CITY OF VANCOUVER

CITY CLERK'S DEPARTMENT
Access to Information & Privacy

File No.: 04-1000-20-2018-493

January 8, 2019

s.22(1)

Dear s.22(1)

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 11, 2018 for:

> **Materials related to Arbutus Streetcar (2012) mentioned on the Request for Proposals No. PS20171493 under Background Documents and Existing Issues.**

All responsive records are attached. Some information in the records has been severed, (blacked out), under s.13(1), s.17(1) and s.21(1) of the Act. You can read or download this section here: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/96165_00

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 (#04-1000-20-2018-493); 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
Barbara.vanfraassen@vancouver.ca
453 W. 12th Avenue Vancouver BC V5Y 1V4

*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.

Records are placed in an FTP.

:ma

MOTT MACDONALD

DIALOG

URBAN systems

CITY OF VANCOUVER

Arbutus Greenway Project

Arbutus Street – W 33rd Avenue to W 37th Avenue
Draft Functional Planning Design Report

February 19, 2018

City of Vancouver

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	2018/01/26	K. Miller	G. Farmer	A. Gardner	DRAFT – Issued for Client Review
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1 Introduction

The Arbutus Corridor, located parallel to Arbutus Street in south-central Vancouver, is approximately 9 kilometres long and 15-20 metres wide between Fir Street in the north and Milton Street in the south, and represents approximately 42 acres of open space. It has always been, and remains an important north-south corridor that links False Creek to the Fraser River, and connects neighbourhoods like Marpole, Kerrisdale, and Kitsilano. The area surrounding the Corridor is one of diverse land uses, neighbourhoods, communities, and natural features.

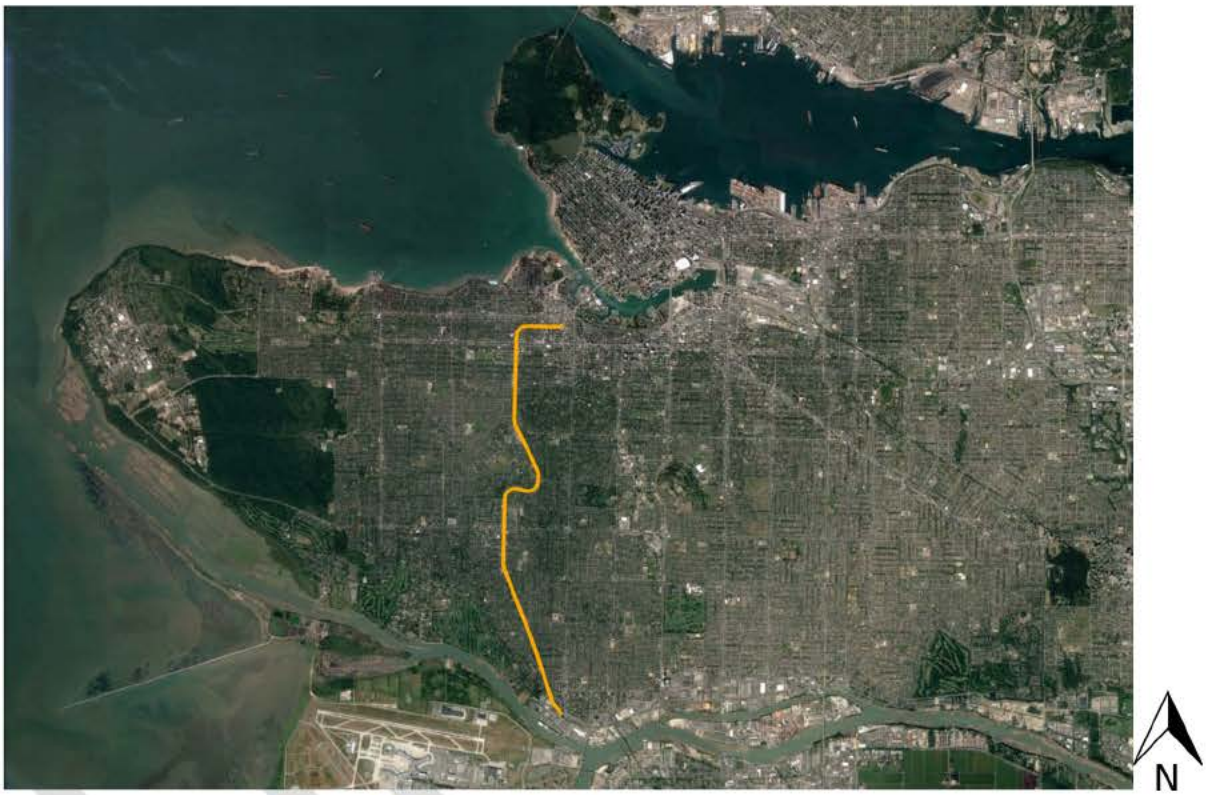


Figure 1-1 Arbutus Corridor within Vancouver

The City of Vancouver purchased the disused freight rail corridor from Canadian Pacific Rail in 2016, with the view in the long term to create a thoroughfare and public space for use by all. In the short term, temporary paving has been laid and today it is used by myriad outdoor recreation and ecology enthusiasts as a place to visit, gather, and travel by foot, bike, skateboard, and other modes.

The Arbutus Greenway Project (AGP) is a master planning and engagement assignment led by the City of Vancouver, dedicated to transforming the Arbutus Corridor into a world-class active transportation and green space. The vision for the Greenway is to be a series of new beautiful, recreational, ecological, and educational destinations in Vancouver but also to function as a safe and efficient part of Vancouver's wider multimodal transportation network including cycling, walking, and streetcar infrastructure.

The purchase of the corridor by the City was on the basis that it will be used as a transportation corridor that features light rail transit. Further, aspirations of the City mandate multimodal functionality for the greenway, while appropriately considering a planning approach to multimodal operational characteristics. Additionally, while allocating space for future streetcar (enabling its relatively easy and affordable implementation in

future) is a key component of our design process, the AGP is not simply a transportation project, but a city-shaping one, as captured in the Vision statement:

"The Arbutus Greenway will be a defining element of Vancouver's urban landscape as a vibrant and beautiful public space for walking, cycling, and streetcar. It will be a destination which fosters both movement and rich social interaction - inspired by nature and the stories of the places it connects."

In addition to the development of a streetcar alignment within the purchased corridor, the City of Vancouver Arbutus Project Team (CoV APT) has requested further investigation into the feasibility of streetcar running on Arbutus Street between West 33rd Avenue to West 37th Avenue.

1.1 Purpose of Study

The purchased corridor is 20.1m wide through the section from West 33rd Avenue to West 37th Avenue (the 'S-Curve'), and is in close proximity to residential properties on both sides and for a portion, a narrow laneway adjacent to the north . Additionally, there is a significant cross slope which means that there are large embankments and the current usable space is much less than the 20.1m purchased corridor width. Figure 1-2 shows that the temporary paths, which utilizes approximately 6-8m.

Figure 1-2 The Arbutus temporary path along the 'S-Curve'

The placement of the streetcar within this section is likely to require significant civil works to construct retaining walls, cantilevered pathways, and/or compromises to the cross-section of at least one transportation mode (i.e. streetcar operates on a single track, or absolute minimum width is provided for active transportation pathways). Additionally, the type of properties along this route mean that significant densification is unlikely to occur in the near to medium term. The CoV APT has shared a perspective that a streetcar alignment on Arbutus Street, particularly from West King Edward Avenue to West 37th Avenue, could serve more people and compliment developments in current medium density areas, as well as providing more available space through the "S-Curve" for walking, cycling and urban realm improvements without the same extent of civil works.

The CoV APT has identified the need to examine the feasibility of streetcar running on Arbutus Street from West 33rd Avenue to West 37th Avenue, instead of within the Arbutus purchased corridor. Initial work in the development of the schematic concepts identified steep road grades on this section of Arbutus Street, particularly from West 33rd Avenue to West 34th Avenue, where the gradient is known to be in excess of

10%. This is in excess of the normal design parameters for streetcar and urban style light rail transit systems currently operating or being developed in North America.

This study is being carried out in parallel to the preferred concept work. This means this additional streetcar scope has been conscious of the other conversations and decisions being made on the AGP as the development of the preferred concept progresses.

This report outlines the study context, streetcar design philosophy, design parameters and industry best practices. It also discusses the design parameters used for road lanes and sidewalks. Consideration of the technical feasibility of placing streetcar on Arbutus Street in this area has been undertaken in two ways. The first option considered is regrading Arbutus Street to meet industry best practices including the recommended maximum vertical grade. The second option included reviewing existing streetcar, tram and LRT systems, as well as discussions with streetcar vehicle suppliers to see if there is a vehicle now or in the future that could likely to be able to navigate the existing grades.

The objective of the study is not to conclude which option may be the best, but to identify the opportunities, constraints and challenges associated with the different alternative approaches. The identification of the issues will allow the City to decide if the challenges related to this route option are likely to be acceptable in the future. If they are then the development of infrastructure within the purchased corridor can proceed without making allowance for streetcar in the future.

2 Context

Figure 2-1 shows the area of interest, Arbutus Street from West 33rd Avenue to West 37th Avenue, and the preferred streetcar alignment that has been developed to date north of West 36th Avenue.

Figure 2-1 Arbutus Street between West 33rd Avenue to West 37th Avenue

Depending upon the technical feasibility of putting streetcar on Arbutus Street from West 33rd Avenue to West 37th Avenue, the streetcar alignment through this area will need to connect to the preferred concept design for the Arbutus Greenway in the vicinity of West 37th Avenue. There is some flexibility in the location of the connection to the preferred concept design as the Arbutus road ROW and purchased corridor become adjacent to each other north of the West 37th intersection.

North of West 33rd Avenue the Arbutus Street road ROW is approximately 30.35m wide. This allows for different cross-sectional layouts. These layouts have not been developed as discussion and better understanding of the potential future development plans along this section is required to determine the most suitable layout to pursue for this area. It is feasible to have a different cross section for the area north of West 33rd Avenue to West King Edward Avenue as long as a transition is accounted for at or near the West 33rd Avenue intersection. It is also necessary for the streetcar alignment along Arbutus Street between West 33rd Avenue to West King Edward Avenue to connect to the preferred alignment north of West King Edward Avenue as shown in Figure 2-2.

Figure 2-2 Arbutus Street at West King Edward Avenue

3 Design Philosophy and Parameters

3.1 Streetcar

The report 381002-MMD-00-P0-RP-TR-0001 – Streetcar Planning and Design Context Memo provides information on what streetcar is and why it has been selected for the Arbutus Greenway. The document also outlines streetcar design philosophy and parameters that are to be used for the AGP. The design parameters outlined in Section 7 of 381002-MMD-00-P0-RP-TR-0001 have been utilized during this investigation with the following being some key design parameters.

Table 3-1 Key Streetcar Design Parameters

Parameter	Proposed Criteria	Comments
Geometry		
Minimum Radius – Horizontal	25 m	Although it maybe poss ble to acquire vehicles capable of tighter radii, 25m is consider achievable by most modern streetcars.
Minimum Radius – Vertical	250 m (crest) 250 - 350 m (sag)	Typical parameters adopted by other systems
Maximum Gradient	6% preferred 10% absolute	6% is what is recommended in TCRP 155 but previous market research and project experience has shown that manufacturers will supply vehicles capable of 8% gradients. APTAs Modern Streetcar identified that sustained gradient over 9% are problematic but there are many systems which currently operate on 10% gradients.
Streetcar Length	35 m	Consistent with NEFC assumptions
Streetcar Width	2.65 m	Standard width for vehicles supplied by most manufacturers. 2.4m vehicles are also common but impose capacity constraints
Dynamic Envelope (DE) Width – Straight Track	3.4 m	Considered a conservative assumption which allows for a range of vehicles and will allow for some shallower curves without additional widening
Dynamic Envelope (DE) Width – Curved Track	Varies	Depending on the radius of curve a minimum in-swing and out-swing will need to be accounted for. The effect of superelevation will need to be considered on the inside of curves. For simplicity, the effects can be assumed to add twice the applied superelevation to the in-swing of the vehicle.
Typical Design Speed	30 – 50 km/h	Design speed of the streetcar will generally depend on the road classification, adjacent parking lanes, proximity to parks and school, and sightline issues. This will be further analyzed as the project progresses.
Maximum Design Speed	80 km/h	Many manufacturers will supply vehicles capable 80 km/h or higher
Clearances		
Between two streetcars' DEs without centre OCS poles	200 mm	TCRP 155
Between two streetcars' DEs with centre OCS poles	800mm With at least 150 mm to the face of the pole	Most poles will typically be less than 500mm but occasional ones may need to be larger
Isolated Obstruction – Clearance to DE (Applies to Tangent and Curved Track)	600 mm preferred 100 mm absolute	The absolute minimum should only be considered in locations where streetcar is segregated and pedestrian are unlikely to be
Continuous Obstruction – Clearance to DE (Applies to Tangent and Curved Track)	1000 mm preferred 600 mm absolute	This will be further analyzed as the alignment adjacencies and conflicts are investigated.
Edge of pedestrian walkway or bicycle pathway – Clearance to DE (Applies to Tangent and Curved Track)	600 mm preferred 400 mm absolute	This will be further analyzed as the alignment adjacencies and conflicts are investigated.

3.2 Road

Previously, in Memo 381002-MMD-00-P0-MO-TR-0003 – Arbutus Street Cross-Section options Opportunities and Challenges, 3.5m lane widths were assumed. Upon further investigation of truck tracking templates on this section of Arbutus Street, it was found that the 3.5m lanes are actually too narrow for the curve radii in this section (~90m curves). For a 2-lane roadway, trucks track wide on both the inside and the outside of the curves and therefore lane widening is required in both the northbound lane and the southbound lane.

From checking the vehicle tracking for two design vehicles, a WB-17.5 and a WB-20, and it was found that the minimum required lane width is 4.0m for a WB-20 vehicle and 3.8m for a WB-17.5m. As Arbutus Street is designated as an arterial road as well as a designated truck route between West Broadway to West 41st Avenue, it is recommended that a WB-20 is the design vehicle used in the design development of options on Arbutus Street from West 33rd Avenue to West 37th Avenue. On this basis 4.0m wide lanes will be assumed for this study.

3.3 Sidewalks and Boulevards

Previously, in 381002-MMD-00-P0-MO-TR-0003, a minimum sidewalk width of 2.0m was assumed. The CoV APT has indicated they are seeking wider sidewalks, including a utility/boulevard strip for streetlighting, trees, etc. Thus a 3.6m space for an accessible sidewalk and utility/boulevard strip is required and has been accommodated.

4 Industry Best Practices

Industry best practices and design guidelines for urban style LRT and modern streetcars are well-established across the globe, and vary in applicability based on geography and operating characteristics. Technical documents which are well-suited to inform planning and design work for the Arbutus Greenway Project include but are not limited to:

- Transit Cooperative Research Program (TCRP) Report 155: Track Design Handbook for Light Rail Transit – is based upon historic and current practices for many light rail projects across North America. It sets out principles and parameters which are adopted as industry standards by designers when developing rail based transit systems.

- Guidance on Tramways, Railway Safety Publication 2 (RSP2), Office of Rail Regulation – is a guideline published by the UK's regulatory body for railways which has oversight for safety on tramways. It provides useful additional guidance over what is included in the TCRP report, particularly around how these types of systems interact with road traffic, pedestrians, and cyclists.

- APTA RT-ST-GL-001-13: Modern Streetcar Vehicle Guideline – provided typical parameters and capabilities for streetcars and some discussion about how they interact with and influence other aspects of a system's design.

As indicated in 381002-MMD-00-P0-RP-TR-0001 – Streetcar Planning and Design Context Memo, a preferred maximum gradient for the Arbutus Greenway Project is 6% as that is what TCRP 155 recommends. However, previous market research and project experience has shown that most LRV and streetcar manufacturers will supply vehicles capable of 8% gradients. APTAs Modern Streetcar identifies that sustained gradient over 9% are problematic but there are a number of systems which currently operate on 10% gradients, such as Pittsburgh's Brown Line which is now operated only occasionally due to service cuts. The ability for streetcars to ascend or descend steep grades is dependent on the specified capability of the vehicle and its propulsion and braking systems to ensure a sufficient traction is provided to overcome the force of gravity as it ascends or descends the steep grade. The coefficient of friction between the rail and the wheel can vary depending on environmental conditions, such as temperature, precipitation and vegetation. To maintain minimum adhesion levels, it may involve going beyond the use of standard streetcar vehicle features such as sanding to improve adhesion. Additionally, vehicle manufacturers would likely need to assess the weight distribution across a vehicle to ensure that loading is appropriately applied over the bogies to aid grip.

Additionally, as there is an absence of in-operation at-grade modern streetcar systems in British Columbia there is a shortage of definitive design parameters or regulatory literature regarding operations and maximum grade requirements. Previously in operation, the 2010 Olympic Streetcar Demonstration Project used a railway corridor with not significant grades. The South of Fraser Rapid Transit Project, which is in the design stage and will be the province's first modern at-grade light rail system, is anticipated to abide by a maximum grade of 8%.

4.1 TCRP Report 155: Track Design Handbook for Light Rail Transit

Section 3.3.2 of TRCP 155 outlines recommended vertical grades and notes that maximum track grades are dictated by vehicle braking and tractive capabilities. Table 3.3.1 of TCRP 155 provides general guidelines for maximum gradients as follows:

Desired Maximum Unlimited Sustained Grade (any length)	4.0%
Desired Maximum Limited Sustained Grade (up to 2500 feet [750 meters] between points of vertical intersection (PVIs) of vertical curves)	6.0%
Desired Maximum Short Sustained Grade (no more than 500 feet [150 meters] between PVIs of vertical curves)	7.0%
Absolute Maximum Grade Unless Restricted by the Vehicle Design (acceptable length to be confirmed with vehicle designers)	9.0%
Acceptable Minimum Grade for Drainage on Embedded Track	0.5%
Acceptable Minimum Grade for Direct Fixation and Ballasted Trackforms (provided other measures are taken to ensure drainage of the trackway)	0.0%

4.2 APTA RT-ST-GL-0001-13: Modern Streetcar Vehicle Guideline

APTA RT-ST-GL-0001-13 emphasizes that electrically powered transit vehicles can climb and descend steep grades, but notes that the vehicles require specific propulsion and braking systems capabilities and that there are trade-offs with vehicle cost, operational speed and long-term maintenance. It references Table 3.3.1 from TCRP 155 for typical grade limits.

5 Regrading of Arbutus Street

As the existing road grades are in excess of 10% between West 33rd Avenue and West 37th Avenue, and therefore above the recommended maximum for streetcar grades, the feasibility of regrading part of or all of the road right-of-way has been examined. The first phase of this investigation involved developing cross sectional options, which utilized the design philosophy and parameters outlined in Section 3. The second phase further investigated two options through plan and profile design. These cross-sectional options were set out in laid out in 381002-MMD-00-P0-MO-TR-0003 – Arbutus Street Cross-Section Options Opportunities and Challenges, which can be found in Appendix A.

Initially, four cross section options were developed to capture the possible configurations of roads lanes, sidewalks and streetcar. All options could accommodate re-grading the road ROW to achieve acceptable 8% gradient for streetcar with the road and streetcar at similar grades. However, only Options 1, 2 and 4 would allow the road grade to be separate from the streetcar grade. While the cross sections developed indicated an allowance for retaining structures, it should be noted that this may vary from cut walls in some places to fill walls in others, and walls would not be required in some locations.

Based upon the opportunities and challenges laid out in the Cross-Section Options Opportunities and Challenges memo, it was recommended that Option 1 – East Side Running be carried forward through further investigation and that Option 2 – West Side Running be eliminated based on the significant access implications. The CoV APT then decided that Option 3 – Shared Running be assessed further as it would provide a better sense of the extent of regrading required to keep the streetcar and road at the same profile. This would permit a comparison to the significant property impacts of Option 1.

At this stage of the study, plan and profile design of Option 1 and 3 has been progressed to a functional level and drawings are included in Appendices B and C, respectively. The streetcar profile design uses a maximum gradient of 8%. Additionally, further cross-discipline technical considerations have been examined; the following sections include a complete list of opportunities and challenges.

As an early technical assessment of the feasibility of citing streetcar on Arbutus Street, it should be noted that only two options were explored further through plan and profile design,. This does not mean that the other options are not feasible and later stages of project development should explore further options.

Many alternatives could be possible which as well as exploring variants to those which have been developed, could include single track options within the purchased corridor or options which placed one track in the corridor and one on Arbutus Street.

5.1 Option 1 – East Side Segregated Running

See Appendix B for plan-profile and cross section drawings for Option 1 – East Side Running.

Option 1 consists of both streetcar tracks being side running along the east curb of Arbutus Street with one vehicle lane in each direction to their west. This option maintains the existing sidewalk and boulevard on the west side of Arbutus Street.

It was developed by fixing the west property line in its existing position to limit property impacts to only on the east side of Arbutus Street. With the tracks segregated to the east, and with a grade differential of approximately 1.0 to 2.0m between the road and tracks in some locations, accesses and intersections along the east side will be affected. Thus, it is expected that properties on the east would no longer have sufficient access. Retaining walls will be necessary between the road lanes and streetcar for approximately 160m. A retaining structure of a similar length would also be necessary along the back side of the east sidewalk. However, there is a potential to regrade the adjacent properties in order to reduce or avoid the need for a retaining wall. This would be s.13(1), s.17(1) .

Near West 36th Avenue, the streetcar tracks will shift to the east to follow the preferred streetcar alignment, with a streetcar stop north of the West 37th Avenue intersection. At this time different stop layouts have not been explored but further development could consider the use of a centre platform layout. This transition of the streetcar tracks utilizes the wider space available as the Arbutus Street road right-of-way and purchased corridor become adjacent. Additionally, this shift of the streetcar alignment will have minimal impact on other modes, aside from the east sidewalk which would cross the cycling pathway and join with the pedestrian pathway of the arbutus Greenway or cross the Streetcar tracks to continue alongside Arbutus Street.

5.1.1 Opportunities

- Accesses, including driveways, alleyways and intersections will be maintained along the west side.
- Existing and upgraded water mains sited in the existing west curb lane can be maintained.
- Streetcar is segregated running and would not be operationally affected by traffic.
- Aligns with the streetcar alignment on Arbutus Street north of West King Edward Avenue and on West Boulevard south of West 37th Avenue with minimal horizontal transition curves.

5.1.2 Challenges

- One intersection (Quilchena Crescent), s.13(1), s.17(1)
  s.13(1), s.17(1) .
- Properties south of Quilchena Crescent do back onto a one-way alleyway that connects from Arbutus Street to Linden Road but the Arbutus Street entrance would likely be closed due to a lack of protected turn lanes into it.
- s.13(1), s.17(1) further investigation on the circulation of emergency vehicles and servicing vehicles (e.g. garbage trucks) will be required to confirm if these closures are acceptable.
- With the streetcar side running, the headlights of the streetcar may pose a concern being on the wrong side of the roadway, particularly while negotiating the curves. This may require mitigation which could include using headlight screening on top of the retaining wall between the streetcar and northbound vehicle lane.
- Nine existing street trees along the east side of Arbutus Street would need to be relocated, or removed and replaced, to the new boulevard strip.

s.13(1), s.17(1)

- s.13(1), s.17(1) . Further assessment by the CoV real estate team will be required to confirm if they would be deemed as full takes
- Utilities on the east side of the road ROW would require relocation away from the streetcar utility exclusion zone (minimum 2m from track centreline)
- On-street parking on Arbutus Street is removed.
- There are urban realm implications of having the road and streetcar at different grades, with retaining walls, as it creates a physical and visual barrier on the street that is not conducive to a walkable, transit oriented community. It would preclude pedestrians crossing Arbutus Street and the streetcar tracks through this section.
- Northbound right turns at West 33rd Avenue would need to be restricted as there is no room to accommodate a protected right turn lane. However, this may be possible with additional property impacts

5.2 Option 3 – Shared Running

See Appendix C for plan-profile and cross section drawings for Option 1 – East Side Running.

Option 3 consists of the streetcar tracks being sited in mixed traffic/shared running lanes along each curb lane. There could be a turning lane in-between the northbound and southbound lanes. This turning lane would be used to maintain the intersections at West 34th Avenue, West 35th Avenue and West 36th Avenue, but not necessarily to allow for turning access into alleyways and driveways. Regrading of the entire roadway will be required in some locations. To maintain intersections, some regrading along the intersecting roads would be required (see below). Where this is required, preliminary engineering indicates some property accesses may need to be closed. This option was developed with the intention that there would minimal, if any, property impacts on either side of Arbutus Street.

With the new road and streetcar profile, there is a grade differential of approximately 0.5-2.5m between Arbutus Street and adjacent properties in some locations. Retaining walls will be necessary along the east property line for approximately 160m. Many accesses and intersections will be affected, but it is envisaged that most can be maintained through regrading. The regraded driveways would be accommodated in the retaining wall along the east side. On the west property line, a retaining wall may be required for approximately 45m north of West 34th Avenue, and for approximately 90m south of West 34th Avenue although further study with more detailed topographic information may show that regrading into the property frontage could reduce or avoid the requirement.

Near West 36th Avenue, the streetcar tracks will shift to the east to follow the preferred streetcar alignment, with a streetcar stop south of the West 37th Avenue intersection. This transition of the streetcar tracks utilizes the wider space available as the Arbutus Street road right-of-way and purchased corridor become adjacent. Additionally, the shift of the streetcar alignment will impact vehicle traffic. A partially signalized intersection will be needed at West 36th Avenue to stop northbound traffic for the streetcar, travelling in either direction, to merge into and out of shared running lanes. The east sidewalk would cross the cycling pathway and join with the pedestrian pathway of the arbutus Greenway.

5.2.1 Opportunities

- Maintains the existing road ROW and does not require any property boundaries to be setback.
- Allows for the intersections at West 34th Avenue, West 35th Avenue and West 36th Avenue to remain open to vehicular traffic with minimal regrading.

5.2.2 Challenges

- Five alleyways and eight driveways on either side of Arbutus Street would have full access from both directions with the allowance of the shared vehicle turning lane, however some could be restricted to right-in and right-out to minimize the number of vehicles in conflict when turning.
- Eight driveways on the east side and two alleyways along the west side of Arbutus Street will require regrading or closure.
- The intersection of West 34th Avenue will require regrading. As West 34th Avenue drops to the west and we have lowered the Arbutus Street profile we are able to tie in within approximately 5m.
- The Quilchena Crescent intersection will be closed due to grade differences, and since Quilchena Crescent rises to the east, any regrading would be significant.
- The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Avenue which introduces additional horizontal curves.
- On-street parking on Arbutus Street is removed.

- The transition of the streetcar alignment to and from east side running north at West 36th Avenue will require a new signal to control southbound traffic from crossing the streetcar tracks as a streetcar is navigating into and out of shared running lanes.
- The existing street trees, on both the east and west sides, would need to be removed for construction but could be replaced in a similar location.
- Existing and/or upgraded City Owned utilities cannot be accommodated under either curb lane, due to the streetcar utility exclusion zone (an absolute minimum of 2.0 m from track centerline). There is minimal space under the centre lane, boulevards and sidewalks for sanitary, storm and water utilities.
- Regrading of utilities may be required, particularly of shallower pipes.
- Streetcar is shared running with vehicles and could be operationally affected by traffic.
- With a shared lane, tire traction on steel rails versus asphalt, particularly for motorcycles and bicycles, could be a concern.
- The embedded streetcar rails are a possible safety hazard for bicycles whose tires could become stuck in the groove.

5.3 Conclusion

The development of these options showcases the potential implications of regrading Arbutus Street from West 33rd Avenue to West 37th Avenue. Both options assessed are technically feasible and whichever cross section is selected, there will be retaining walls and some implications for access and circulation.

s.13(1), s.17(1)
s.13(1), s.17(1) However, it does provide the streetcar with a better operational condition as it is segregated from traffic.

s.13(1), s.17(1) It also allows for existing access and circulation to be kept relatively unchanged, except for the closure of Quilchena Crescent. Option 3 has the streetcar shared running with vehicles and could be operationally affected by traffic.

Although only these two options were explored further through plan and profile design, this does not mean that other options are not feasible if explored further in the future. This study was carried out as an early technical assessment of the feasibility of citing streetcar on Arbutus Street and was not intended to conclude which would be the best technical solution.

Further refinement of the alignment and profile design could mitigate and/or minimize the challenges listed, however, changes could generate other implications. One refinement example could include regrading the West 33rd Avenue intersection in order to reduce the height of retaining walls and potentially reduce property and access impacts. The regrading of the West 33rd Avenue intersection at Arbutus Street could ultimately be beneficial along Arbutus Street but could have implications along West 33rd Avenue such as impacts to mature street trees.

This information will help the CoV APT to compare the technical feasibility of placing the streetcar on Arbutus Street versus the preferred streetcar alignment which is within the purchased corridor, and understand the opportunities and challenges of the alignment options.

6 Vehicle Investigation

The following section outlines the research that was undertaken to identify if there is potential that streetcar vehicles now or in the future might be able to navigate the existing gradients. It was completed in two parts, one being a review of existing systems and the other being a review of the latest information from vehicle suppliers.

6.1 Existing Systems Review

A review of existing streetcar, tramway and light rail transit systems has been undertaken to understand what systems are in operation with steep grades above industry best practice, and if any systems are applicable examples for Arbutus Street from West 33rd Avenue to West 37th Avenue. The following table identifies systems with actual operational gradients in excess of 7%. It is typical that a system's design guidelines would align with the maximum grade on the system when it is above 4-6%, which are the desirable maximum grades specified in TCRP 155 (see Section 4.1), It is unlikely that most systems will require that their vehicles can negotiate steeper gradients unless there is a known constraint on a future extension. If this is the case it may not have been identified by this review. The research is not necessarily an exhaustive list of all existing streetcar, tramway and light rail systems. It is intended to be a sample of systems that have steeper grades that could be comparable examples. It should also be noted that each system and its vehicle(s) is specific to the environment in which it is situated. The following table outlines existing built and operating streetcar, tramway and light rail transit systems around the world, and their design parameters:

Table 6-1 Existing Streetcar, Tramway and Light Rail Systems

Country	City	System	Line	System Type	System Opening Date	System Top Speed (km/h)	Minimum Horizontal Curve Radius (m)	Minimum Vertical Curve Radius (m)	Maximum Grade (%)	LRV Manufacturer	Primary LRV Type	LRV Description	Comments
Austria	Linz	Linz AG Linien	Pöstlingbergbahn	Tramway	1898	50	17	500	11.6	Bombardier	Flexity Outlook	100% Low floor 3 vehicles supplied in 2009, a 4th supplied in 2011 Three historical trams also run on the system	In 2009, service was extended from Urfahr to the city centre. To permit this change, the railway was regauged from 1,000mm gauge to 900mm and a track connection to the Linz tram network
Canada	Toronto	Toronto Streetcar		Streetcar	1892	70			8	Bombardier UTDC UTDC UTDC	Flexity Outlook (2014) CLRV L1 (1977) CLRV L2 ALRV L3 (1987)	Low Floor High Floor High Floor High floor	Toronto Transit Commission began operating the Flexity Outlook vehicle in 2014. Older vehicles are gradually being gradually retired and replaced with newer vehicles.
Germany	Mainz			Tramway	1883				9.5	Siemens Stadler	M8C/M8S Variobahn	High Floor Low Floor	Narrow gauge of 1,000mm
Ireland	Dublin	Luas		LRT	2004	70			8	Alstom	Citadis 301 Citadis 401 Citadis 402	100% Low Floor	
Portugal	Lisbon		Line 28	Heritage Tram	1958	50			15			Historic High Floor with ultra-short wheelbase	Not suitable for modern LRVs
Spain	Tenerife	Tenerife Tram		Tram	2007	50			8	Alstrom	Citadis 302	100% Low Floor	
United Kingdom	Birmingham	Midland Metro		LRT	1999	70	25		9	CAF	Urbos 3	100% Low Floor On-board energy storage	Previously operated with fleet of Ansaldo-Breda T69 LRVs CAF vehicles are capable of 9% although gradients that steep do not exist on the current system
United Kingdom	Sheffield	Supertram		LRT	1994	80	25	100	10	Siemens-Duewag	Bespoke (Supertram)	40% Low Floor	Additional Vossloh Tram-Train vehicles more recently delivered

Country	City	System	Line	System Type	System Opening Date	System Top Speed (km/h)	Minimum Horizontal Curve Radius (m)	Minimum Vertical Curve Radius (m)	Maximum Grade (%)	LRV Manufacturer	Primary LRV Type	LRV Description	Comments
United Kingdom	Croydon	Tramlink		LRT	2000	80			9	Stadler	Variobahn	100% Low Floor	Old Fleet, which is still in operation in conjunction with the Stadler Variobahn fleet, is Bombardier CR4000 (76% Flow Floor)
United Kingdom	Manchester	Metrolink		Tram	1992	80			9	Bombardier	M5000	High Floor	M5000 trams introduced in 2009 9% is the maximum down gradient specified in the design guide
United Kingdom	Nottingham	Nottingham Express Transit		LRT	2004		18		8.5	Alstom Bombardier	Citadis 302 Incentro AT6/5	100% Low Floor	
United States of America	Atlanta	Atlanta Streetcar		Streetcar	2014	56	18	250	7	Siemens	S70	70% Low Floor	
United States of America	Boston	Massachusetts Bay Transportation Authority	Ashmont-Mattapan High Speed Line Green Line	Heritage Streetcar	1897		10		8	Kinki-Sharyo AnsaldoBreda	Type 7 LRV Type 8 LRV	Rebuilt PCC streetcars operate on the Ashmont-Mattapan Line	
United States of America	Kansas City	KC Streetcar		Streetcar	2016				8.64	CAF	Urbos 3	100% Low Floor	
United States of America	Pittsburgh	Pittsburgh Light Rail	Brown Line	LRT	1984				10	Siemens/CAF	SD-400	High Floor	In March 2011 service was withdrawn due to a system-wide 15% service cut. The line is still used occasionally when the Mt. Washington Tunnel is closed
United States of America	Portland	Streetcar		Streetcar	2001		18		8.75	Škoda Inekon Trams United Streetcar United Streetcar	10T Trio type 12 10T3 100	50% low floor	
United States of America	San Francisco	Muni Metro		LRT	1980	80	13	140	9	Breda Vetrol Siemens	LRV-2/-3 S200 SF	High Floor	
United States of America	Seattle	Seattle Streetcar		Streetcar	2007	70			9	Inekon	Trio-12	Low Floor	In October 2017, contract awarded to CAF for 100% Low Floor Urbos
United States of America	Tacoma	Tacoma Link		Streetcar	2003	48.2 (30mph)	18.3 (60ft)	250 (820ft)	9	Škoda	10T		
United States of America	Washington, DC	DC Streetcar		Streetcar	2016	40mph	20	250	9	Inekon United Streetcar	Trio-12 100		Design Guide has desired maximum grade of 7% and absolute maximum grade of 9%

6.2 Vehicle Supplier Review

A review of the offerings and capabilities of existing vehicle suppliers was conducted by supplying manufacturers with 381002-MMD-00-P0-MO-TR-0002 – Arbutus Greenway Vehicle Investigation System Requirements (see Appendix D). The responses received have been captured in detail in 381002-MMD-00-P0-MO-TR-0005 – Vehicle Supplier Review which is included in see Appendix E. The following table summarizes the supplier responses to five main questions which they were asked.

Table 6-2 Summary of Vehicle Supplier Responses

	Question	Alstom Citadis 305 100% low floor	Bombardier Flexity 100% low floor	Brookville Freedom 60% low floor	CAF Urbos 3 100% low floor	Hitachi Rail Sirio 100% low floor	Inekon 121-Trio 60% low floor	Kinki-Sharyo ameriTRAM 100% low floor	PESA Swing 100% low floor	Siemens S200 High floor	Skoda 15T 100% low floor	Stadler CityLink 48% low floor
1	Can your current models of streetcar (or urban style LRV) safely and reliably negotiate this geometry when climbing or descending under all passenger loading conditions up to and including AW3?	No, unless specific and restrictive operational conditions are employed.	Yes	Yes, but with degraded performance (reduced acceleration and braking rates)	Yes, but small, common modification required for towing/rescue	No. Current models are not required to meet these requirements	Yes	Yes	No	Yes, but only with a high floor design	Not interested	Yes, with the right options selected
2	Is it likely that one of your current vehicles could be developed or modified to negotiate this geometry?	Modifications would only add weight and make the problem worse	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not interested	Yes
3	Are there any potential compromises or modifications to your standard vehicle which would be required in order to achieve the required capabilities, i.e. moving to all powered bogies, reduced acceleration rates, improved braking rates or operating speed through the area, etc.?	Nothing that would be recommended	66 to 100% driven axles needed	Yes – reduced acceleration and modified braking needed	Boost mode required to be installed	All bogies will need to be powered with reduced acceleration rates	No unless on-board energy management system is also required	No	Yes	No modifications needed	Not interested	Yes – see details in Stadler section
4	What are the potential order of magnitude cost and schedule implications of required modifications, i.e. it would require an additional 6 months of design and incur a 40% cost increase per vehicle?	Modifications not recommended	Minimal – standard option to increase the number of driven axles	Approximately 3 months for modifications and 8% cost increase	Minor cost and schedule impacts for modification	To be determined based on final quantities and specifications	None	None	12 months to develop modifications and cost dependent on type of tram	None	Not interested	Minimal since options are already designed
5	If you consider it unlikely that a vehicle could negotiate the geometry, please suggest the maximum acceptable gradient on the assumption that the horizontal curvature cannot be adjusted.	8.5%	10.5%	7% without modifications	10.5% with boost mode	6% without modifications	10.5%	11.5%	6%	10%	Not interested	10.5%

6.3 Vehicle Investigation Conclusion

The review of existing systems demonstrates that although there are some existing systems that operate on grades in excess of 10%, they are few and far between; a maximum gradient of 8% or 9% being much more common. The one example of a system with a maximum operating grade in excess of 10% is Pöstlingbergbahn in Linz, Austria. This system has a narrow gauge of 900mm, and being able to acquire the same vehicle type with similar performance specifications is uncertain. Of the two systems that have a maximum grade of 10%, the Supertram in Sheffield, UK is the most comparable but it uses a bespoke vehicle. The Brown Line in Pittsburg has a maximum grade of 10% is a high floor system and is not directly comparable to the Arbutus Greenway, regular service has been withdrawn on this line due to funding cuts.

The vehicle supplier investigation concluded that there are a number of vehicle suppliers which may supply a streetcar capable of negotiating the 10.5% gradient. However, the requirement would restrict the number of suppliers available which could result in a less competitive procurement process. The limited size of the potential order may also deter other suppliers especially considering the up-front costs to modify the vehicles since there isn't a great demand for vehicles that are capable of negotiating a 10.5% gradient. Nevertheless, the investigation shows that it's likely to be a feasible option at an increased cost if regrading is not desired.

All suppliers indicated a need for operational constraints irrespective of whether modifications are required or not. For example, acceleration rates would be reduced and there will be a need to carry out failed vehicle rescue with empty vehicles (passengers would have to be offloaded). Suppliers would also need to consider adhesion levels during the vehicle design stage. Some suppliers are indicating that it will take anywhere from 3 months to a year to develop the modifications necessary to negotiate the 10.5% gradient. This is in addition to the typical 2 or 3-year design, manufacturing, and assembly activities of the first vehicle.

These findings indicate that it is feasible to use a grade steeper than 8%, such as 9% or 10.5%, along Arbutus Street for the streetcar profile, but that there could be increased cost and schedule implications during procurement of streetcar vehicles. Additionally, commentary from vehicle suppliers indicates that operational constraints will be necessary which would also ultimately have operations and maintenance cost and service reliability implications.

If other sections of the streetcar network are constructed in advance of the Arbutus section, it would be necessary to include the additional requirements associated in this area to ensure that the streetcars purchased would be able to operate there in the future.

7 Next Steps

This study has shown that it is technically feasible to accommodate streetcar on Arbutus Street in the study area, whether this is achieved by regrading the street or by procuring a specialized streetcar vehicle capable of negotiating the existing grade.

Regrading of Arbutus Street is feasible and, if the City wishes to pursue it, will require further refinement of design options, which could include an evaluation of options that utilizes 9-10% gradients, balancing the trade-offs between infrastructure design and vehicle procurement. The further refinements will need to consider the following in order to optimize the trade-offs:

- Land acquisition
- Access implications
- Traffic operations implications
- Streetcar operational implications
- Retaining walls
- Street tree impacts
- Utility impacts
- Urban realm implications

Keeping Arbutus Street at, or as close as possible to, its existing grade is also feasible but would be likely to require the procurement of a streetcar vehicle designed specifically for the City and capable of negotiating the geometry. This is likely to limit the list of vehicle suppliers and has implications on the procurement process. It is difficult to quantify the potential costs associated with procurement of a suitable vehicle as suppliers will not share that type of information until required during a procurement process. Whether the streetcars will be required to cope with the 10.5% gradient does not need to be decided now but must be resolved prior to procurement of the first vehicles for any streetcar system within the City, whether the Arbutus Corridor route is developed at that time or not.

The information provided in this report has shown the potential requirements which will need to be addressed if the streetcar is not placed through ‘the Curves’ of the purchased corridor. However, the technical feasibility of the different options is not the sole factor in the decision whether or not to follow Arbutus Street. It needs to be a holistic decision and account for the potential future neighbourhood area planning and how those plans could be supported by streetcar.

If the City decides not to pursue the preferred streetcar alignment within the purchased corridor, then the further development of the Arbutus Street route should be included with a neighbourhood area plan. As part of such a process a multiple account evaluation could consider the infrastructure works required against the potential development benefits which could be realised. The study should compare the preferred streetcar alignment concept (with streetcar within the purchased corridor) against a few options with the streetcar alignment on Arbutus Street, such as the ones presented in Section 5 of this report. At that time alternate designs that use maximum grades of 9 to 10.5% should also be included. These options should be evaluated against economic, socio-community, environmental, financial, transportation (customer service) and First Nation accounts.

Appendices

A. 381002-MMD-00-P0-MO-TR-0003 – Arbutus Street Cross-Section Options Opportunities and Challenges

B. Option 1 – East Side Running Drawings

C. Option 3 - Shared Running Drawings

D. 381002-MMD-00-P0-MO-TR-0002 – Arbutus Greenway Vehicle Investigation System Requirement

E. 38100-2MMD-00-P0-MO-TR-0005 – Vehicle Supplier Review

A. 381002-MMD-00-P0-MO-TR-0003 – Arbutus Street Cross-Section Options Opportunities and Challenges

Memorandum

Subject	Arbutus Street Cross-Section Options Opportunities and Challenges – DRAFT FOR DISCUSSION
To	CoV Arbutus Project Team
From	Mott MacDonald Canada Limited – Prepared by Katherine Miller and Gary Farmer
Our reference	381002-MMD-00-P0-MO-TR-0003
Date	January 24, 2018 – Rev B

Due to the constrained nature of the purchased corridor through the curves north of Kerrisdale, the project team has identified the need to examine the feasibility of having streetcar on Arbutus Street from West 33rd Avenue to West 37th Avenue. Initial work in the development of the schematic concepts identified steep road grades on this section of Arbutus Street, particularly from West 33rd Avenue to West 34th Avenue, where the gradient is known to be in excess of 10%. This is more than the normal design parameters for streetcar and light rail transit systems operating in North America and therefore the following additional work is being carried out:

1. A Functional Planning Design exercise to confirm the consequences of reducing the track gradient to be in line with normal streetcar design parameters; and
2. A Vehicle Investigation to identify if there is potential that streetcar vehicles now or in the future might be able to navigate the existing gradients.

This memo deals with the Functional Planning Design only. The Vehicle Investigation will be addressed separately through a review of existing systems and discussions with suppliers which will be completed through December 2017 and January 2018.

The first stage of the functional planning design exercise is to develop potential cross sections of Arbutus Street for W 33rd Avenue – West 37th Avenue where the current road right-of-way (ROW) is approximately 20.1m. The following memo outlines the four cross section options for this area that have been developed and their opportunities and challenges.

Context

Figure 1 shows the area of interest, Arbutus Street from West 33rd Avenue to West 37th Avenue, and the preferred streetcar alignment that has been developed north of West 36th Avenue.

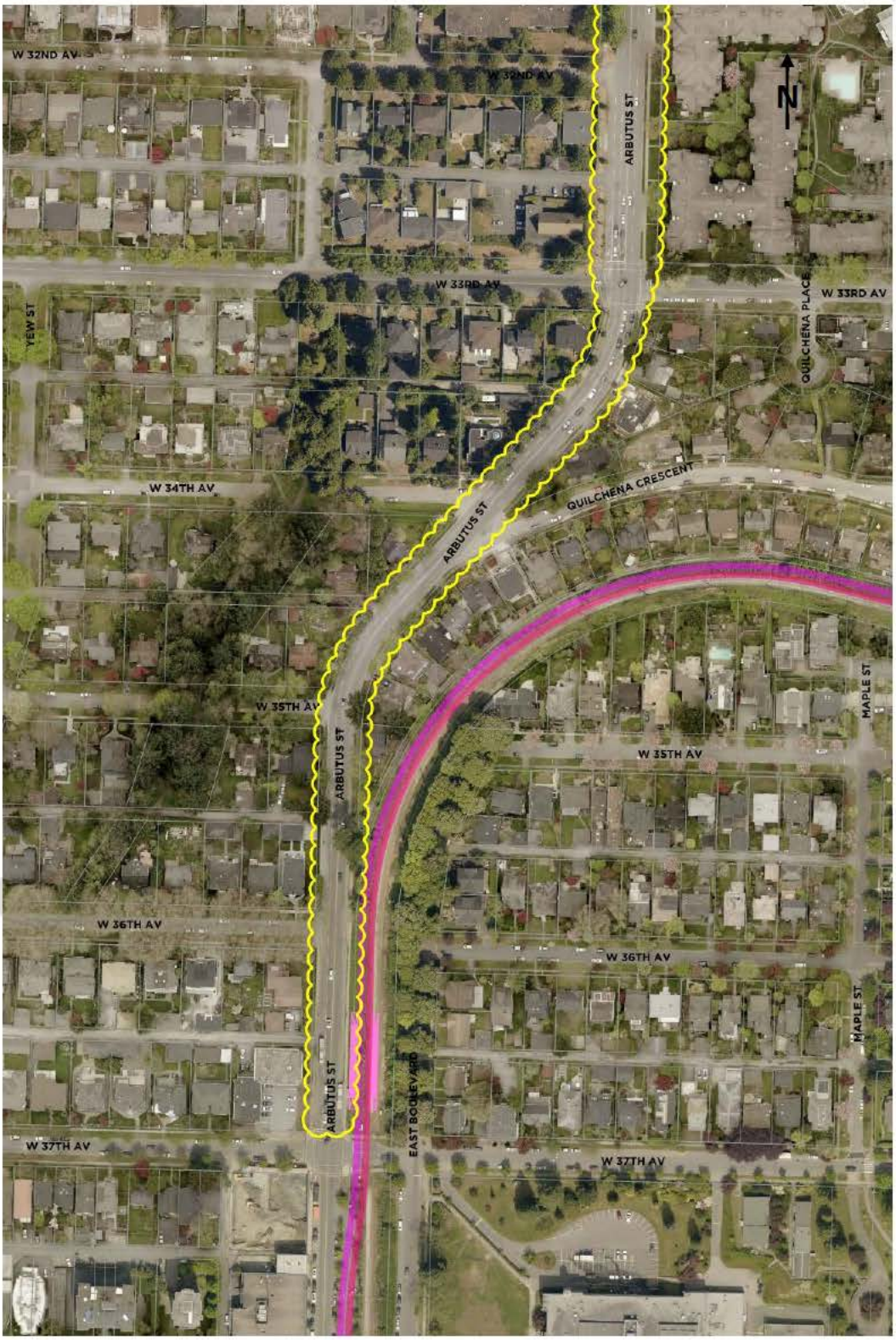


Figure 1 Arbutus Street between West 33rd Avenue to West 37th Avenue

Depending upon the technical feasibility of putting streetcar on Arbutus Street from West 33rd Avenue to West 37th Avenue, the streetcar alignment through this area will need to connect to the preferred alignment around West 37th Avenue with some flexibility as the Arbutus road ROW and purchased corridor become adjacent to each other north of the West 37th intersection.

North of West 33rd Avenue the Arbutus Street road ROW is approximately 30.35m wide. This allows for different cross-sectional layouts. These layouts have not been developed as discussion and better understanding of the potential future development plans along this section, Arbutus Street between West King Edward to West 33rd Avenue, is required to determine the most suitable layout to pursue for this area. It is feasible to have a different cross section for the area north of West 33rd Avenue to West King Edward Avenue as long as a transition is accounted for at or near the West 33rd Avenue intersection. It is also necessary for the streetcar alignment along Arbutus Street between West 33rd Avenue to West King Edward Avenue to connect to the preferred alignment north of West King Edward Avenue as shown in Figure 2.

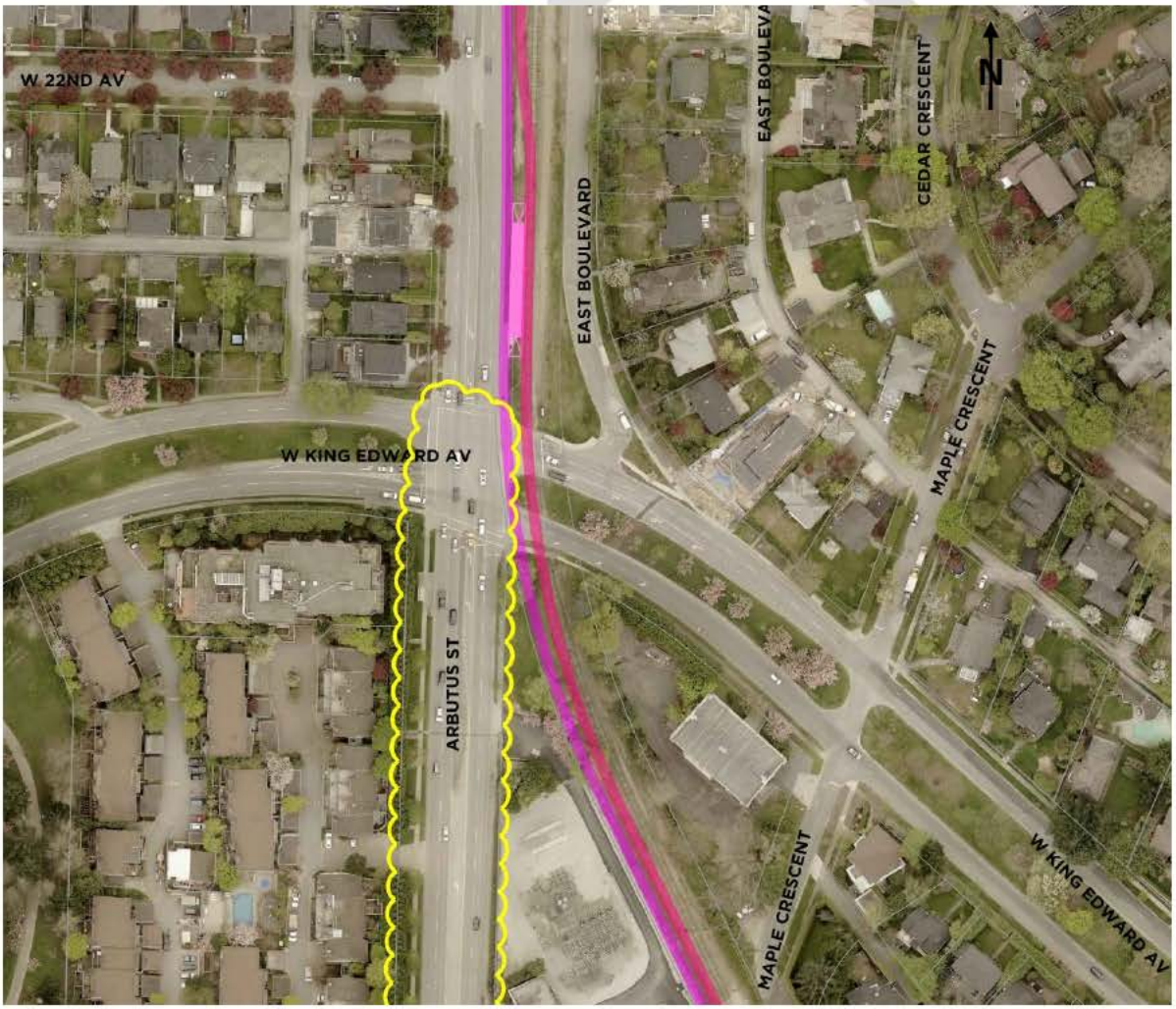


Figure 2 Arbutus Street at West King Edward Avenue

Options

Four options have been developed to capture the possible configurations of roads lanes, sidewalks and streetcar. All options could accommodate re-grading the road ROW to achieve acceptable gradient for streetcar with the road and streetcar at similar grades. However, only Options 1, 2 and 4 have allowance for the road grade to be separate from the streetcar grade. While the cross sections developed indicate an allowance for retaining structures, it should be noted that this may vary from cut walls in some places to fill walls in others, and walls will not be required at all in some locations. This will be refined in further stages depending on the final grading plan. Allowances have been incorporated to permit either option. Overhead catenary system (OCS) poles have also been accounted for in all options. Options 1, 2 and 4 have centre OCS poles which are located between the streetcar tracks. As Option 3 has shared running streetcar with vehicle traffic the OCS poles are located on either side of the road in a boulevard.

Option 1 – East Side Segregated Running

Option 1 (as shown in the appended sketches) consists of both streetcar tracks being side running along the east curb of Arbutus Street with one vehicle lane in each direction to their west. This option maintains the existing sidewalk on the west side of Arbutus Street.

It was developed by fixing the west property line in its existing position to limit property impacts to one side of Arbutus Street. With the tracks segregated to the east, and with a potential grade differential between the road and tracks in some locations, accesses and intersections along the east side will be affected. s.13(1), s.17(1)

Opportunities

- Accesses, including driveways, alleyways and intersections could be unaffected along the west side.
- Existing and upgraded water mains sited in the existing west curb lane can be maintained.
- Streetcar is segregated running and would not be operationally affected by traffic.
- Aligns with the streetcar alignment on Arbutus Street north of West King Edward Avenue and on West Boulevard south of West 37th Avenue with minimal horizontal transition curves.

Challenges

s.13(1), s.17(1)

- Properties south of Quilchena Crescent do back onto an alleyway that connects to from Arbutus Street to Linden Road but the Arbutus Street end would likely be closed.
- Due to loss of access (intersection and alleyway), further investigation on the circulation of emergency vehicles and servicing vehicles (e.g. garbage trucks) will be required to confirm if these closures are acceptable.
- With the streetcar side running, the headlights of the streetcar may pose a concern being on the wrong side of the roadway, particularly while negotiating the curves. This may require mitigation

which could include using headlight screening on top of the retaining wall between the streetcar and northbound vehicle lane.

- Nine existing street trees along the east side of Arbutus Street would need to be relocated, or removed and replaced, to the new boulevard strip.
- There are urban realm implications of having the street and streetcar at different grades, with retaining walls, as it creates a physical and visual barrier on the street that is not conducive to a walkable, transit oriented community. It would preclude pedestrians crossing Arbutus Street and the streetcar tracks through this section.

Option 2 – West Side Segregated Running

Option 2 (as shown in the appended sketches) consists of both streetcar tracks being side running along the west curb of Arbutus Street with one vehicle lane in each direction to their east. This option maintains the existing sidewalk on the east side of Arbutus Street.

It was developed by fixing the east property line in its existing position in order to limit property impacts to one side of Arbutus Street. s.13(1), s.17(1)
s.13(1), s.17(1)
s.13(1), s.17(1) As identified in the challenges below, the access implications of this option are likely to rule it out of further consideration.

Opportunities

- Accesses, including driveways, alleyways and intersections could be maintained along the east side.
- Existing and/or upgraded sewer mains sited in the existing east curb lane can be maintained.
- Streetcar is segregated running and would not be operationally affected by traffic.

Challenges

s.13(1), s.17(1)

- Due to Ravine Park, West 34th Avenue, West 35th Avenue, West 36th Avenue and three alleyways are dead-ended with current access only from Arbutus Street. s.13(1), s.17(1)
  s.13(1), s.17(1)
  s.13(1), s.17(1) The northern most alley also provides supplementary access and servicing to 6 properties which front onto West 33rd Avenue, which means changes to the alley access may not be critical
- With the streetcar side running, the headlights of the streetcar may pose a concern being on the wrong side of the roadway, particularly while negotiating the curves. This may require mitigation which could include using headlight screening on top of the retaining wall between the streetcar and southbound vehicle lane.
- On-street parking on Arbutus Street is removed.

- The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Avenue which introduces additional horizontal curves.
- The transition of the streetcar alignment to and from east side running will need to be accommodated at a signalized intersection, or a new signal will need to be put into place to manage the crossing of streetcar tracks and vehicle lanes.
    - If the transition is accommodated at West 36th Ave the streetcar stop placement at West 37th Ave does not need to be adjusted.
    - The transition on the north end of the section will depend on the cross section configuration north of West 33rd Avenue as indicated in Context Section.
- Eight existing street trees along the east side of Arbutus Street would need to be relocated, or removed and replaced, to the new boulevard strip.
- There are urban realm implications of having the street and streetcar at different grades, with retaining walls, as it creates a physical and visual barrier on the street that is not conducive to a walkable, transit oriented community. It would preclude pedestrians crossing Arbutus Street and the streetcar tracks through this section.

Option 3 – Shared Running

Option 3 (as shown in the appended sketches) consists of the streetcar tracks being sited in mixed traffic/shared running lanes along each curb. There could be a turning lane in-between the northbound and southbound lanes. This turning lane would be used to maintain the intersections at West 34th Avenue, West 35th Avenue, West 36th Avenue and Quilchena Crescent, but not necessarily to allow for turning access into alleyways and driveways. Regrading of the entire roadway will be required in some locations. To maintain intersections, some regrading along the intersecting roads could be required. s.13(1), s.17(1) s.13(1), s.17(1) This option utilizes the existing road ROW to permit increased sidewalk widths and the inclusion of a boulevard for street lighting and side OCS poles.

Opportunities

- Maintains the existing road ROW and does not require any property boundaries to be setback.
- Potentially allows for the intersections at West 34th Avenue, West 35th Avenue, West 36th Avenue and Quilchena Crescent to remain open to vehicular traffic.
- Potential to optimize cross-section further by optimizing lane widths.
- The existing street tress can kept in place.

Challenges

s.13(1), s.17(1)

- The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Avenue which introduces additional horizontal curves.

- The transition of the streetcar alignment to and from east side running will need to be accommodated at a signalized intersection, or a new signal will need to be put into place to manage the crossing of streetcar tracks and vehicle lanes.
    - If the transition is accommodated at West 36th Ave the streetcar stop placement at West 37th Ave does not need to be adjusted.
    - The transition on the north end of the section will depend on the cross section configuration north of West 33rd Avenue as indicated in Context Section.
- Existing and/or upgraded City Owned utilities in the curb lanes will need to be relocated.
- Streetcar is shared running with vehicles and would be operationally affected by traffic.

Option 4 – Centre Segregated Running

Option 4 (as shown in the appended sketches) consists of the streetcar tracks adjacent to one another being situated in the middle of the road ROW. The intersections at West 34th Avenue, West 35th Avenue, West 36th Avenue and Quilchena Crescent along with driveway and alleyway access can be maintained as right-in-right-out only unless additional turning lanes and fully signalized intersections are incorporated.

The cross-section shown indicates a property setback is required along the east side of Arbutus Street. There is an opportunity to shift the property setback requirement to occur on the west side or be split the across both sides of the Arbutus Street.

Opportunities

- Accesses (driveways and alleyways) and intersections can remain open to right-in-right-out vehicle traffic
- The road lanes and sidewalks may be kept at their existing grades.
- Streetcar is segregated running and would not be operationally affected by traffic.
- The impacts to existing and/or upgraded City Owned utilities will likely be avoided is existing curb lanes maintained.

Challenges

- With limiting accesses and intersections to right-in-right-out only this may have significant effects on access and circulation.
- On-street parking on Arbutus Street is removed.
- The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Ave which introduces additional horizontal curves.
- The transition of the streetcar alignment to and from east side running will need to be accommodated at a signalized intersection, or a new signal will need to be put into place to manage the crossing of streetcar tracks and vehicle lanes.
    - If the transition is accommodated at West 36th Ave the streetcar stop placement at West 37th Ave does not need to be adjusted.

    - The transition on the north end of the section will depend on the cross section configuration north of West 33rd Avenue as indicated in Context Section.
- Nine existing street trees along the east side of Arbutus Street would need to be relocated, or removed and replaced, to the new boulevard strip.
- There are urban realm implications of having the street and streetcar at different grades, with retaining walls, as it creates a physical and visual barrier on the street that is not conducive to a walkable, transit oriented community. It would preclude pedestrians crossing Arbutus Street and the streetcar tracks through this section.

Recommendations and Next Steps

Based on the opportunities and challenges laid out in this document, it is recommended that the Option 1 – East Side Segregated Running be carried forward through further investigation. It is also recommended that Option 2 – West Side Segregated Running be eliminated based on the significant access implications. Further discussion is required for s.13(1), s.17(1)
s.13(1), s.17(1)

- Due to Ravine Park, West 34th Avenue, West 35th Avenue, West 36th Avenue and three alleyways are dead-ended with current access only from Arbutus Street. s.13(1), s.17(1)
  s.13(1), s.17(1)
  s.13(1), s.17(1) The northern most alley also provides supplementary access and servicing to 6 properties which front onto West 33rd Avenue, which means changes to the alley access may not be critical
- With the streetcar side running, the headlights of the streetcar may pose a concern being on the wrong side of the roadway, particularly while negotiating the curves. This may require mitigation which could include using headlight screening on top of the retaining wall between the streetcar and southbound vehicle lane.
- On-street parking on Arbutus Street is removed.
- The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Avenue which introduces additional horizontal curves.
- The transition of the streetcar alignment to and from east side running will need to be accommodated at a signalized intersection, or a new signal will need to be put into place to manage the crossing of streetcar tracks and vehicle lanes.
    - If the transition is accommodated at West 36th Ave the streetcar stop placement at West 37th Ave does not need to be adjusted.
    - The transition on the north end of the section will depend on the cross section configuration north of West 33rd Avenue as indicated in Context Section.
- Eight existing street trees along the east side of Arbutus Street would need to be relocated, or removed and replaced, to the new boulevard strip.

- There are urban realm implications of having the street and streetcar at different grades, with retaining walls, as it creates a physical and visual barrier on the street that is not conducive to a walkable, transit oriented community. It would preclude pedestrians crossing Arbutus Street and the streetcar tracks through this section.

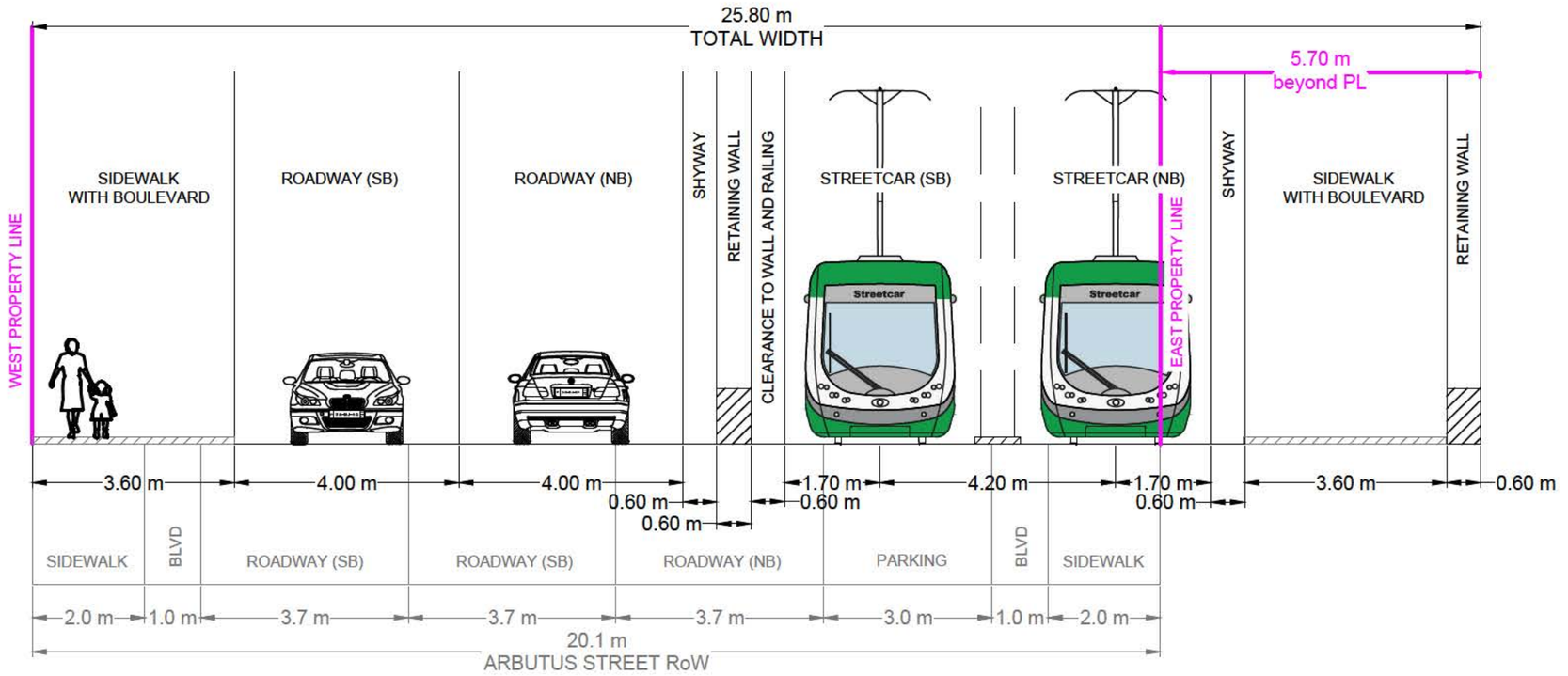
Option 3 – Shared Running and The streetcar alignment will need to transition to and from east side running south of West 37th Avenue and at least north of West King Edward Avenue which introduces additional horizontal curves.

- The transition of the streetcar alignment to and from east side running will need to be accommodated at a signalized intersection, or a new signal will need to be put into place to manage the crossing of streetcar tracks and vehicle lanes.
    - If the transition is accommodated at West 36th Ave the streetcar stop placement at West 37th Ave does not need to be adjusted.
    - The transition on the north end of the section will depend on the cross section configuration north of West 33rd Avenue as indicated in Context Section.
- Existing and/or upgraded City Owned utilities in the curb lanes will need to be relocated.
- Streetcar is shared running with vehicles and would be operationally affected by traffic.

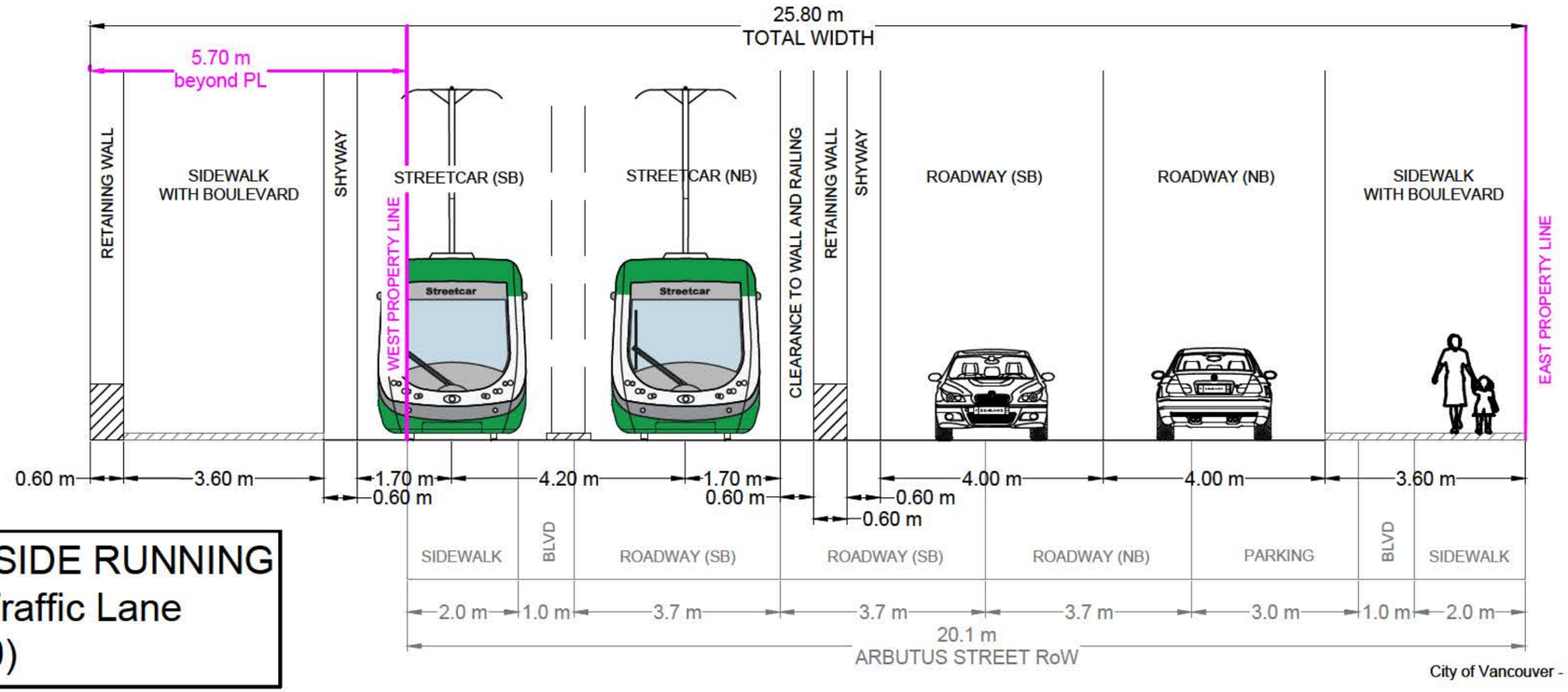
Option 4 – Centre Segregated Running upon CoV's preference for segregation of streetcar versus potential property impacts.

After further discussion occurs, two options will be investigated further through development of streetcar horizontal and vertical design, and accompanying the road design and property implications.

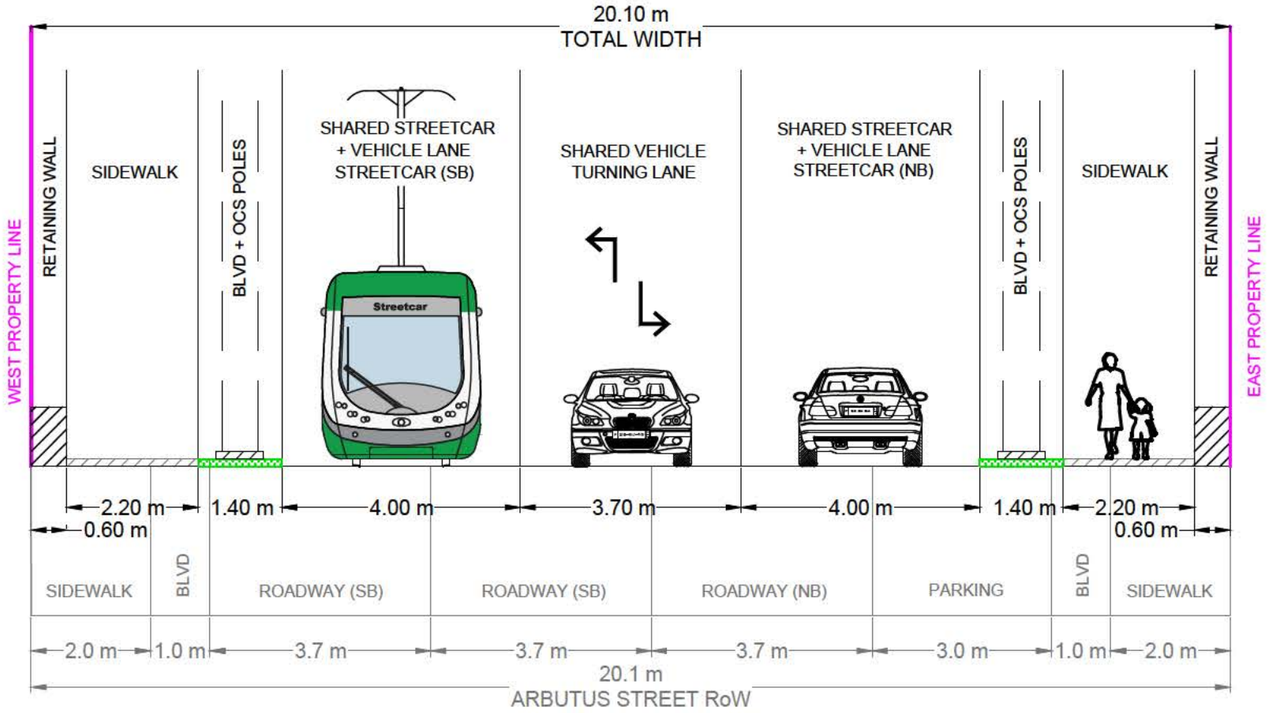
OPTION 1 - EAST SIDE RUNNING
On-Arbutus Street Traffic Lane Configuration (1:100)



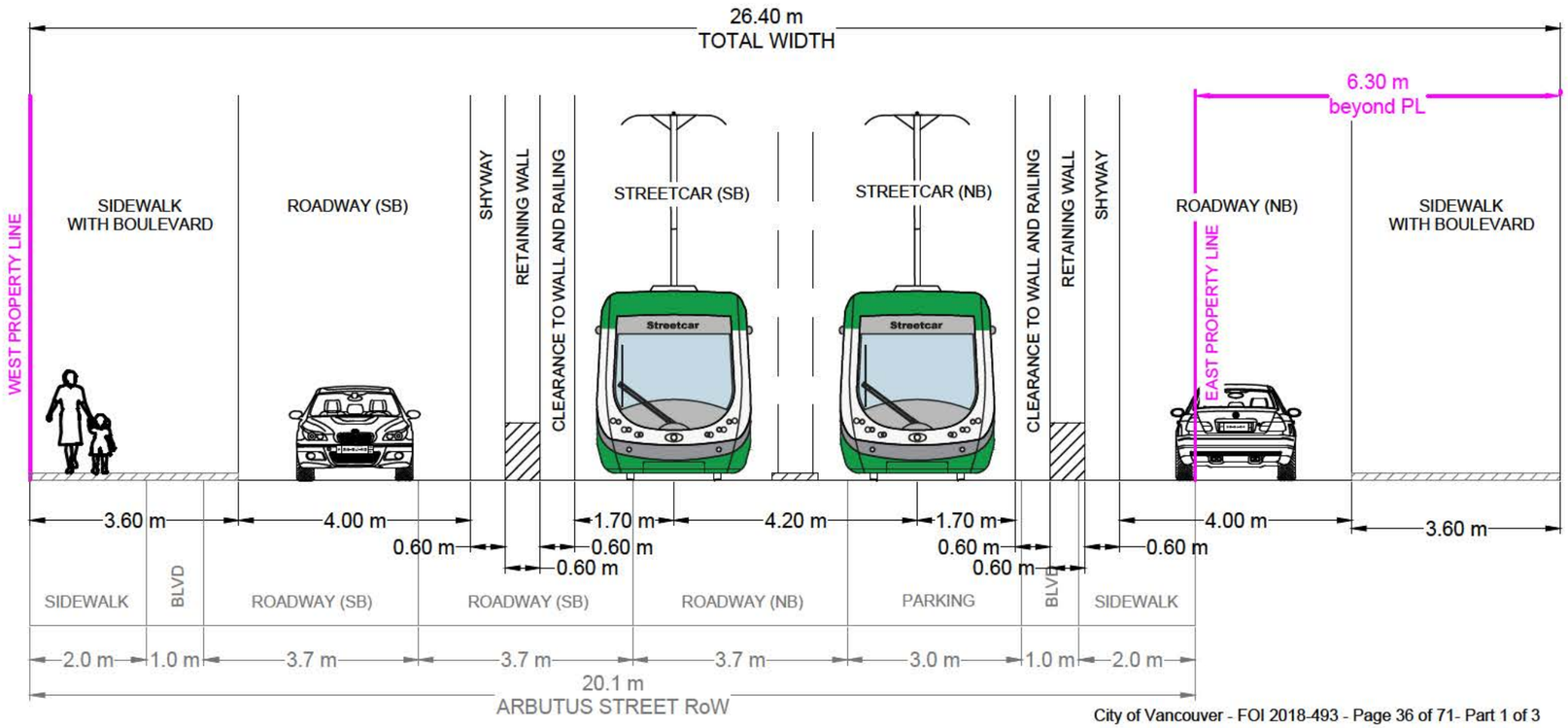
OPTION 2 - WEST SIDE RUNNING
On-Arbutus Street Traffic Lane Configuration (1:100)



OPTION 3 - SHARED RUNNING
On-Arbutus Street Traffic Lane Configuration (1:100)



OPTION 4 - CENTRE RUNNING
On-Arbutus Street Traffic Lane Configuration (1:100)



B. Option 1 – East Side Running Drawings

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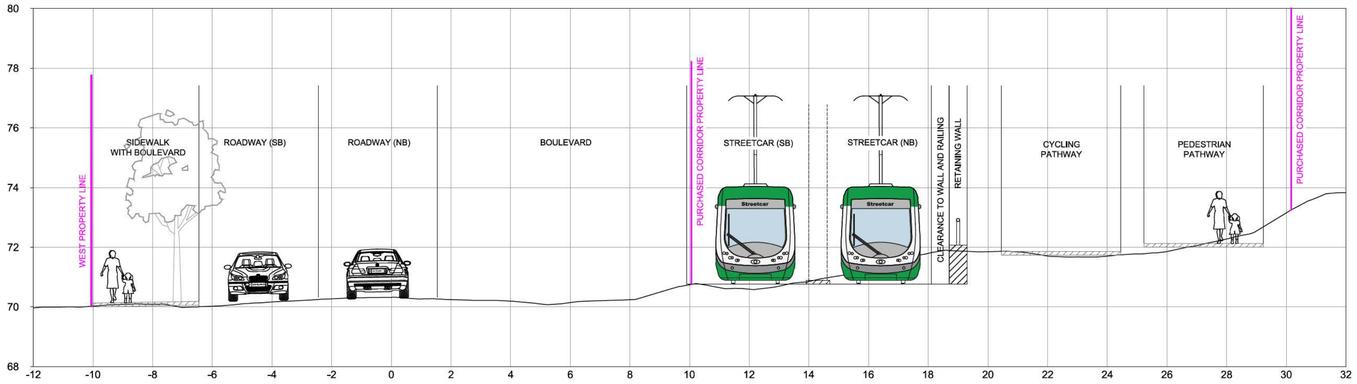

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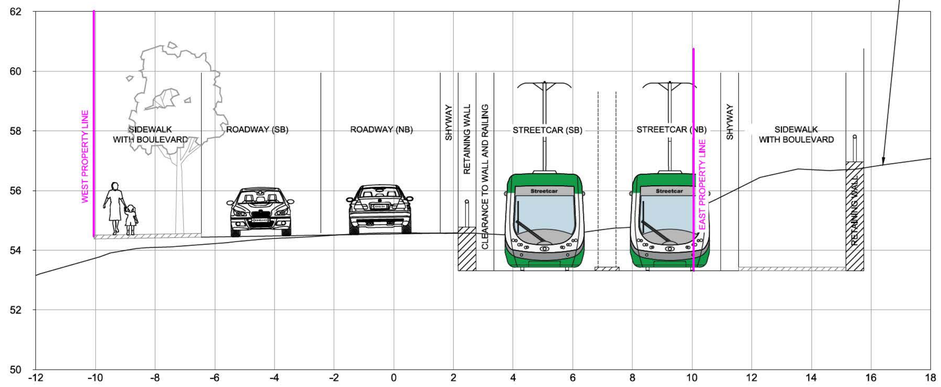
POTENTIAL TO REGRADE ADJACENT SITE AND REDUCE OR AVOID THE NEED FOR A RETAINING WALL (DEPENDENT ON LAND ACQUISITION AND DEVELOPMENT).



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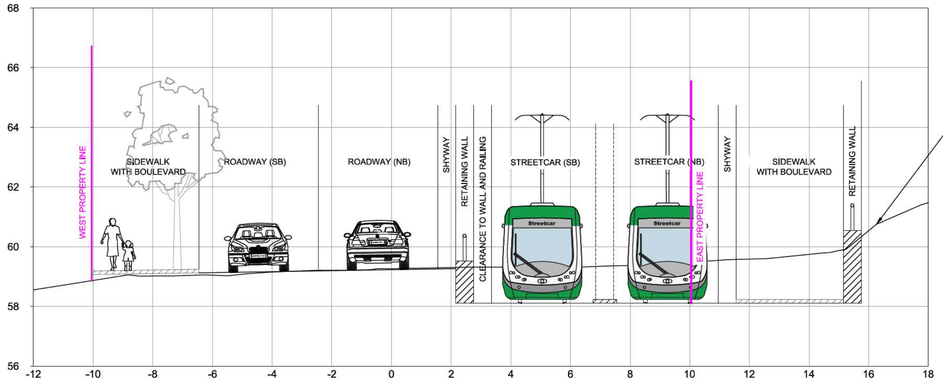
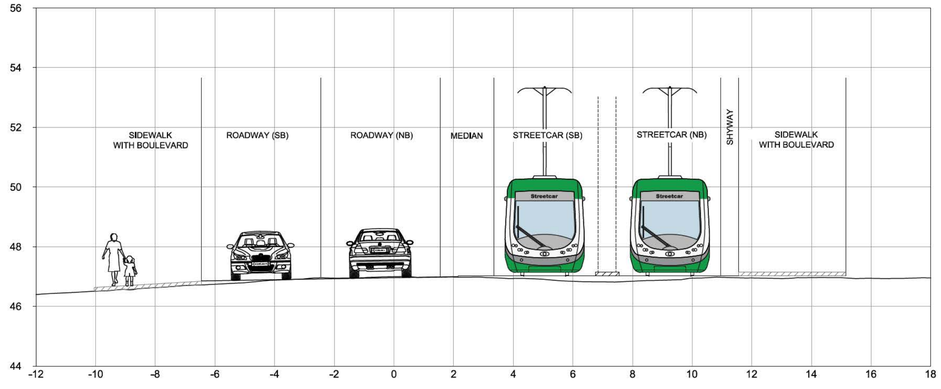


POTENTIAL TO REGRADE ADJACENT SITE AND REDUCE OR AVOID THE NEED FOR A RETAINING WALL (DEPENDENT ON LAND ACQUISITION AND DEVELOPMENT).

0+580.00



1 m 0 1:100 5 m

Legend:

Engineer's Seal:

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	2018/01/25	LA	DRAFT - ISSUED FOR CLIENT REVIEW	KM	GF

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453 West 12th Ave
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V5Y 1V4

Project Team: DIALOG; URBAN systems

Designed By:	L. ANDERSON	2018/01/25	Eng. Check:	K. MILLER	2018/01/25	
Drawn By:	L. ANDERSON	2018/01/25	Coordination:	K. MILLER	2018/01/25	
Dwg Check:	K. MILLER	2018/01/25	Approved:	G. FARMER	2018/01/25	
Scale at D Size:	As Noted	Status:	DRAFT	Rev:	A	Security: STD

Drawing Number: 381002-MMD-00-P0-DR-TR-0101

Title:
ARBUTUS GREENWAY PROJECT
ARBUTUS STREET
W 37th AVE TO W 33rd AVE
OPTION 1 - EAST SIDE RUNNING
CROSS SECTIONS

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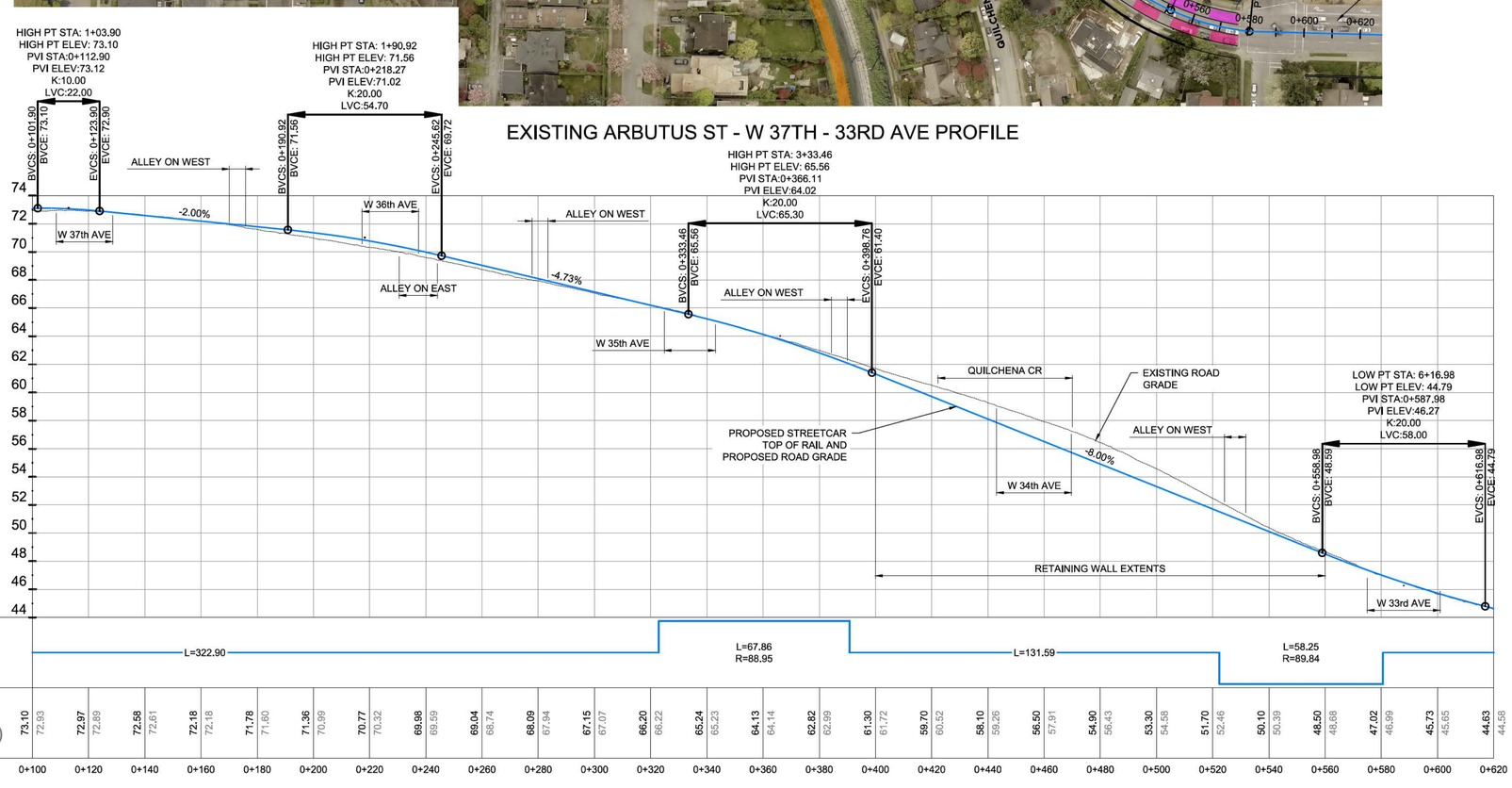
s.13(1), s.17(1)

C. Option 3 - Shared Running Drawings

ROAD AND STREETCAR LAYOUTS HAVE NOT BEEN DEVELOPED NORTH OF WEST 33rd AVENUE TO WEST KING EDWARD AVENUE AS DISCUSSION AND FURTHER UNDERSTANDING OF FUTURE DEVELOPMENT PLANS IS REQUIRED TO DETERMINE THE MOST SUITABLE LAYOUT.

EXISTING ARBUTUS ST - W 37TH - 33RD AVE PROFILE



NOTES:

1. ROAD LANES ARE 4.0m WIDE TO ALLOW FOR WB-20 VEHICLE TO NAVIGATE THE CURVES WITHOUT OVER TRACKING INTO THE ONCOMING LANE.
2. SIDEWALKS ARE 3.6m TO ALLOW FOR ACCESSIBLE SIDEWALK AND BOULEVARD.
3. NO WIDENING TO OCCUR.
4. STREETCAR CLEARANCE OFFSETS AS PER 381002-MMD-00-P0-RP-TR-0001.
5. SEE 381002-MMD-00-P0-DR-TR-0103 FOR CROSS SECTIONS.

LEGEND:

- FUTURE POTENTIAL STREETCAR STOPS
- NORTHBOUND STREETCAR
- IN-STREET NORTHBOUND STREETCAR
- SOUTHBOUND STREETCAR
- IN-STREET SOUTHBOUND STREETCAR
- PEDESTRIAN WALKWAY
- BICYCLE PATHWAY

VERTICAL SCALE 2 m 0 1:200 10 m

HORIZONTAL SCALE 10 m 0 1:1000 50 m

Legend:

Engineer's Seal:

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	2018/01/25	LA	DRAFT - ISSUED FOR CLIENT REVIEW	KM	GF

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Project Team: DIALOG; URBAN systems

Designed By:	L. ANDERSON	2018/01/25	Eng. Check:	K. MILLER	2018/01/25
Drawn By:	L. ANDERSON	2018/01/25	Coordination:	K. MILLER	2018/01/25
Dwg Check:	K. MILLER	2018/01/25	Approved:	G. FARMER	2018/01/25

Scale at D Size:	Status:	Rev:	Security:
As Noted	DRAFT	A	STD

Drawing Number: 381002-MMD-00-P0-DR-TR-0102

Title:
ARBUTUS GREENWAY PROJECT
ARBUTUS STREET
W 37th AVE TO W 33rd AVE
OPTION 3 - SHARED RUNNING
PLAN AND PROFILE

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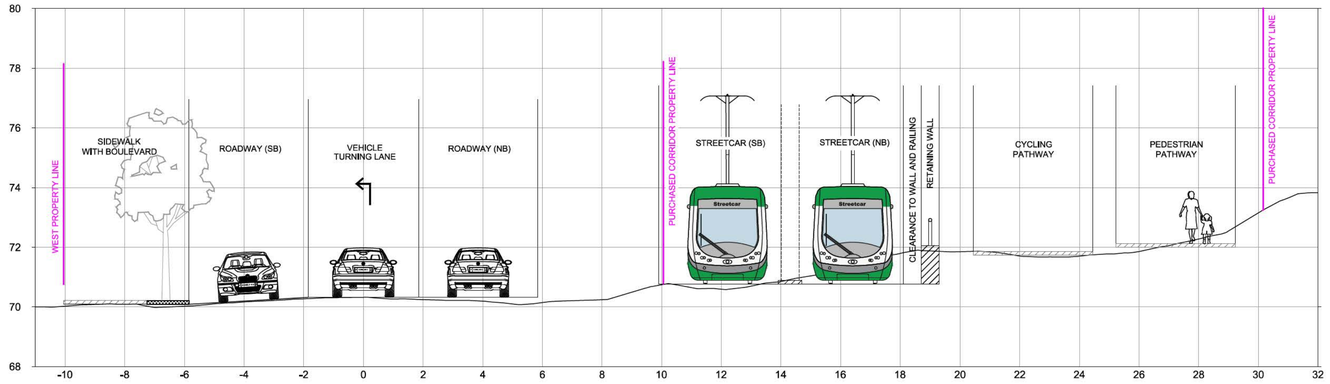

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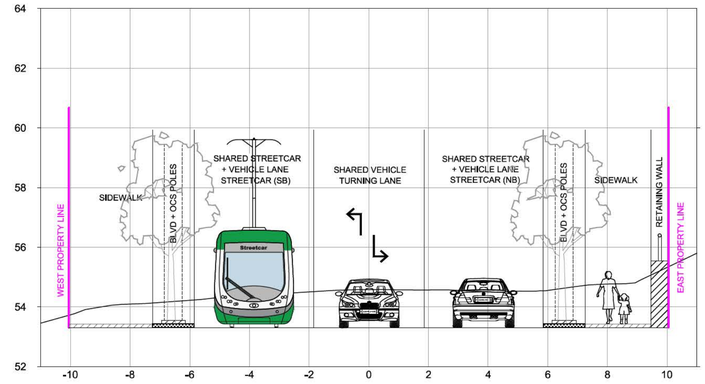

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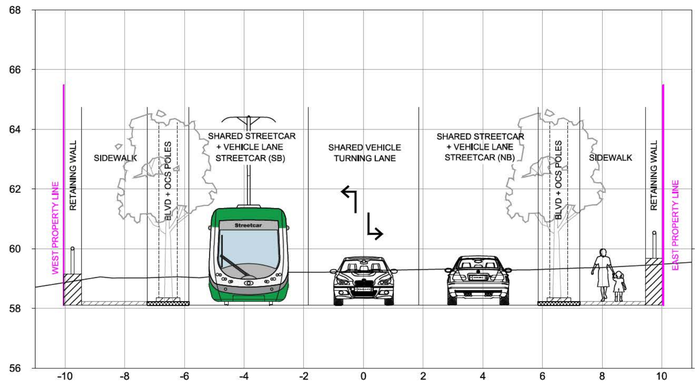

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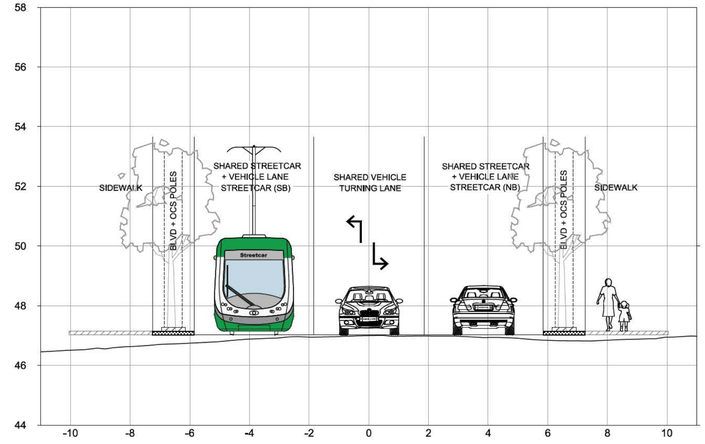

1 m 0 1:150 6 m

Legend:

Engineer's Seal:

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	2018/01/25	LA	ISSUED FOR DISCUSSION - DRAFT	KM	GF

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Project Team: DIALOG; URBAN systems

Designed By:	L. ANDERSON	2018/01/25	Eng. Check:	K. MILLER	2018/01/25
Drawn By:	L. ANDERSON	2018/01/25	Coordination:	K. MILLER	2018/01/25
Dwg Check:	K. MILLER	2018/01/25	Approved:	G. FARMER	2018/01/25

Scale at D Size:	Status:	Rev:	Security:
As Noted	DRAFT	A	STD

Drawing Number: 381002-MMD-00-P0-DR-TR-0103

Title:
ARBUTUS GREENWAY PROJECT
ARBUTUS STREET
W 37TH AVE TO W 33rd AVE
OPTION 3 - SHARED RUNNING CROSS SECTIONS

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D. 381002-MMD-00-P0-MO-TR-0002 – Arbutus Greenway Vehicle Investigation System Requirements

Subject	Arbutus Greenway Vehicle Investigation System Requirements
To	Whom it May Concern
From	Mott MacDonald Canada Limited – Prepared by Katherine Miller
Our reference	381002-MMD-00-P0-MO-TR-0002
Date	December 12, 2017

Project Background

The City of Vancouver (CoV) purchased a disused freight rail corridor, which runs from near the Fraser River in the south of Vancouver nearly to Granville Island on the north shore of Kitsilano, from Canadian Pacific Rail in 2016. The City has a long-term vision to create a thoroughfare and public space for use by all residents. The City has identified streetcar in the Arbutus Greenway a key component of the City's future transportation network; meant to have transit functionality, serving passengers effectively and safely, with minimal physical and operational impacts to its surroundings. The Arbutus Corridor will be a part of a city-wide streetcar network which is being considered. However, streetcar on the Arbutus Corridor is not anticipated to be constructed in the near term.

As an alternative to staying within a constrained portion of the rail corridor, CoV has identified the need to examine the feasibility of siting streetcar on Arbutus Street from West 33rd Avenue to West 37th Avenue. Initial work in the development of concepts identified steep road grades on this section of Arbutus Street, particularly from West 33rd Avenue to West 34th Avenue, where the gradient is in excess of 10%. This is more than the normal design parameters for most streetcar and light rail transit systems operating in North America, an investigation into potential streetcar vehicle capabilities is being carried out.

Design Constraints

The following figure shows the area of interest, Arbutus Street from West 33rd Avenue to West 37th Avenue. Working from north to south, Arbutus Street is gradually sloped at 2.5-5.5% rising up towards the West 33rd Avenue intersection before the grade increases to approximately 10.5% through the intersection and for approximately 100 m to the south. This steep grade is coincident with a horizontal curve with a radius less than 100m (radii of centerline of road = 87.9m).

The steep grade then eases off to a grade of 4.5-6%. There is a second curve on this grade with a horizontal curve with a radius less than 100m (radii of centerline of road = 88.5m).

Any significant changes to the roadway gradients to reduce the slope in this section may affect intersections and accesses and could result in the need for property to be attained. This could be avoided if

a vehicle could be acquired which could negotiate tracks which were to closely match the existing road geometry.

Figure 1 Arbutus Street between West 33rd Avenue to West 37th Avenue

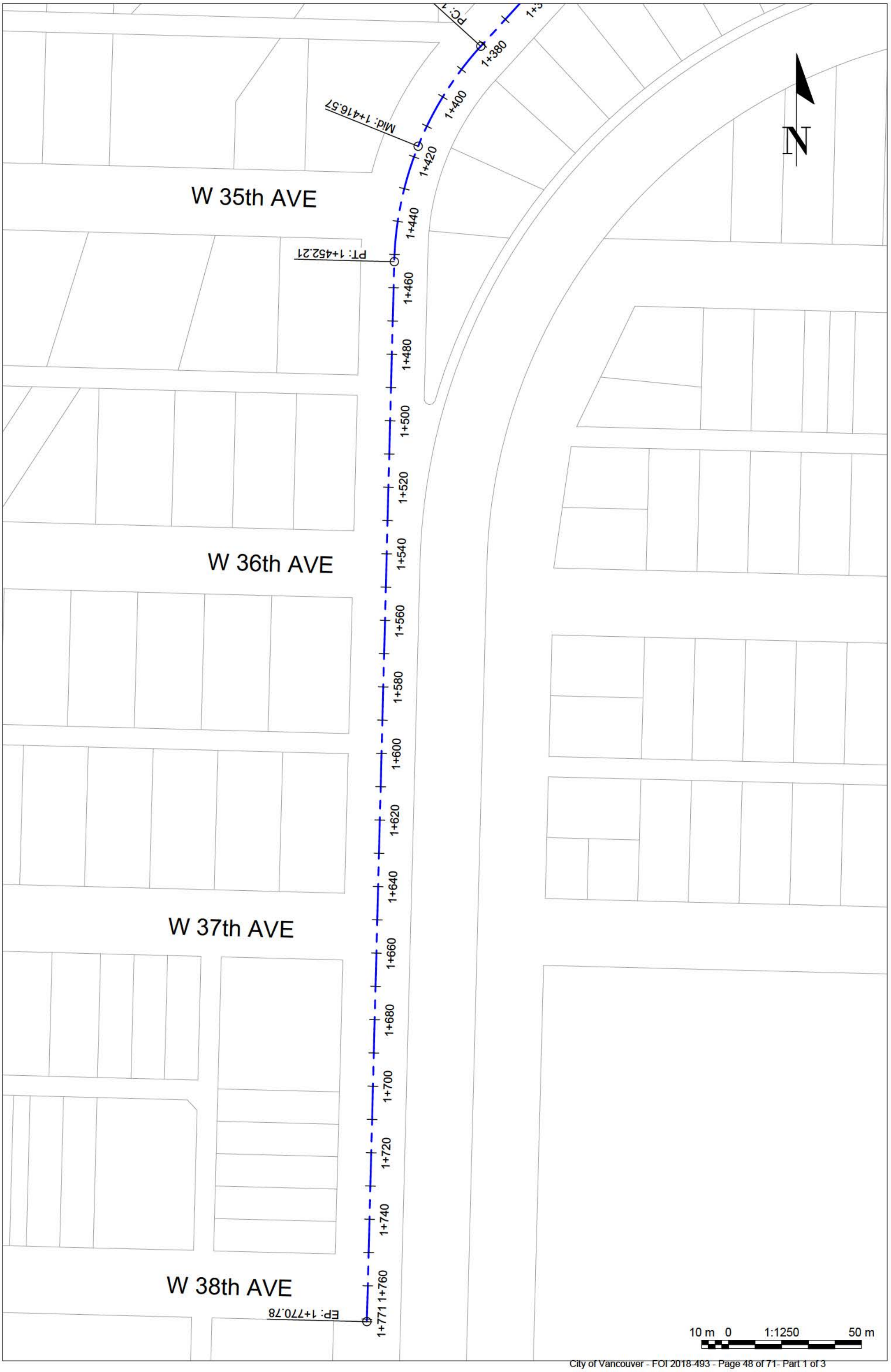
Next Steps

On behalf of the City of Vancouver, we are investigating whether streetcar vehicles, either available on the market now or with foreseen advances in the future may be able to negotiate the described geometry or whether infrastructure changes must be planned for. We would like to pursue a discussion on your views to try and understand the following:

- Whether your current models of streetcar (or urban style LRV) could safely and reliably negotiate this geometry when climbing or descending under all passenger loading conditions up to and including AW3;
- Whether it is likely that one of your current vehicles could be developed or modified to negotiate this geometry;
- Any potential compromises or modifications to your standard vehicle which would be required in order to achieve the required capabilities, i.e. moving to all powered bogies, reduced acceleration rates, improved braking rates or operating speed through the area, etc.
- The potential order of magnitude cost and schedule implications of required modifications, i.e. it would require an additional 6 months of design and incur a 40% cost increase per vehicle; and
- If you consider it unlikely that a vehicle could negotiate the geometry please suggest the maximum acceptable gradient on the assumption that the horizontal curvature cannot be adjusted.

If you require further details of this technical challenge please contact Mark Terry.

We would like to receive information from you by January 5th, 2018.


W 35th AVE
W 36th AVE
W 37th AVE
W 38th AVE
PC: 1+
1+380
1+400
Mid: 1+416.57
1+420
1+440
PT: 1+452.21
1+460
1+480
1+500
1+520
1+540
1+560
1+580
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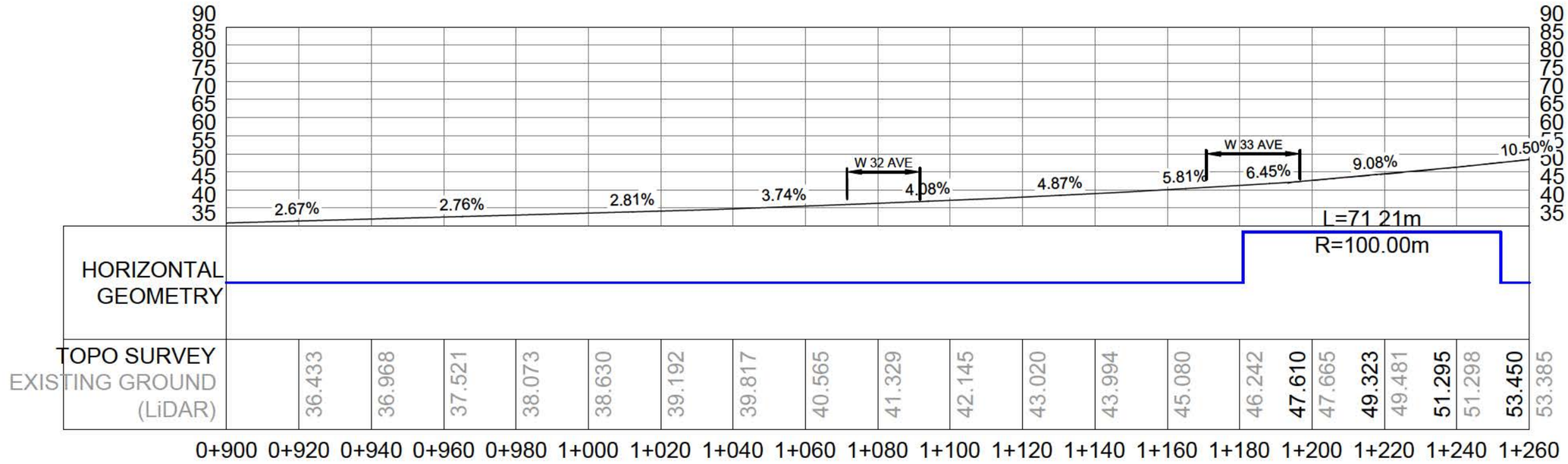

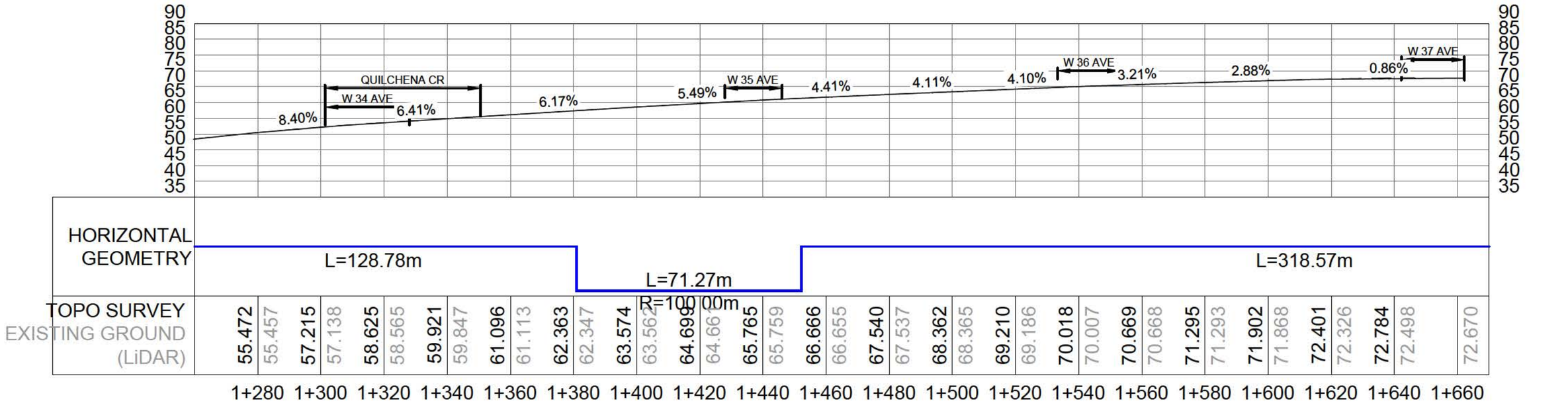

10 m 0 1:1250 50 m

E. 381002-MMD-00-P0-MO-TR-0005 – Vehicle Supplier Review

Memorandum

Subject	Arbutus Greenway Vehicle Supplier Review
To	CoV Arbutus Project team
From	Mott MacDonald Canada Limited – Prepared by Brandon Johnson and Mark Terry
Our reference	381002-MMD-00-P0-MO-TR-0005
Date	February 19, 2018

Due to the constrained nature of the purchased corridor through the curves north of Kerrisdale, the project team has identified the need to examine the feasibility of having streetcar on Arbutus Street from West 33rd Avenue to West 37th Avenue. Initial work in the development of the schematic concepts identified steep road grades on this section of Arbutus Street, particularly from West 33rd Avenue to West 34th Avenue, where the gradient is known to be in excess of 10%. This is more than the normal design parameters for streetcar and light rail transit systems operating in North America and therefore a vehicle assessment is needed to identify if there is potential for streetcar vehicles now or in the future to be able to navigate the existing gradients.

The Functional Planning Design is being addressed separately through cross section development (presented in 381002-MMD-00-P0-MO-TR-0003 – Arbutus Street Cross-Section Options Opportunities and Challenges) and subsequent plan-profile design (see and Section 5 of 381002-MMD-00-P0-RP-TR-0002 – Draft Functional Planning Design Report).

This initial assessment of the streetcar market involved contacting both North American and International manufacturers, to investigate whether streetcar vehicles, either available on the market now or with foreseen advances in the future, may be able to negotiate tracks designed to match the existing roadway. The suppliers were provided with a description of the geometry in 381002-MMD-00-P0-MO-TR-0002 – Arbutus Greenway Vehicle Investigation System Requirements, which is in Appendix D of 381002-MMD-00-P0-RP-TR-0002. Subsequently correspondence was pursued with several suppliers to understand the following:

- Whether their current models of streetcar (or urban style LRV) could safely and reliably negotiate the geometry when climbing or descending under all passenger loading conditions up to and including AW3 (which is an LRV weight plus weight of seated passengers at maximum seating capacity and weight of standing passengers at density of 6 passengers per square metres);
- If they currently don't make a suitable vehicle, whether it is likely that one of their current models could be developed or modified to negotiate this geometry;
- What compromises or modifications to their standard vehicle, or what operational restrictions could be applied in order to achieve the required capabilities, i.e. moving to all powered bogies,

reduced acceleration rates, improved braking rates or reduced operating speed through the area, etc.

- The potential order of magnitude cost and schedule implications of required modifications, i.e. it would require an additional 6 months of design and incur a 40% cost increase per vehicle;
- If they considered it unlikely that any of their vehicles could negotiate the geometry what would be the maximum acceptable gradient on the assumption that the horizontal curvature present cannot be adjusted.

This memo presents supplier responses followed by a summary of responses in Table 1. It ends with conclusions and recommendations based upon the information gathered and the technical knowledge of the Mott MacDonald team.

s.21(1)

[redacted]

s.21(1)

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