Options for Transit Terminal Access near a Steep Hill – Roadway Functional Design

Abstract.

A Canadian city was planning a set of future transit service modifications, including introduction of new bus routes. These would be accommodated at a future neighbourhood bus terminal, with an adjacent park and ride lot. The site was chosen in part because high volumes of traffic currently pass by the location, providing a potential travel market for the new services.

West of the site, the adjacent road climbs a hill with grades over 11%. The need for a new bus terminal access near the base of the steep hill has potential operational and safety problems during winter, including downhill stopping and uphill climbing from the bus terminal. These challenges required exploration of several design options, including traffic control, modified intersection configurations, and revised alignments and profiles for the collector road. These options were evaluated with City stakeholder input, considering operational, safety, complete streets and travel time objectives. The final functional design was a combination of a modified profile for the collector road, with a traffic signal introduced at the new access point.

This paper describes the design objectives, existing conditions, resulting challenges, options developed, and the considerations that led to selection of the functional design for the bus terminal site access.

1. Introduction

A city in Canada[i] was planning transit service modifications, including introduction of new bus routes and construction of a neighbourhood bus terminal. This new transit terminal was to be located southwest of the intersection of a collector street and arterial road. The future transit plan proposed that several future bus routes would lay over within the terminal. Another route would pass by on-street, serving the adjacent neighbourhood to the west. A shared transit and recreation parking lot was also planned, replacing an existing unpaved lot. The design challenges related to the functional needs of the new terminal, within the context of the location.

The adjacent collector road currently drops in elevation as it heads west from the arterial at roughly -1% for 200 metres, and then makes an abrupt transition and continues uphill at an 11% grade. The current bus route stops on the collector road in the relatively flat part of the profile, just west of the intersection with the arterial. According the roads and transit departments, that existing location provided sufficient distance for buses to accelerate for the uphill climb, and stopping distance downhill.

The future bus transit terminal underwent its own design exercise. Its size was a function of the number of bus stops required by the service plan, while its configuration was a result of property impact and parking supply trade-offs with the adjacent land. The recommended terminal configuration was proposed as a loop with buses stopping on both sides, oriented parallel to the collector, and with one

connection to the street system. This was to reduce the likelihood of transit passengers crossing the paths of moving buses, and to minimize the loop's footprint in the recreation space. However, this configuration meant the access point would be close to the base of the 11% uphill grade. This would create a potential stopping hazard from downhill vehicles and a climbing challenge for buses and other vehicles, especially those turning left out of the terminal access driveway. These issues would be worse in winter conditions.

A range of options was considered to facilitate this access point into the terminal including traffic control and physical modifications to the street and intersection. These options were evaluated with City stakeholder input, considering operational, safety, complete streets and travel time objectives. The final functional design was a combination of a modified profile for the collector road, with a traffic signal introduced at the new access point.

This rest of this paper describes the design objectives, existing conditions, resulting challenges, options developed, and the considerations that led to selection of a functional design for the bus terminal site access. The recommendation was then carried into a final design process[ii] (beyond the scope of this paper).

2. Design Objectives

Transit Terminal

The proposed transit terminal was to be located on municipal lands, located in the southwest quadrant of the intersection of a collector street and arterial road. The future transit service plan proposed that up to five bus routes would terminate at the transit loop. Another route would pass by on-street, serving the adjacent neighbourhood west of the proposed terminal, up a short but steep hill. One of the new routes ending at the terminal would go up the hill into the adjacent neighbourhood. This is shown schematically on Figure 1.

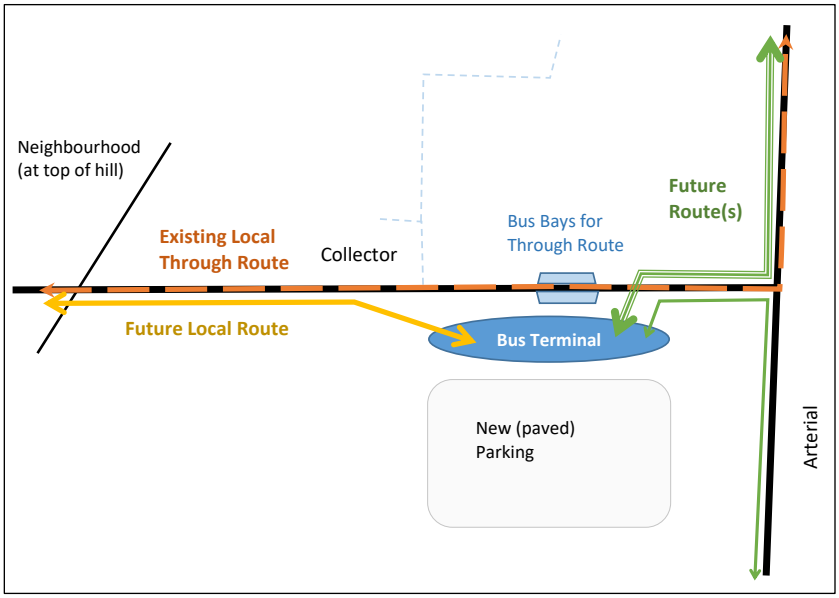

Figure 1 – Proposed Transit Functions around Future Terminal

To serve the proposed bus routes, the terminal would ideally sufficient for four to five standard length (40-foot) buses to stop at one time, and allow the buses to turn around. A review of in-terminal options (not the focus of this paper) resulted in the transit agency choosing a turn-around loop with saw-tooth bus bays on each side of the terminal roadway.

Since the bus operating on the collector road would have better travel time by staying on the street, its stops would remain on-street. Laybys were requested by the transit department, because the stop near the transit terminal is a logical timing point for that route. Sidewalks and layby spaces would have to be improved to the municipal construction standards for bus stops, passenger waiting areas, adjacent sidewalks and bus bay treatments. A convenient connection between the on-street bus bays and the off-street terminal will be required, and logically this would include a pedestrian-actuated crossing of the collector.

Shared Parking

The facility will construct a new shared transit and recreation parking lot, replacing a smaller existing unpaved lot. Adjacent municipal lands include a park with several playing fields. The associated peak demand is weekday evenings from late spring to early fall for organized sports, and midday weekends in summer for tournaments.

The proposed parking lot was sized using a shared parking principle, based on the observed recreation and projected commuter peaks. The departure of a portion of the commuters before the arrival of the evening recreation users would allow for turnover of parking spaces, rightsizing the parking lot.

Active Modes

The City planning this facility perceived the construction project as an opportunity to fill gaps in the pathway network, so the cross section of the reconstructed street would need to incorporate as many (or all) pedestrian and cycling elements that fit within the right of way.

3. Existing Conditions

Collector Street Layout and Adjacent Uses

The proposed site of the transit terminal is southwest of the intersection of a collector road and an arterial. The collector starts at the arterial and extends west past the site into a neighbourhood on a hill overlooking the site. The property south of the collector is municipal land used primarily for recreation, including several sports fields. There is also an unpaved parking area (100 m x 75 m), with two short driveways located 75m and 135 metres west of the intersection with the arterial road. The site and its immediate vicinity are shown by Figure 2.

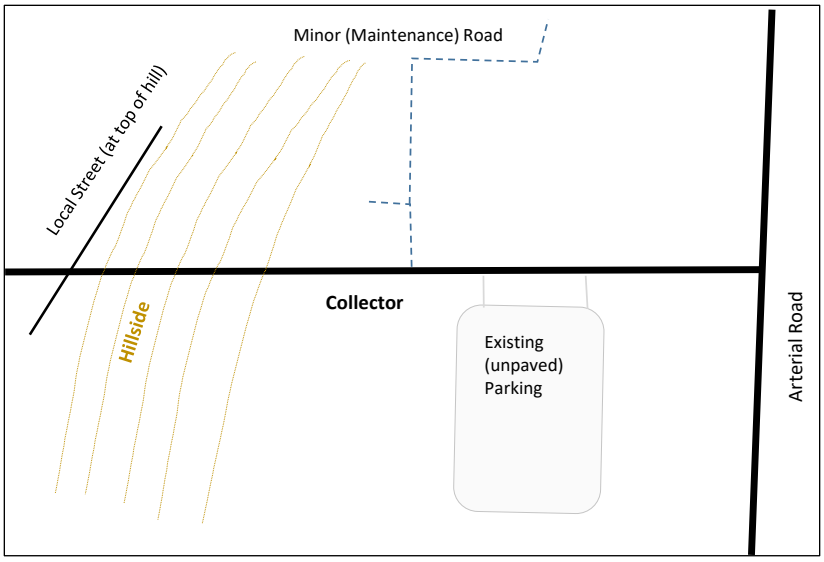

Figure 2 – Schematic Diagram of Existing Site and Vicinity

The collector road currently drops in elevation as it heads west from the arterial at an average of approximately 1% for 200 metres, and then makes an abrupt transition and continues uphill at grades exceeding 11%.

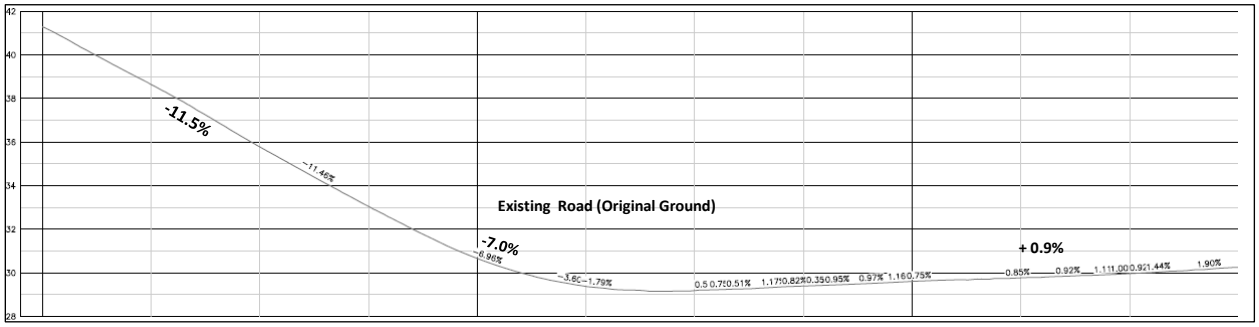

Figure 3 – Existing Profile

There is a T-intersection at the transition point in the profile, but buses and other vehicles do not need to stop at that intersection, because the minor road is only used for City maintenance access to facilities on the north side of the collector, and it is not open to general traffic.

The existing street is 13.4 metres wide curb-to-curb, marked as two lanes per direction near the arterial. On each side of the street, there is a boulevard and a multi-use pathway set back behind it.

In the section with the steep grade, the street has two uphill lanes, one downhill traffic lane and one downhill cycling lane. There are no boulevards and only the multi-use pathway on the north side of the street continues, immediately adjacent to the curb. The south side of the street has no path or sidewalk, and has a side slope due to the street grade.

Traffic Operations

Both the collector and arterial are commuting routes, with a significant directional bias in traffic flow. In the AM peak, most traffic is northbound, with a heavy flow of eastbound cars turning left from the collector onto the arterial. In the PM peak, the flows are reversed, with most of the traffic southbound. The PM peak also sees some additional traffic related to the sports fields during the seasons they are in use. Figure 4 indicates the design volumes (year 2039) for this location, for the AM and PM peak hours.

In keeping with the traffic flow, the westbound lanes on the collector are marked for left-only and left/right turns at the intersection with the arterial. In addition, in the southbound direction, the curb lane on the arterial is marked for right turns only while the middle lane is for southbound through traffic.

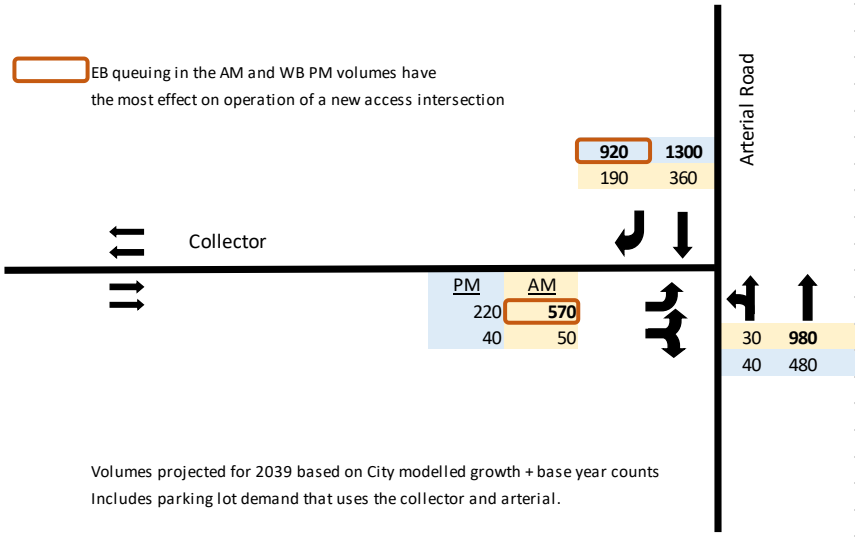

Figure 4 – Intersection Diagram (2039 Volumes)

Transit Operations

An existing local bus route stops on the collector road in the relatively flat part of the profile, approximately 100 metres west of the arterial. According the roads and transit departments, this existing bus stop location provides sufficient distance from the base of the hill for buses to accelerate for the uphill climb, and enough stopping distance downhill.

Eastbound buses continue north on the arterial after serving the area. To facilitate that upcoming turn, the bus stop is far enough back to allow buses to stop and re-enter traffic. The stop is also adjacent to the existing unpaved parking lot. The westbound bus stop is directly across the street. The stops consist of a sign post, and paved extensions within the boulevard, between the curb and multi-use pathway.

4. Constraints and Challenges

The design challenges relate to the functional needs of the new terminal, within the context of the location. The new bus transit terminal is proposed as a loop, oriented parallel to the collector. This was to reduce the likelihood of transit passengers crossing the paths of moving buses, and to minimize the footprint of the terminal and parking areas within the recreation space. Placing the access point west of

the terminal meant it would be near the base of the 11% uphill grade. This would create a potential stopping hazard from downhill vehicles and a climbing challenge for buses and other vehicles, especially those turning left out of the terminal access driveway. These issues would be worse in winter conditions. The local transit agency's preferred grade for transit terminal access is 4% or less.

Operations relative to traffic. The bus terminal access point needs to work in the eastbound and westbound direction, and ideally would be located so that any queuing from the signal at the collector/arterial intersection would not extend too close to the proposed location; otherwise buses would have challenges turning out of the bus terminal

Transit priority. The City would like the flexibility to have some form of transit priority to facilitate faster exit off/entrance onto the collector. This would either need to be transit turn lanes, or could be built into signal operations (based on vehicle position detection) if the access point were signal-controlled.

Complete Streets. The new design should at a minimum retain the existing width of pedestrian and cycling paths, and where possible extend or widen those. Connections between the transit terminal and both sides of the collector road need to be as direct, safe and transparent as possible. This will help with transfers to the bus route passing by, and residents of the neighbouring walking or cycling to the transit terminal.

5. Option Development

A range of options was considered to facilitate this access point into the terminal driveway, including:

- Stop signs (one-way, two-way, or three-way stopping);
- Traffic signal;
- Alternative routes;
- Protected T intersection;
- Re-locating the access point; and
- Modifying the profiles of the collector road and driveway.

Each of these is briefly described and illustrated in the following section.

Stop Signs

As indicated by Figure 5, stop signs were considered as a traffic control option for the terminal exit, the terminal exit plus the eastbound (downhill) collector, and for all three directions. The three-way stop would provide gaps in the through traffic on the collector for buses to exit the terminal. The one-way stop on the terminal exit would prioritize through traffic, while the two-way stop would allow westbound traffic to retain momentum while approaching the steep hill, while introducing some gaps in collector traffic for buses, especially the majority that would be turning right, to enter the street.

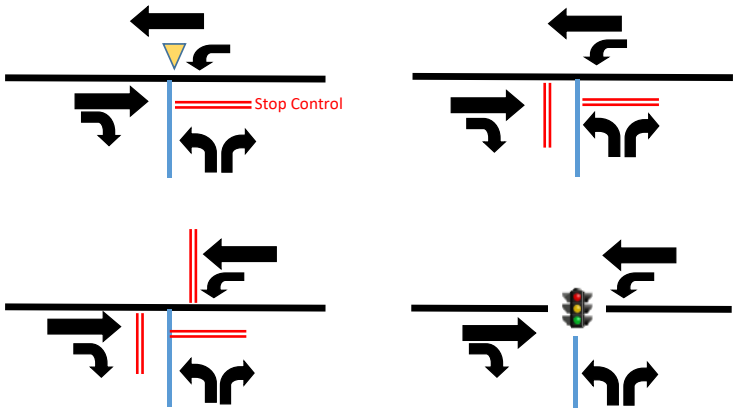

Figure 5 – Traffic Control Options for Terminal Access Point (Stop Signs or Signal)

Signals

Introducing a new traffic signal would allow for a more flexible variation on the three-way stop. If the signal were actuated based on vehicle detection (buses approaching or queues forming), then east-west traffic could proceed through the intersection at most times, and would only have to stop for transit vehicles, or say, when a queue of vehicles from the parking lot was detected. Refer also to Figure 5.

Alternative Routes

Two variations of this approach were considered: 1) to realign the collector between the access point and top of the hill; and 2) a bypass route using part of the maintenance road and a new connection back to the collector, at a lesser grade than the collector road. The intent of both of these was to reduce the effects of the steep grade on transit operations at the terminal access point. These are illustrated schematically in Figure 6. Other transit agencies in North America with bus routes on steep hills re-route those buses on planned detours with lesser grades, where feasible, to keep them running after winter storms.

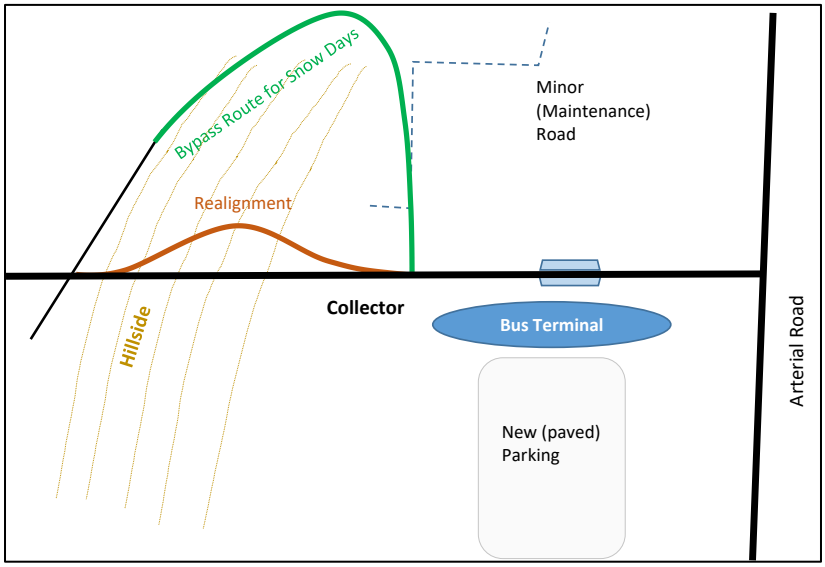

Figure 6 – Alternative Routes - Schematic

Protected "T" Intersection

This type of intersection is unsignalized and often applied at intersections where the volume on the major street might preclude left turns onto or off of the side street. The key feature is a median space that includes a left turn exiting and receiving lane physically separated by a barrier from the through lane. This allows the left turns to proceed without complications from the adjacent through traffic.

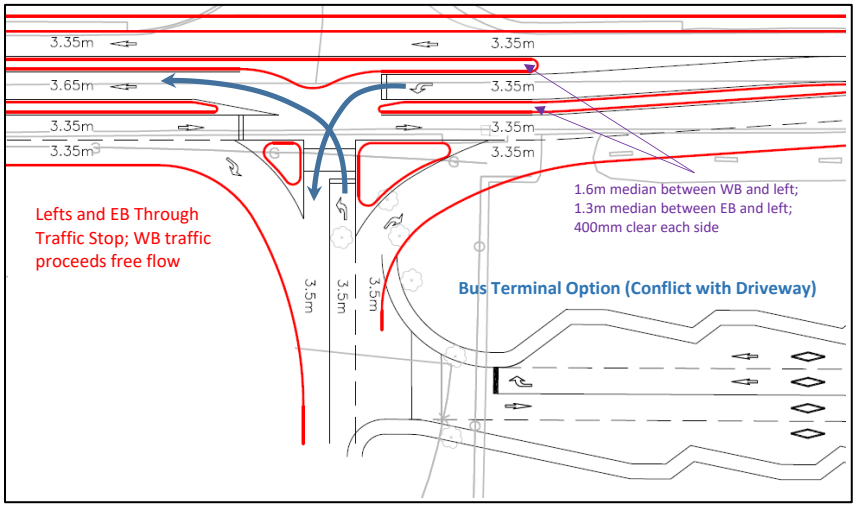

Figure 7 – Protected T Intersection Concept

Modified Access Point Location

This concept involves relocating the transit terminal access point away from the base of the hill and closer to the intersection of the collector with the arterial road. This would be coupled with shifting the on-street bus stops from their existing positions to new ones that will facilitate transfers.

Modified Profile

This option proposes to increase the grade of the flat section of the collector road, allowing the grade for the steep section of the street to be reduced. Provided that the grades can be sufficiently reduced, then buses and other traffic would have an easier path uphill, and downhill stopping distance at the terminal access point would be less. Figure 8 illustrates a modified profile, where the constraints is to match existing elevations at the intersections at each end of the street.

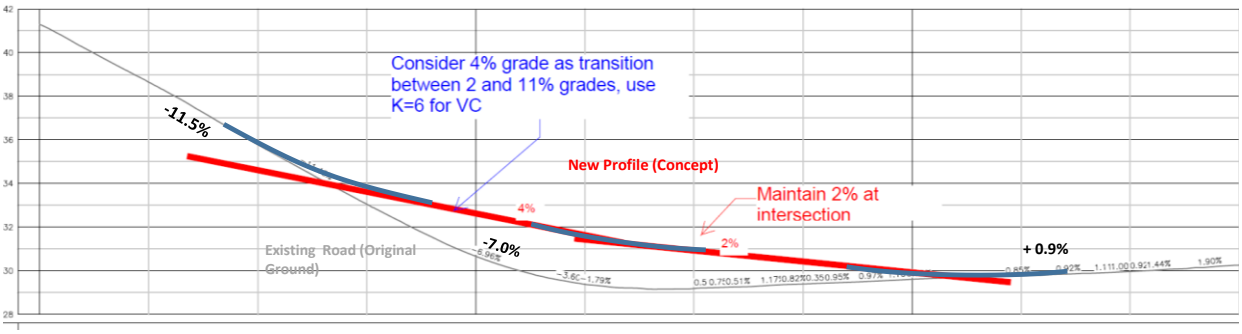

Figure 8 – Modified Profile Concept

6. Selection of Functional Design

The options were developed conceptually and assessed with City stakeholder input. Variations in the more promising options, including combinations, were evaluated against operational, safety, complete streets and travel time objectives. The final functional design was a combination of a modified profile for the collector road, with a traffic signal introduced at the new access point.

Table 1 presents a summary of the advantages and disadvantages identified for each of the options.

Option	Advantages	Disadvantages
Stop signs (one-way, two-way, or three-way stopping)	• With one-way or two-way stops, the uphill traffic is able to retain its momentum • Two-way or three-way stop allows for left turns in and out of the terminal	• One-way stops give the least priority to buses leaving the terminal • Left turns out of the terminal have little momentum entering the steep grade; with three-way stops, all uphill traffic would have winter issues • Downhill traffic may have difficulty stopping in winter
Traffic signal	• Signal has potential to provide transit priority • Use of signal instead of stop sign means some mitigation of uphill climbing issues for through traffic and downhill stopping challenges in winter	• Left turns out of the terminal have little momentum entering the steep grade • Any uphill or downhill traffic stopped at the signal will have the same climbing and stopping challenges; this will be less often than with stop signs
Alternative routes	• Reduced grade to mitigate uphill climb issues and downhill stopping	• Realignment option would still have 9-10% grade; not a sufficient reduction • Bypass route option would require significant fill/cut as existing slopes do not naturally provide for a more gradual grade; some potential property issues connecting to the local street
Protected T intersection	• Uphill traffic is able to retain its momentum • Improved safety for left turns	• Left turns out of the terminal have little momentum entering the steep grade • Downhill traffic may have difficulty stopping in winter • Wider than existing street, compromises space for pathways and forces transit loop and parking farther into park space
Re-locating the access point	• The farther the point moves away from the base of the hill, challenges with grades reduce	• Queuing of traffic (especially in AM peak) where the collector meets the arterial could extend back and block the access if too far east • Limits the size and functionality of the transit loop if too far east
Modifying the profiles of the collector road and driveway	• Reduced grades for uphill and downhill traffic • Feasible for buses to turn left and proceed uphill	• Results in collector road being raised as much as 2.5m above existing profile; requiring retaining wall and/or grading that extend into park • Increases the grade of the transit terminal and park and ride approach

Table 1 - Conceptual Options Trade-Off Summary

The result of the evaluation was to develop a hybrid solution, focusing on the potential for re-profiling the collector street, adjusting the intersection point for the driveway to be compatible with that profile, and then layering a traffic signal on top of the physical modifications. Figure 9 illustrates a plan view of the new access arrangement, while Figure 10 shows the modified profile of the collector.

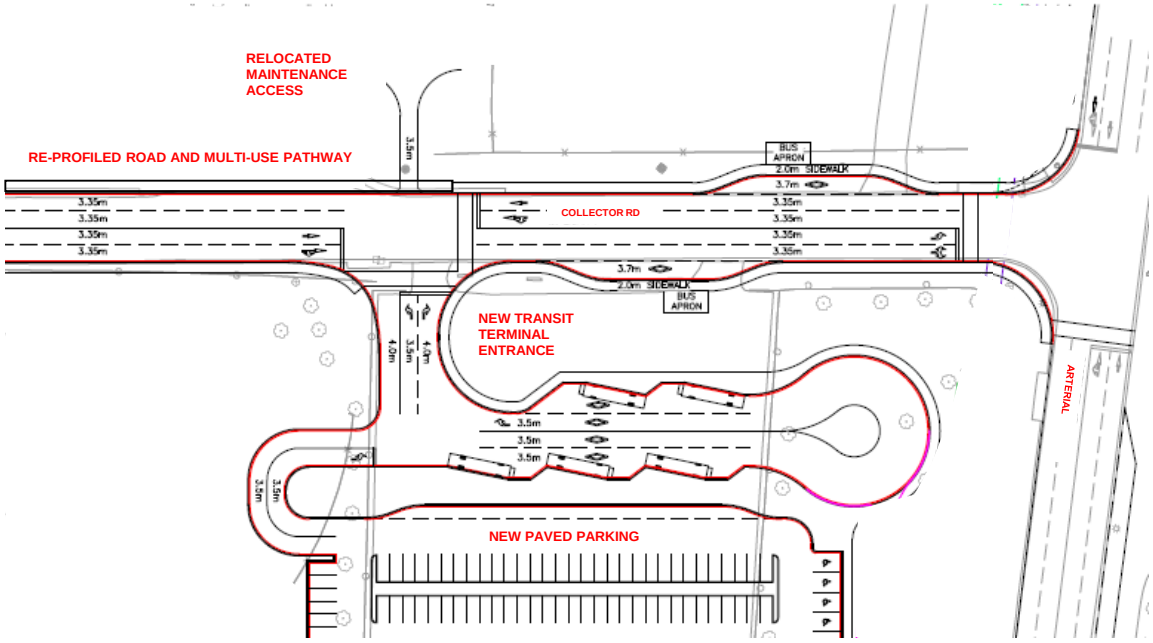

Figure 9 – Layout of Selected Functional Design

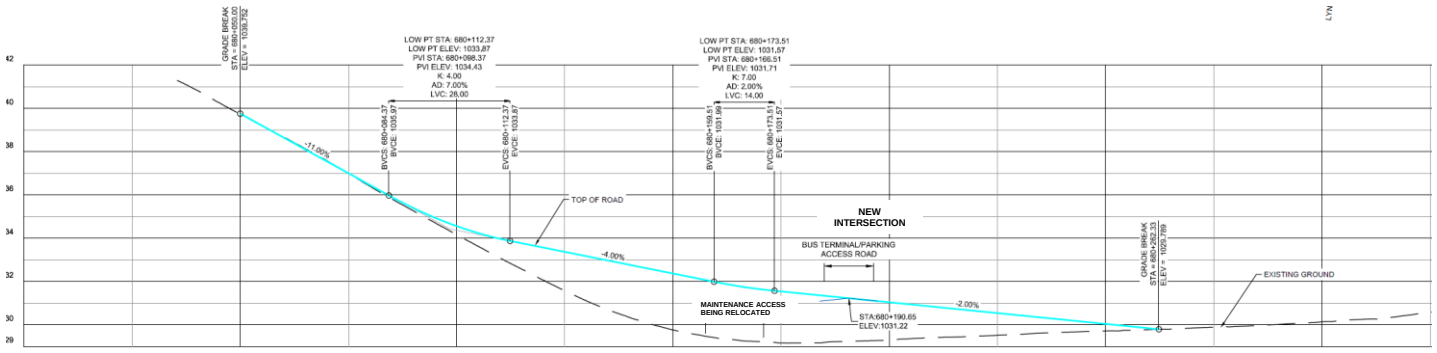

Figure 10 – Proposed Profile Revision of Collector Road

7. Project Status

The resulting design was then carried into a final design process being led by other consultants, which is addressing the road design and re-grading, utilities, stormwater management, and site preparation. Construction is underway and expected to be completed in 2018.

REFERENCES

Transportation Association of Canada (June 2017): Geometric Design Guide for Canadian Roads, Chapter 3 (Alignment and Lane Configuration), Chapter 9 (Intersections).

Transportation Association of Canada (2011 update to 1999 edition): Geometric Design Guide for Canadian Roads, Volume 2: Design Elements.

Alberta Infrastructure (April 1995): Highway Geometric Design Guide. Sections D-5 (Design Vehicles) and D-7 (Intersection Treatments –Two Lane Undivided Highways); Section B-4 (Vertical Alignment)

BC Ministry of Transportation and Infrastructure (June 2007): BC Supplement to TAC Geometric Design Guide. Sections 330 (Horizontal and Vertical Alignment), 710 (Intersection Drawings), 720 (Design Vehicles).

Ministry of Transportation of Ontario (MTO) (June 2017): MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads.

Authors' Information:

Blair Smith, P. Eng.
Senior Transportation Engineer
IBI Group

Suite 700, 1285 West Pender Street
Vancouver BC V6E 4B1 Canada
Phone +1 604 683 8797
Email: bsmith@ibigroup.com

Eugene Giller, EIT
Transportation Engineer in Training
IBI Group

Suite 400, 333 Preston Street
Ottawa ON K1S 5N4 Canada
Phone +1 613 225 1311
E-mail: Eugene.Giller@ibigroup.com

[i] Location names have been made generic, to make the lessons learned more broadly applicable.
[ii] Final design being completed by others. The paper focuses on the option development and evaluation during the functional stage, which ended in February 2017.