain to existing pipe at hot taps and divert flows. Install caps on abandoned section and removal stopples.

vii) Complete remainder of south side wood waste / unsuitable material excavation and construct remaining new south side utilities and roadway.

4.7 Area A – South Boulevard Alignment and Cut Slope Cross Section

The south boulevard cross section showing the Area A ultimate forcemain alignment and interaction of utilities and cut slope for Option 4 is detailed on **Figure 8.0 and 9.0**. The forcemain will be located generally at 2.6 m depth, providing a minimum of 0.5 m vertical separation to the proposed tree root ball and soil cells above. The profile of the forcemain will be adjusted to suit the existing property service connections and utility crossings at Manitoba and Columbia Streets.

4.8 Area B – South Boulevard Alignment

Area B involves installation of a new 900 mm ϕ forcemain along the south boulevard between Station 0+505 to 0+735 and abandonment of the existing 900 mm ϕ forcemain under the roadway median. The costs represented for Area B are for only the additional cost to install the forcemain, as Area A costs account for tie-ins.

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4.9 Area C – South Boulevard Alignment and Utility Cross Section

A preliminary cross section showing the Area C forcemain along the south boulevard and interaction of existing and proposed utilities is detailed on **Figure 10.0**. Similar to Areas A and B, the forcemain will be located generally at 2.6 m depth, providing a minimum of 0.5 m vertical separation to the proposed tree root ball and soil cells above. The profile of the forcemain will be adjusted to suit the existing property service connections and larger utility crossings at Ontario and Quebec Streets.

4.10 Area C – South Boulevard Alignment

Area C involves installation of a new 900 mm ϕ forcemain along the south boulevard between Station 0+850 to 1+000 and abandonment of the existing 900 mm ϕ forcemain under the future roadway median. The costs represented are for only the additional cost to install the forcemain, as Area A costs account for tie-ins.

An existing 300 mm ϕ watermain currently is in place at an offset of 5.3 to 5.6 m north of the existing south property line of First Avenue. A corridor for the proposed forcemain has been set at 3.30 m north of the existing south property line. A preliminary review suggest that on an interim measure the existing 300 mm ϕ watermain could remain in place providing the existing joints are wrapped and the watermain is protected during construction. Please note, the proposed ultimate corridor for the watermain is 2.15 m south of the existing north property line. Ultimate watermain design and construction in Area C may best be delayed to coincide with area redevelopment, ultimate roadway construction and other municipal utility works (i.e. storm and sanitary sewers) proposed for the area.

5.0 Opinion of Probable Cost

5.1 Overview

Opinion of probable costs have been provided for each of the four (4) forcemain relocation options outlined for Area A above. Separate costs has been identified to complete Areas B and C. The forcemain cost breakdowns are included in **Appendix C** and are summarized in **Table A**.

The cost opinions provided are based upon historical contract rates and budgetary forcemain stopple and hot tap costs including 600 mm valve provided by Pacific Flow Control.

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All costs are in 2007 $'s, and include a separate 40% engineering and contingency allowance. No allowance has been made for City of Vancouver, GVRD costs or the GST.

TABLE A – SUMMARY OF OPINION OF PROBABLE COSTS

	Option 1 (Original Concept (1))	**Option 2** (Reinstate at Existing Alignment)	**Option 3** (South Boulevard Alignment Pinnacle Stays)	**Option 4** (South Boulevard Alignment Pinnacle Goes)
Area A	$ 1,157,800	$ 1,522,500	$ 1,288,000	$ 938,000
Provisional Sheet Piling Cost	n/a	n/a	$ 350,000	$ 350,000
Area A – Subtotal	**$ 1,157,800**	**$ 1, 522,500**	**$ 1,638,000**	**$ 1,288,000**
Area B	n/a	n/a	$ 322,000	$ 322,000
Area C	n/a	n/a	$ 210,000	$ 210,000
Total Cost (not including GST)	n/a	n/a	**$ 2,170,000**	**$ 1,820,000**

- **Area A - Manitoba Street to Ontario Street**
- **Area B - Columbia Street to Manitoba Street**
- **Area C - Ontario Street to Quebec Street**

1) Option 1 has not been approved by all parties.

Additional costs associated with repair of the track structure in the event of a forcemain failure under the street car system is included in **Appendix D**.

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We trust the enclosed Functional Design Memorandum addresses options to relocate the GVRD forcemain along First Avenue from Columbia to Quebec Streets.

If you have any questions or require additional information please do not hesitate to contact the undersigned at your convenience.

STANTEC CONSULTING LTD.

Garry K. Romanetz, P.Eng.
Managing Principal
garry.romanetz@stantec.com

Attachment:	Appendix A	–	Figures
	Appendix B	–	September 26, 2006 Levelton Report
	Appendix C	–	Opinion of Probable Costs
	Appendix D	–	Dec. 08, 2007 Letter to Dale Bracewell from Hatch Mott MacDonald

Appendix K Cost Estimate Breakdown

VANCOUVER STREET CAR - SYSTEM SUMMARY	$	$	$
SUMMARY	DHR	DHR Plus (Recommended)	Modern
SITE PREPARATION	502,410	1,014,410	3,149,590
ROADWORKS	131,720	89,720	815,720
TRACK BED	1,082,920	1,817,760	9,700,600
TRACKWORK	2,943,400	4,118,400	13,015,000
CIVIL AND BUILDING WORKS IN CONNECTION WITH SYSTEM	83,100	55,000	4,168,900
POWER SUPPLY AND DISTRIBUTION	953,900	842,700	4,020,800
TESTING AND COMMISSIONING	47,695	42,135	986,200
STOPS	825,000	900,000	3,159,500
OMC			0
VEHICLES			0
TOTAL CIVILS AND SYSTEMS	**6,570,145**	**8,880,125**	**39,016,310**
DESIGN	394,209	532,808	2,340,979
PROJECT MANAGEMENT	483,952	888,013	3,901,631
CONSTRUCTION MANAGEMENT	254,338	444,006	1,950,816
TOTAL	7,702,643	10,744,951	47,209,736
CONTINGENCIES	1,540,529	2,148,990	9,441,947
TOTAL	9,243,172	12,893,942	56,651,683
IDC	554,590	773,636	4,958,412
TOTAL ESTIMATE (NOT INCLUDING VEHICLES/OMC)	**$9,797,762**	**$13,667,578**	**$61,610,095**
TOTAL ESTIMATE (INCLUDING VEHICLES/OMC)			**$90,616,084**

VANCOUVER STREET CAR - GRANVILLE ISLAND TO CAMBIE STREET	$	$	$
SUMMARY	DHR	DHR Plus	Modern
SITE PREPARATION	76,000	741,000	2,592,800
ROADWORKS	18,000	8,000	14,100
TRACK BED	114,000	1,006,000	1,379,400
TRACKWORK	950,000	2,295,000	4,560,000
CIVIL AND BUILDING WORKS IN CONNECTION WITH SYSTEM	12,000	12,000	2,090,000
POWER SUPPLY AND DISTRIBUTION	297,000	289,500	1,804,000
TESTING AND COMMISSIONING	14,850	14,475	90,200
STOPS	59,000	234,000	967,000
TOTAL CIVILS AND SYSTEMS	**1,640,850**	**4,599,975**	**13,497,500**
DESIGN	98,451	275,999	809,850
PROJECT MANAGEMENT	49,226	459,998	1,349,750
CONSTRUCTION MANAGEMENT	32,817	229,999	674,875
TOTAL	1,821,344	5,565,970	16,331,975
CONTINGENCIES	364,269	1,113,194	3,266,395
TOTAL	2,185,612	6,679,164	19,598,370
IDC	131,137	400,750	1,959,837
TOTAL ESTIMATE	**$2,316,749**	**$7,079,914**	**$21,558,207**

VANCOUVER STREET CAR - FIRST AVENUE	$	$	$
SUMMARY	DHR	DHR Plus	Modern
SITE PREPARATION	354,190	134,190	381,190
ROADWORKS	113,720	81,720	113,720
TRACK BED	812,920	600,960	4,415,600
TRACKWORK	1,550,400	1,250,400	4,435,000
CIVIL AND BUILDING WORKS IN CONNECTION WITH SYSTEM	71,100	3,000	1,198,900
POWER SUPPLY AND DISTRIBUTION	591,900	488,200	1,428,800
TESTING AND COMMISSIONING	29,595	24,410	71,440
STOPS	574 000	574 000	1,305 500
TOTAL CIVILS AND SYSTEMS	**4,097,825**	**3,156,880**	**13,350,150**
DESIGN	245,870	189,413	801,009
PROJECT MANAGEMENT	409,783	315,688	1,335,015
CONSTRUCTION MANAGEMENT	204,891	157,844	667,508
TOTAL	4,958,368	3,819,825	16,153,682
CONTINGENCIES	991,674	763,965	3,230,736
TOTAL	5,950,042	4,583,790	19,384,418
IDC	357,003	275,027	1,938,442
TOTAL ESTIMATE	**$6,307,044**	**4,858,817**	**$21,322,860**

VANCOUVER STREET CAR ONTARIO STREET TO SCIENCE WORLD	$	$	$
SUMMARY	DHR	DHR Plus	Modern
SITE PREPARATION	72,220	139,220	175,600
ROADWORKS	0	0	687,900
TRACK BED	156,000	210,800	3,905,600
TRACKWORK	443,000	573,000	4,020,000
CIVIL AND BUILDING WORKS IN CONNECTION WITH SYSTEM	0	40,000	880,000
POWER SUPPLY AND DISTRIBUTION	65,000	65,000	788,000
TESTING AND COMMISSIONING	3,250	3,250	824,560
STOPS	92,000	92,000	887,000
OMC	0	0	0
VEHICLES	0	0	0
TOTAL CIVILS AND SYSTEMS	**831,470**	**1,123,270**	**12,168,660**
DESIGN	49,888	67,396	730,120
PROJECT MANAGEMENT	24,944	112,327	1,216,866
CONSTRUCTION MANAGEMENT	16,629	56,164	608,433
TOTAL	922,932	1,359,157	14,724,079
CONTINGENCIES	184,586	271,831	2,944,816
TOTAL	1,107,518	1,630,988	17,668,895
IDC	66,451	97,859	1,060,134
TOTAL ESTIMATE	**$1,173,969**	**$1,728,847**	**$18,729,029**

Appendix L Risk/Opportunity Register

PROJECT RISK REGISTER
Spreadsheet Version 10/14/2003

DATE OF ASSESSMENT: 19-Dec-07

PROJECT: Vancouver Streetcar
Job No. 237388
STAGE OF ASSESSMENT: Next Steps
Rev: PA

Area of Work	Threat / *Opportunity*	Consequences	IMPACT	LIKELIHOOD	RISK	RISK/TYPE	**Potential Risk Control Measures / Actions** Please indicate desired intention from options:- **'Remove', 'Decrease', 'Transfer', 'Manage',** and then how to be achieved.	OWNER	Action (by when)	Risk (fail to implement action to mitigation risk)
Policy	CoV have to make a decision on the prefered Design Option.	Delay to scheme. Demonstration Line unachievable.	VH	H	20	Programme	Ensure client understands time critical nature of decision.	CoV	Active	4
Technical	Demonstration line	Implications on final design solution and programme.	VH	H	20	Cost	CoV to confirm aspirations.	CoV	Active	6
Technical	Demonstration line	Implications on final design solution and programme.	H	H	16	Programme	CoV to confirm aspirations.	CoV	Active	9
Policy	Funding Initiatives – How will funding be secured by CoV?	Delay to scheme. Demonstration Line unachievable.	VH	M	15	Programme	CoV to activly persue/secure funding.	CoV	Active	20
Technical	Pinnacle Development: How will phasing work?	Construction impacts.	VH	M	15	Programme	Descusions with Pinnacle developments.	CoV	Active	12
Legal	Delivery Framework (DB,P3 etc.)	Impacts on cost and programme.	VH	M	15	Cost	Decision on delivery framework.	CoV	Not Active	
Legal	Delivery Framework (DB,P3 etc.)	Impacts on cost and programme.	VH	M	15	Programme	Decision on delivery framework.	CoV	Not Active	
Policy	CoV have to make a decision on the prefered Design Option.	Delay to scheme. Demonstration Line unachievable.	M	H	12	Cost	Ensure client understands time critical nature of decision.	CoV	Active	4
Technical	Pinnacle Development: How will phasing work?	Construction impacts.	H	M	12	Cost	Descusions with Pinnacle developments.	CoV	Active	16
Technical	Vehicle: Procurement of modern vehicle	Delay to system opening.	H	M	12	Cost	Identify prefered vehicle and begin procurement process within programme.	CoV/Design Consultant	Not Active	
Technical	Vehicle: Procurement of modern vehicle	Delay to system opening.	H	M	12	Programme	Identify prefered vehicle and begin procurement process within programme.	CoV/Design Consultant	Not Active	
Technical	Science World: Property acquisition	Abortive work/redesign and cost/programme risk.	H	M	12	Cost	Engage Science World in negotiations.	CoV	Not Active	
Technical	Science World: Property	Abortive work/redesign and	H	M	12	Programme	Engage Science World in	CoV	Not Active	
Policy	Reuse of Existing Rail Equipment	Increased Lead time for ordering new rail.	VH	L	10	Programme	CoV determines acceptability of rail.	CoV	Active	9
Policy	Funding Initiatives – How will funding be secured by CoV?	Delay to scheme. Demonstration Line unachievable.	M	M	9	Cost	CoV to activly persue/secure funding.	CoV	Active	25
Policy	Reuse of Existing Rail Equipment	Increased Lead time for ordering new rail.	H	L	8	Cost	CoV determines acceptability of rail.	CoV	Active	9
Policy	Operations: who will operate Streetcar once its built – Translink's mandate?	Completed streetcar line cannot be operated.	H	L	8	Programme	CoV to engage Translink in negotiations.	CoV	Not Active	25
Technical	Continuous survey for full corridor.	Abortive work/redesign and cost/programme risk.	H	L	8	Cost	Obtain continuous survey at start of detailed design.	Design Consultant	Not Active	4
Technical	Continuous survey for full corridor.	Abortive work/redesign and cost/programme risk.	H	L	8	Programme	Obtain continuous survey at start of detailed design.	Design Consultant	Not Active	4
Technical	Trackform	Abortive work/redesign and cost/programme risk.	H	L	8	Cost	CoV to confirm aspirations and Design Consultant to feed into design.	CoV/Design Consultant	Detailed Design - Not Active	4
Technical	Trackform	Abortive work/redesign and cost/programme risk.	H	L	8	Programme	CoV to confirm aspirations and Design Consultant to feed into design.	CoV/Design Consultant	Detailed Design - Not Active	4
Technical	Trackform: Emergency services review	Abortive work/redesign and cost/programme risk.	H	L	8	Cost	Engage Emergency Services in dialogue.	CoV/Design Consultant	Active	20
Technical	Trackform: Emergency services review	Abortive work/redesign and cost/programme risk.	H	L	8	Programme	Engage Emergency Services in dialogue.	CoV/Design Consultant	Active	20

Project Risk Summary

	Cost	Programme
Total	147	146
Highest	20	20
Ave	9.2	9.1
Number	16	16
Significant	7	9
Intolerable<=20	3	4
Intolerable. 20	2	1

Risk Assessment Results

Try to Strengthen Mitigation Measures for Significant Risks to reduce Likelihood of Occurrence to Tolerable

RISK is INTOLERABLE Increase Mitigation to reduce Likelihood of event. If cannot then discuss with DM