Fermor Avenue & Kingsclear First Nation Pedestrian-Cyclist Underpasses – Case Studies on Improved Safety for VRUs

D.R.C. Amorim, M.Sc., P.Eng., Associate, Dillon Consulting Limited

J.N. Crang, P.Eng., PTOE, Associate, Dillon Consulting Limited

R.C. Dunbar, M.Sc.E, P.Eng., Partner, Dillon Consulting Limited

J.A. Tapia, P.Eng., Associate, Dillon Consulting Limited

Paper prepared for presentation at the Improving Safety for Vulnerable Road Users Session

of the 2019 TAC-ITS Canada Joint Conference, Halifax, NS

Abstract

This paper presents case studies of two recently completed pedestrian-cyclist underpasses projects in Canada – the Fermor Avenue underpass located in Winnipeg, Manitoba and the Kingsclear First Nation (KFN) underpass located in KFN, New Brunswick. These projects are evidence that pedestrian-cyclist underpasses can be successfully implemented, despite their generally negative reputations, provided that user comfort and safety remain at the forefront throughout the design process.

Crossing under the TransCanada Highway, the Fermor underpass is a 6.0m wide x 3.0m high cast-in-place concrete box structure constructed over two years in two stages. The structure type was selected following a conceptual design study comparing underbridge pathway, overpass, and underpass options. The final design features long and comforting sightlines along its approach pathways and is well lit with attractive vandal resistance lighting fixtures allowing users to completely see through to the other side of the 37m long underpass. The box structure entrances feature 17m long cantilevered cast-in-place concrete headwalls complete with aesthetic treatments – the walls are constructed perpendicular to the box structure to avoid the ‘funnelling-in’ sensation typically associated with these structures. While the overall cost of the Fermor structure and associated works will not be insignificant – and possibly much more than many jurisdictions are able to spend on a similar structure– successful underpasses can be constructed economically and rapidly as evidenced by the KFN underpass project.

Crossing under the high-speed Highway NB-102 which bisects the community of KFN, the KFN underpass is a 3.0m wide x 3.0m tall precast concrete box structure which developed from a conceptual level to substantially constructed and opened to traffic in under three months. The structure was built in response to a fatal vehicular-pedestrian strike in September 2018 after numerous years of unsuccessful lobbying by the Community to lower the speed-limit along Highway NB-102. The structure was operational before the end of 2018. The project was spearheaded by the Community in partnership with their Joint Venture with significant labour (over 40%) provided by community members. The project works included the 32m long structure featuring vandal resistance lighting fixtures and attractive precast concrete block wingwalls, 100m of paved active-transportation pathways complete with landscape lighting, and a security system with a direct feed to the nearby KFN Band Hall. Constructed rapidly and at a minimal cost, this underpass will have a significant impact on the Community.

1.0 Introduction

Whether you like them or not, pedestrian and cyclist underpasses have a place amidst our urban environment. Although these underpasses – often called "pedestrian tunnels" or other unsavoury terms by the general public and media – have strong negative reputations of being dark, wet, and generally unsafe facilities (a reputation earned as a result of applications such as that shown below in **Figure 1**) they can be extremely effective if designed properly.

Figure 1 – Small, Dark, Uninviting Pedestrian Underpass

As far as active transportation (AT) facilities are concerned, pedestrian/cyclist underpasses and overpasses are generally considered facilities of last resort by professionals. In many cases, a mixture of traffic calming measures and pedestrian activated signals (half signals) may provide a more desirable route for pedestrians and cyclists than the often long and circuitous overpasses or dark and unsafe-looking underpasses. However, in situations where it is desirable to keep pedestrian/cyclist flow and traffic flow completely separate, such as for crossings of high-speed freeways, railways, or other natural barriers, overpasses or underpasses may be the only feasible facility options. In these situations, it is necessary for the designers to ensure that the facility is safe, well lit, and perhaps most importantly, provides a direct connection. Studies have shown that pedestrians and cyclists will not use underpass and overpass facilities if they can cross at street level in roughly the same amount of time in situations in which the underpass or overpass appears unsafe.

Both overpasses and underpasses carry significant design challenges: the topography of the area may preclude one or the other as feasible options; overpasses typically require significant approach ramp structures and in some cases elevators to meet strict jurisdictional requirements with respect to universal access; special consideration for drainage and lighting is critical to ensure underpasses remain in the dry and well lit; and safety and security are paramount to either facility to ensure pedestrians and cyclists do not instead risk dangerous crossings of the highway, railway, or other barrier.

This paper addresses the authors' experiences on two recent projects in which pedestrian-cyclist underpasses have been implemented across a high-speed facility.

2.0 Case Study No. 1 – Fermor Avenue Pedestrian-Cyclist Underpass

The following section presents a case study on the design of the Fermor Avenue Pedestrian-Cyclist Underpass located in Winnipeg, Manitoba. Design and construction of the underpass is included as part of the larger City of Winnipeg 2018-2019 capital project to rehabilitate the Fermor Avenue Bridge over the Seine River and complete associated roadworks.

2.1 Project Background

In 2016, the City of Winnipeg (City) advertised a Request for Proposal (RFP) for Engineering Consulting Services for the Preliminary Design of the Fermor Avenue Bridge Rehabilitation and Associated Roadworks. The Fermor Avenue Bridge – crossing the Seine River – is located on Fermor Avenue forming part of the Trans-Canada Highway running through the City of Winnipeg, Manitoba, Canada. Due to the deteriorating condition of the bridge, it was scheduled for rehabilitation. In addition to the project's structural scope of work, the RFP called for significant improvements to the corridor's active transportation (AT) network. The project study area, including significant items of interest, is shown in **Figure 2**.

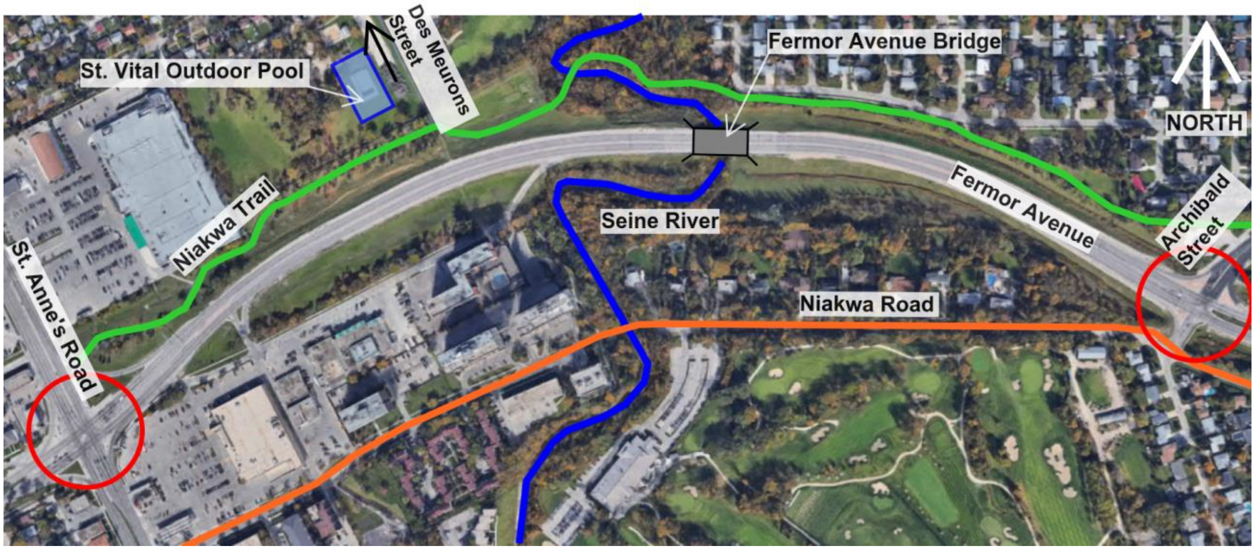

Figure 2 – Fermor Avenue Project Study Area

Running parallel and to the north of Fermor Avenue is the off-road Niakwa Trail (shown in **Figure 2** in green) – a major east-west AT facility within the City of Winnipeg. Running parallel and to the south of Fermor Avenue is the "informal low stress" bike route along Niakwa Avenue (shown in **Figure 2** in orange). For a length of nearly 1.25 km along Fermor Avenue (between the intersections with St. Anne's Road and Archibald Street, shown as the red circles in **Figure 2**), there is no north-south AT connection connecting these two facilities. Signs of well-worn informal north-south crossing paths were observed during initial site visits at various points along the 1.25 km long corridor. These crossings of the 70 km-hr Fermor Avenue are a significant safety risk, further increased due to the large percentage of illegal crossings made by senior citizens travelling between living accommodations on the south side of Fermor Avenue and a large grocery store on the north side of Fermor Avenue.

Recently, the St. Vital Outdoor Pool – located approximately 300 m west of the Fermor Avenue Bridge on the north side of the corridor (outlined in blue in **Figure 2**) – completed a major renovation. In light of the recent pool renovation and the fact that there are no north-south links connecting the Niakwa Trail and the Niakwa Avenue AT facilities, the City's RFP expressed the desire for the provision of a pathway crossing Fermor Avenue *beneath the bridge*.

2.2 Conceptual Design

Early in the assignment, it was immediately clear that while the underbridge path would provide the desired north-south AT connection, it might not be the most effective north-south connection possible due to its circuitous nature. The possibility of investigating a more direct pedestrian-cyclist underpass or overpass was raised with conceptual alignments as shown in **Figure 3**; the City ultimately agreed Conceptual Design Report was subsequently prepared comparing all three options and provided a recommendation for the preferred north-south connection. The high level

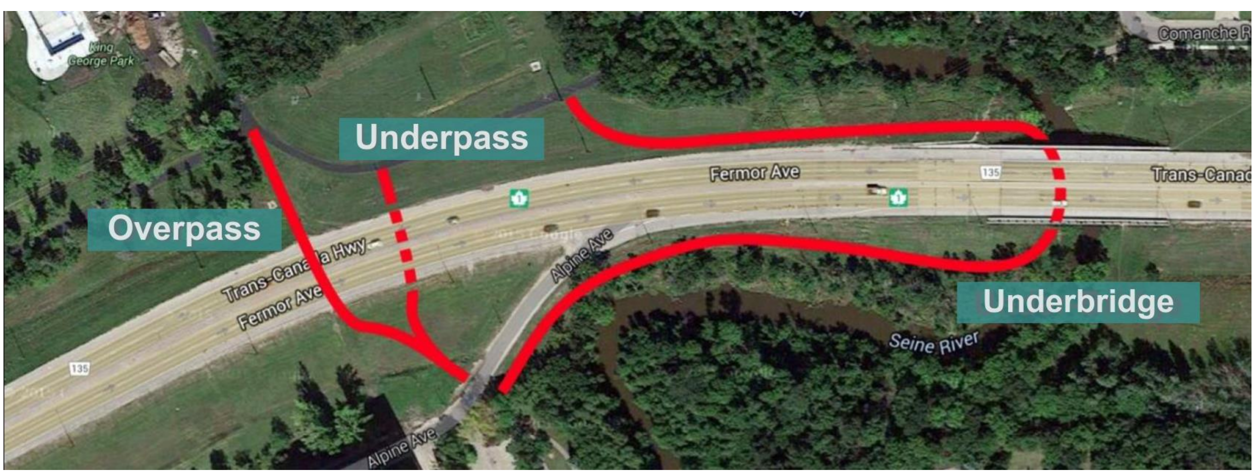

Figure 3 – Overview of North-South Connection Conceptual Design Options

2.2.1 Trip Generators and Attractors and Project Flow

The first step in evaluating the preference for a north-south connection was to examine major trip generators and attractors in the area. The primary generators and attractors in the immediate vicinity on the north side of Fermor Avenue include the residential neighborhood of Glenwood, Superstore (a major grocery chain), St. Vital Curling Club, the Niakwa Trail, and the St. Vital Outdoor Pool. The primary generators and attractors in the immediate vicinity on the south side of Fermor Avenue include numerous high-rise apartment and condo complexes, Safeway (a major grocery store), a liquor vendor, a bowling alley, and multiple restaurants.

The City of Winnipeg Pedestrian and Cycling Strategies Manual and engineering judgment were utilized to project pedestrian and cyclist traffic patterns in the area post provision of a north-south connection. The qualitative flow-map shown in **Figure 4** was prepared identifying low-traffic desire lines (narrowest blue lines) to high-traffic desire lines (widest blue lines). The provision of a north-south crossing generally in-line with Des Meurons Street (approximately 300m west of the Fermor Avenue Bridge) appeared to provide the most direct link between the generators/attractors on the north and south sides. A connection in that location would provide an almost direct link between the St. Vital Outdoor Pool and greatly minimize the circuitous nature of connecting the residential areas south of Fermor Avenue with the attractions north of Fermor Avenue.

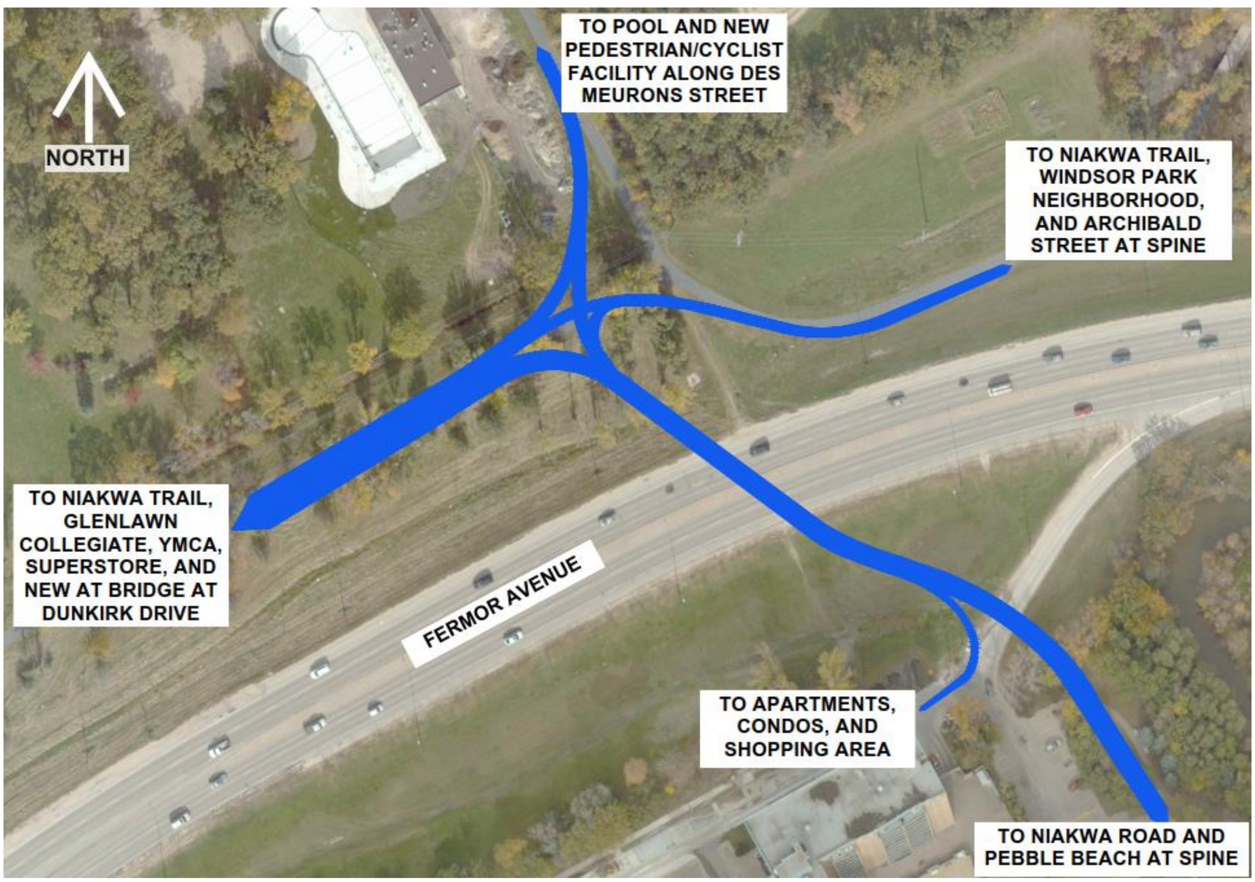

Figure 4 – Qualitative Pedestrian-Cyclist Traffic Flow Map

2.2.2 Design Criteria

Design criteria for the options developed were in accordance with the *TAC Geometric Design Guide for Canadian Roadways* (1999), *AASHTO Guide for the Development of Bicycle Facilities* (2012), and *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* (2004). Primary design criteria was as follows:

Pathways

- Design speed – 30 km/h;
- Minimum radius – 18 m or 15 m on overpass ramps;
- Width – 3.5 m;
- Cross slope – 2%;
- Buffer adjacent to side slopes – 1.0 m;
- Buffer adjacent to retaining walls – 0.3 m;
- Maximum gradient – 5%;
- 4:1 side slopes; and,
- Asphaltic concrete surface with granular structure.

Overpass Structure

- Clear width – 4.7 m;
- Vertical clearance to roadway below – 5.3 m;
- Maximum gradient, frequency and size of landings – as per local accessibility guidelines; and,
- Provision of safety netting to prevent objects from being thrown to the roadway below.

Underpass Structure

- Clear height – 3.0 m;
- Clear width – 6.0 m; and,
- Provision of adequate lighting.

2.2.3 Evaluation Criteria

The Conceptual Design study utilized a context sensitive design approach. The primary goal was to provide an effective pedestrian/cyclist facility for both the user and the surrounding community while achieving harmony with adjacent land use and preserving the important environmental and aesthetic features of the area. The following evaluation criteria were developed and used to assess the three conceptual options. The importance of each criteria as they generally apply to the comparison of these facility types is also described.

Directness of Route – A pedestrian/cyclist pathway should connect to desirable locations with as few detours as practicable. Multiple turns can disorient the user and unnecessarily complicate and lengthen a trip. Within the Fermor Avenue study area in particular, pedestrian and cyclist traffic composition was predicted to be part recreational and part utilitarian. More so than recreational trips, utilitarian trips necessitate facilities that are direct and have flat topography.

The *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* indicates that the effectiveness of grade-separated crossings depends on their perceived ease of accessibility. An overpass or underpass will not be used simply because it improves safety. Pedestrians tend to weigh the perceived safety of using the facility against the extra effort and time required to do so. **Figure 5** illustrates the relationship between percentage of pedestrians using the safe route versus the ratio of time to travel on the overpass/underpass and the time to travel at ground level.

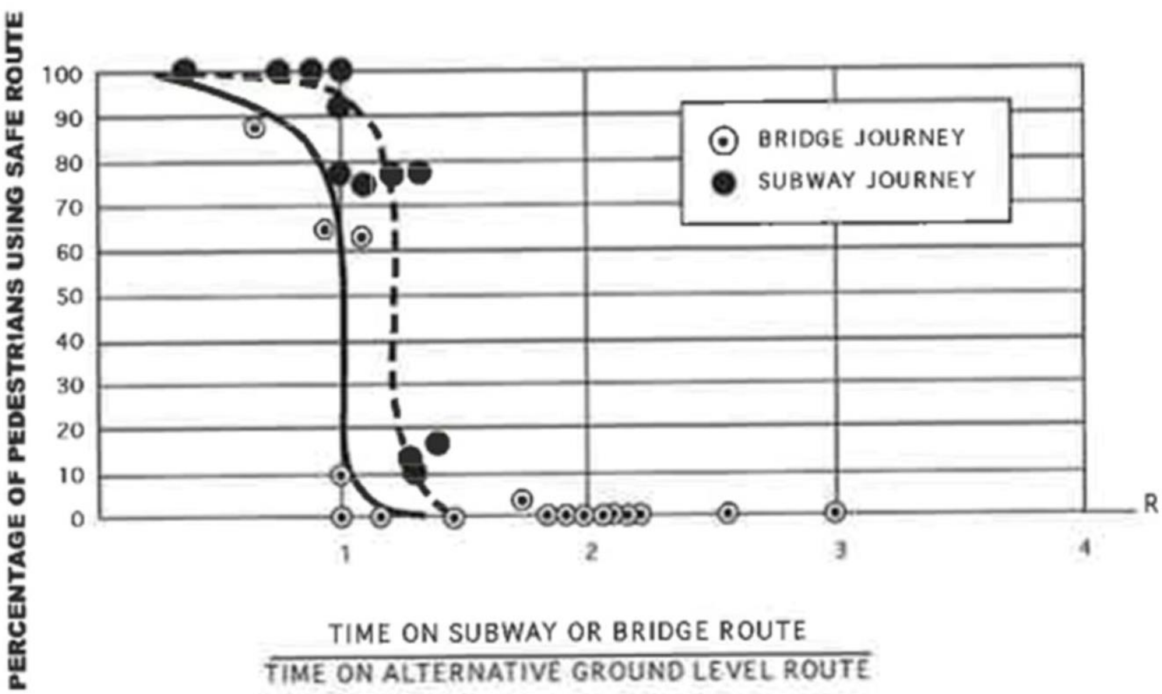

Figure 5 – Exhibit 3-39; Pedestrian Use of Bridges / Tunnels Based on Convenience [1]

Security/Safety – Security/safety issues are important to consider especially for sections of shared use paths that are not visible from roads and neighboring buildings. Utilitarian trips typically involve only a single pedestrian or cyclist so security in the form of good sight lines and appropriate lighting levels are very important. Traversing the subject facility may occur at any hour of the day or night.

Ease of Use – Users will vary from children to adults. Due to the varying skills and abilities of users, it is imperative to design a facility that is relatively easy to navigate. The facility must be visible, convenient, and well-designed if it is to be utilized. For the Fermor project area in particular, there was a significant number of senior citizens expected to be making trips due to the presence of senior living apartments and condos located to the south of Fermor Avenue.

Aesthetics – Scenery is an important consideration along a facility, particularly so for a facility that will serve a primarily recreational purpose. Tree cover can provide cooler walking and riding conditions in the summer and a windbreak in the winter.

Local Flooding Restrictions – Underpasses are particularly prone to being damp or wet facilities if drainage is not carefully considered. Additionally, depending on proximity to major water bodies, flooding may also be a concern. The Seine River is in close proximity to the desired crossing area and therefore flooding during spring runoff events was a concern. Desirably, a pedestrian/cyclist facility would be located outside of flood-prone areas and be operable 365 days a year.

Technical Challenges – Other site specific technical challenges require careful consideration. For the Fermor project area in particular, slope stability near the Seine River, traffic staging, the existing geometry of Fermor Avenue, and the requirement for major alteration to public and private utilities were all considered.

Impact to Environment – It is always important to consider the impact to the environment – both temporary and permanent – that the new construction will have. As the Seine River, an ecologically valuable feature of the City of Winnipeg closely protected by an environmental group entitled *Save our Seine*, it was necessary to carefully weigh the environmental impacts of each option.

Cost – Finally, capital and maintenance costs must be considered.

2.2.4 Underbridge Pathway

The underbridge pathway option was generally composed of a 3.5 m wide asphalt pathway following the Seine River as shown in plan in **Figure 6**. To the south, the pathway would join an existing private pathway near the Alpine Avenue egress to Fermor Avenue. To the north, the pathway would join the existing Niakwa Trail just west of the low-level flood-prone bridge crossing the Seine River along the Niakwa Trail. Between these two fixed points, the trail meanders along the north and south side slopes of Fermor Avenue. It is important to note that the underbridge pathway would be prone to flooding once every five years.

In order to compare the travel path of all three options, two common points were established – one at the junction with the private path to the south and the other approximately 60 m north of Fermor Avenue along the projection of Des Meurons Street (proximate the St. Vital Outdoor Pool); the distance between these two nodes is approximately 550 m for the underbridge pathway option.

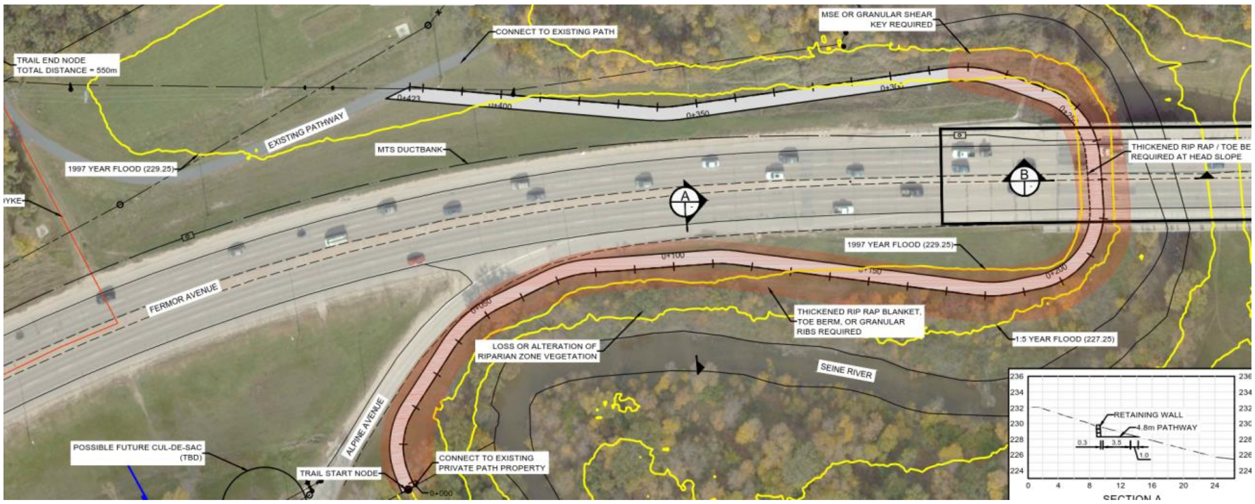

Figure 6 – Plan View of Underbridge Pathway Option

2.2.5 Overpass

The overpass option generally consisted of a 32 m clear span steel truss supported on concrete piers founded on steel H-piles driven to refusal in bedrock. The truss would be enclosed by a steel-wire mesh enclosure for safety of overpass users and to prevent objects from being thrown to the roadway below. Concrete ramps, also supported on steel H-piles, would be provided on the approaches to the clear span structure. In order to meet the maximum pathway gradient of 5%, the ramps were quite lengthy and circuitous. The overpass option is shown in plan in **Figure 7** and in elevation in **Figure 8**. It should be noted that no flat landings were provided on the ramps as they are technically not required for pathway gradients of 5% or less however if the option was selected as the preferred option, flat landings would have been implemented in the design.

The pathway off-structure was composed of a 3.5 m wide asphalt pathway with a maximum gradient of 5%. Pathway segments adjacent to a sloped embankment would have a buffer of 1.0 m to the edge of slope. The width of pathway on the overpass structure and approach ramps would be 4.7 m (3.5 m plus 0.6 m buffer on each side from railing) and the maximum radius on the approach ramps was limited to 15 m.

To the south, the pathway would join an existing private pathway near the Alpine Avenue egress to Fermor Avenue. To the north, the pathway would joins the Niakwa Trail in-line with Des Meurons Street, approximately 60 m north of Fermor Avenue. Between these two points, the trail traverses up pathway embankments until 3 m above grade at which point the ramp structures would commence. The total pathway length would be 385 m.

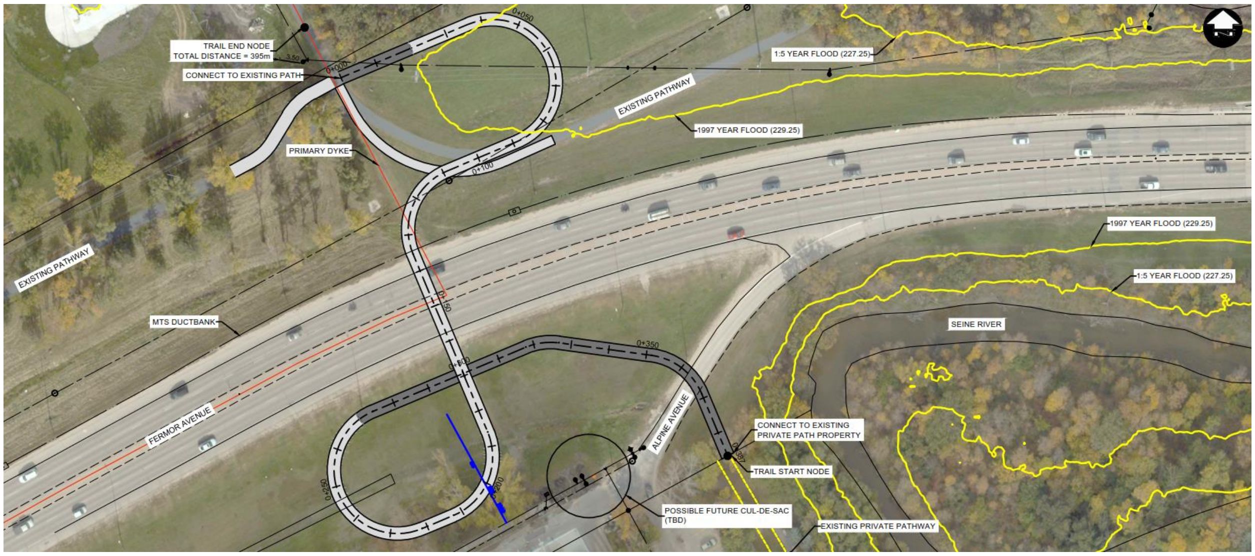

Figure 7 – Plan View of Overpass Option

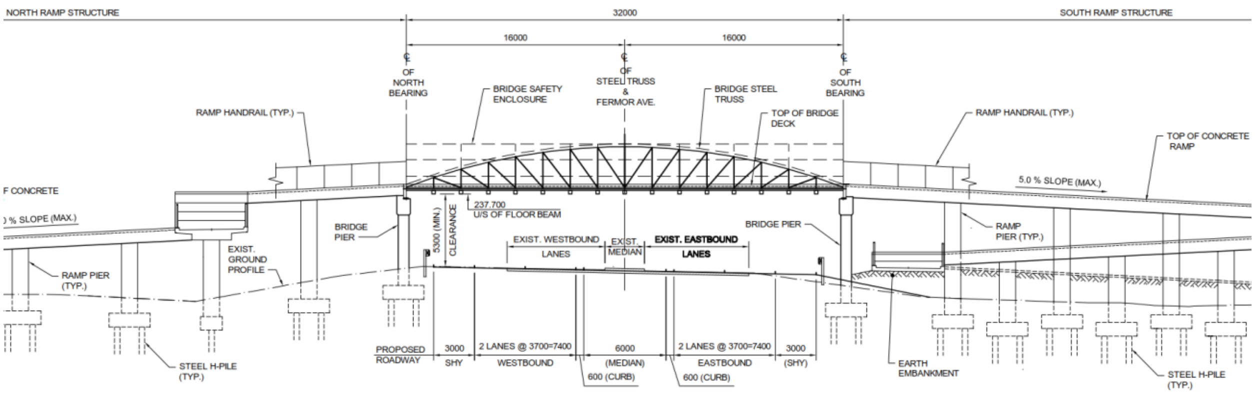

Figure 8 – Elevation View of Overpass Option

2.2.6 Underpass

The underpass option generally consisted of a cast-in-place reinforced concrete rigid frame structure founded on pile caps supported on steel piles driven to refusal in bedrock. The underpass would have an opening in the median area to all allow daylight into the enclosed section and lighting would also be provided in the soffit of the underpass for night time use. The open section in the median would be supported by MSE walls with precast concrete panel facing and a chain link fence on top for safety. The underpass option is shown in plan in **Figure 9**, in elevation in **Figure 10**, and in section in **Figure 11.**

To the south, the pathway would join an existing private pathway near the Alpine Avenue egress to Fermor Avenue. To the north, the pathway would join the Niakwa Trail in-line with Des Meurons Street, approximately 60 m north of Fermor Avenue. Between these two points, the trail traverses Fermor Avenue at a 31-degree skew in order to maximize sight lines along approach pathways. The total new pathway length is 305 m (230 m north/south + 75 m east/west tie-in).

As can be seen on the structures vertical profile, shown in **Figure 12**, Fermor Avenue was proposed to be raised by approximately 1 m to limit the burial of the underpass structure. This provided a number of benefits, namely mitigating the potential for flooding of the structure, but most importantly, offering a significant sight line from one end well past the other end of the structure as shown by the line in red.

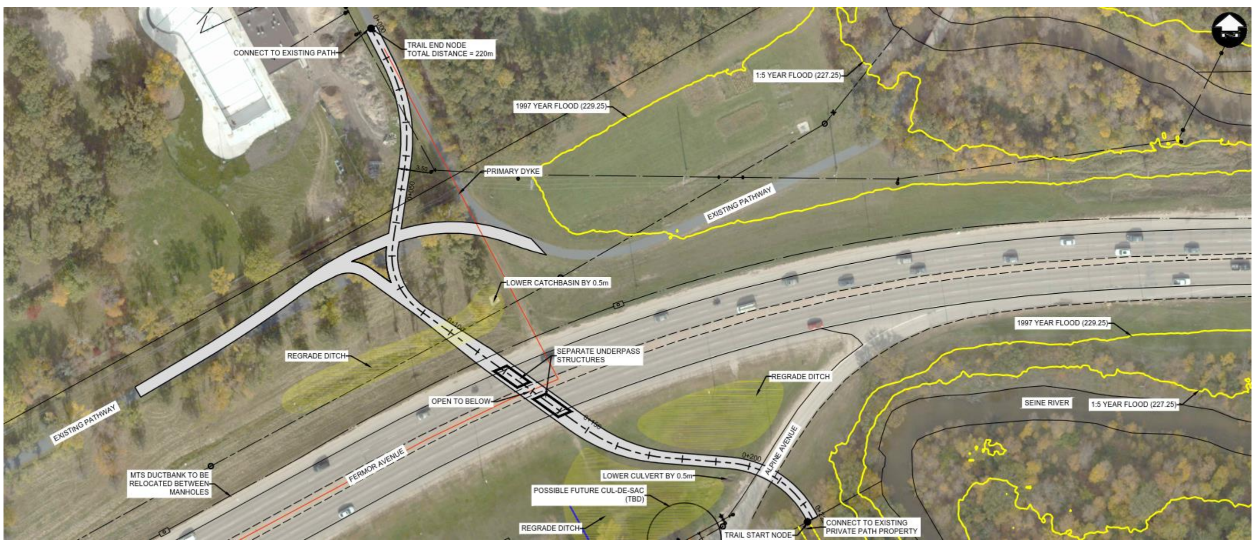

Figure 9 – Plan View of Underpass Option

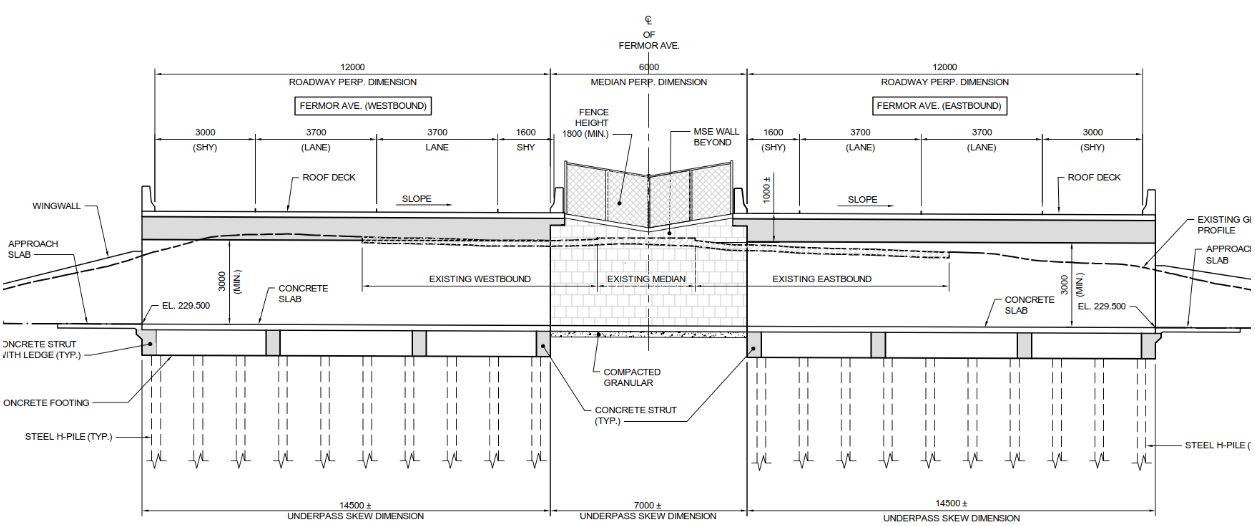

Figure 10 – Elevation View of Underpass Option

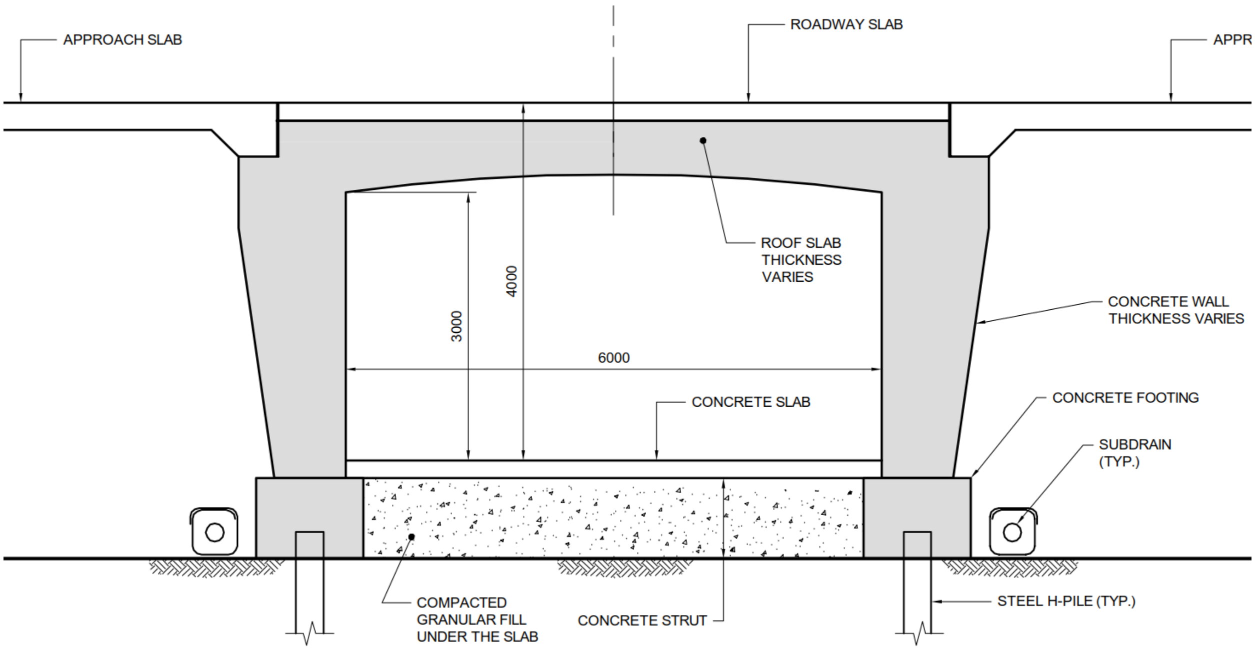

Figure 11 – Section View of Underpass Option

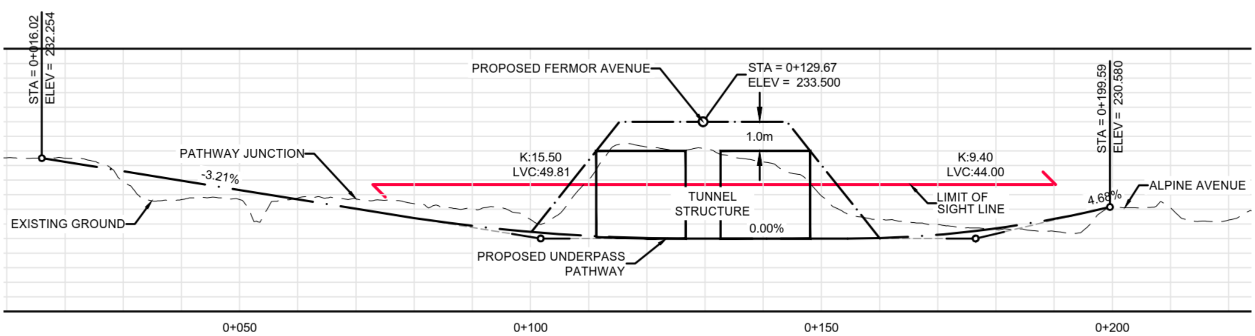

Figure 12 – Underpass Option Vertical Profile

2.2.7 Recommended Option

All three options investigated were ultimately determined to be feasible with no major fatal flaws. Of the nine criteria determined to be most relevant for this particular corridor and previously presented, the three most critical criteria (and consequently most heavily weighted) were identified as project cost, directness of route, and potential for flooding.

In accordance with published AASHTO research and based on engineering judgment, it was expected that the underbridge pathway would not be highly utilized due to its circuitous nature; additionally, the underbridge pathway would be expected to be flooded once every five years; as a result, the underbridge pathway scored lowest in the evaluation in spite of having the lowest total cost. The overpass option had the highest total cost and due to the circuitous nature of the approach ramps, it also left the project team with doubts that it would be well utilized if constructed; as a result, the overpass option scored second lowest. Finally, although the underpass ranked second with respect to total cost, it ranked best overall due to the importance given to the directness of route criteria and other high ranking criteria such as its ease of use. Therefore, the recommendation was made to proceed with the underpass option to preliminary design.

2.3 Preliminary Design / Detailed Design / Construction

The underpass option was developed further during the preliminary and detailed design phases. The design evolved numerous times from the conceptual design previously shown in **Figure 11**, to a buried cast-in-place concrete box structure supported on grade schematically shown in **Figure 13**, to the final buried cast-in-place box structure shown under construction in **Figure 14**. The final design featured large concrete wingwalls cantilevered off of the box structure complete with an aesthetic treatment that wraps around and continues throughout the inside of the structure. The large headwalls serve to eliminate the *herding-in* and *funneling* effect often associated with flared wingwalls typically used to simplify design and minimize construction costs. Attractive yet extremely vandal resistant lights were specified to ensure sufficient lighting of the underpass.

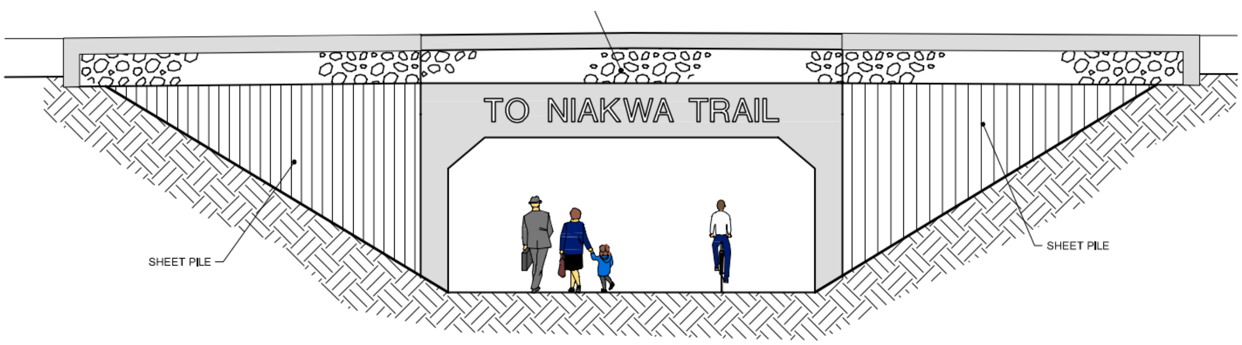

Figure 13 – Schematic Sketch of Preliminary Underpass Design

Figure 14 – Pedestrian-Cyclist Underpass Under Construction

3.0 Case Study No. 2 – Kingsclear First Nation Pedestrian-Cyclist Underpass

The following section presents a case study on the conception and design of the Kingsclear First Nation Pedestrian-Cyclist Underpass located in Kingsclear First Nation (KFN), New Brunswick. The project was undertaken by the KFN community in response to a fatal pedestrian strike which occurred after a number of near misses over the years.

3.1 Project Background

Kingsclear First Nation is an Indigenous community near Fredericton with a population of approximately 800. The community was bisected by the Trans-Canada Highway (presently NB-Hwy 102) in the 1960's, separating housing and community amenities north of the highway from the traditional indigenous land to the south. Today, KFN has expanded considerably with development on both sides of the highway. The project study area, including significant items of interest, is shown in **Figure 15**.

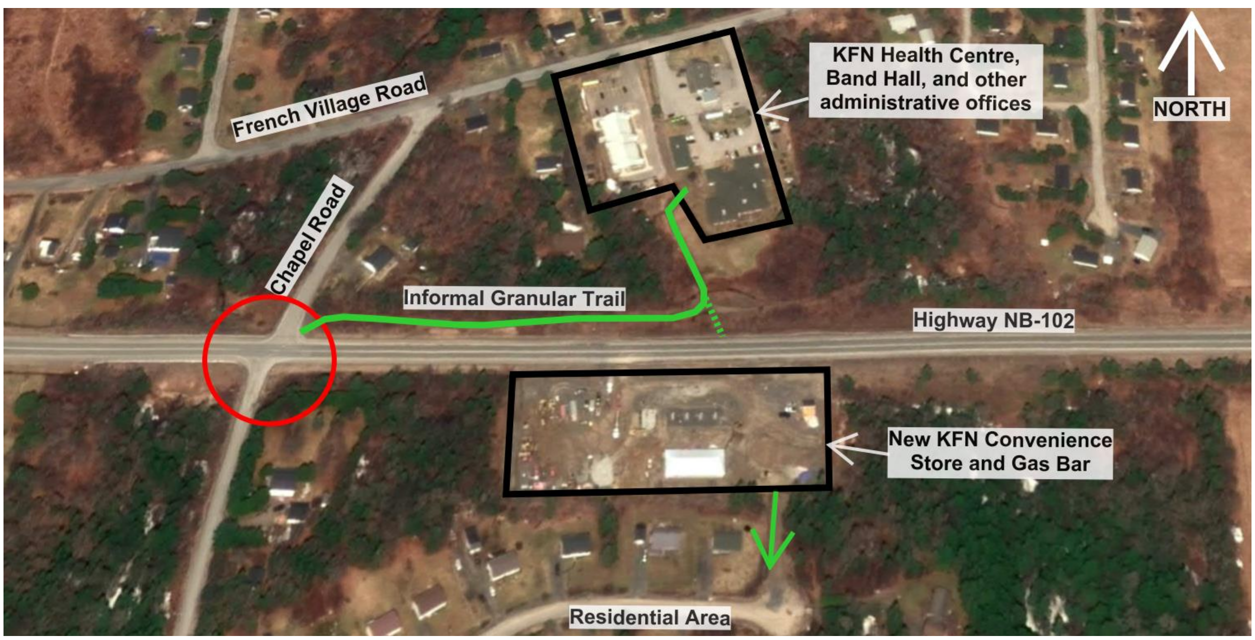

Figure 15 – Plan View of KFN Underpass Project Area

Bisection of the community by the 100 km-hr highway presents a significant safety risk for local pedestrian and vehicle traffic within KFN, an issue that KFN has historically raised with Government to no avail. Many residents rely on walking to the local convenience store for daily amenities as access to Fredericton is often difficult. Since the construction of the new convenience store adjacent NB-Hwy 102 two years ago, two pedestrian collisions have occurred. In September 2018, a KFN's Alyssia Paul was fatally struck while crossing the highway – a tragic event covered by national news outlets. As a result, KFN residents demanded a safer way to cross the highway and to travel within the community be put in place. The project team was retained by KFN in September 2018 to develop the design for an underpass and subsequently provide contract administration services during construction.

3.2 Conceptual Design

The major complexity with this project was the highly accelerated schedule. KFN desired an immediate solution and targeted implementation before year-end (2018). This message was conveyed to the community putting pressure on the team to deliver a successful project. Luckily, an underpass concept had previously been completed for KFN pro-bono due to the increased collision risk identified after the opening of the new convenience store adjacent the highway in 2017. This concept, shown in **Figure 16**, provided a starting point for the detailed design which began in earnest in October 2018.

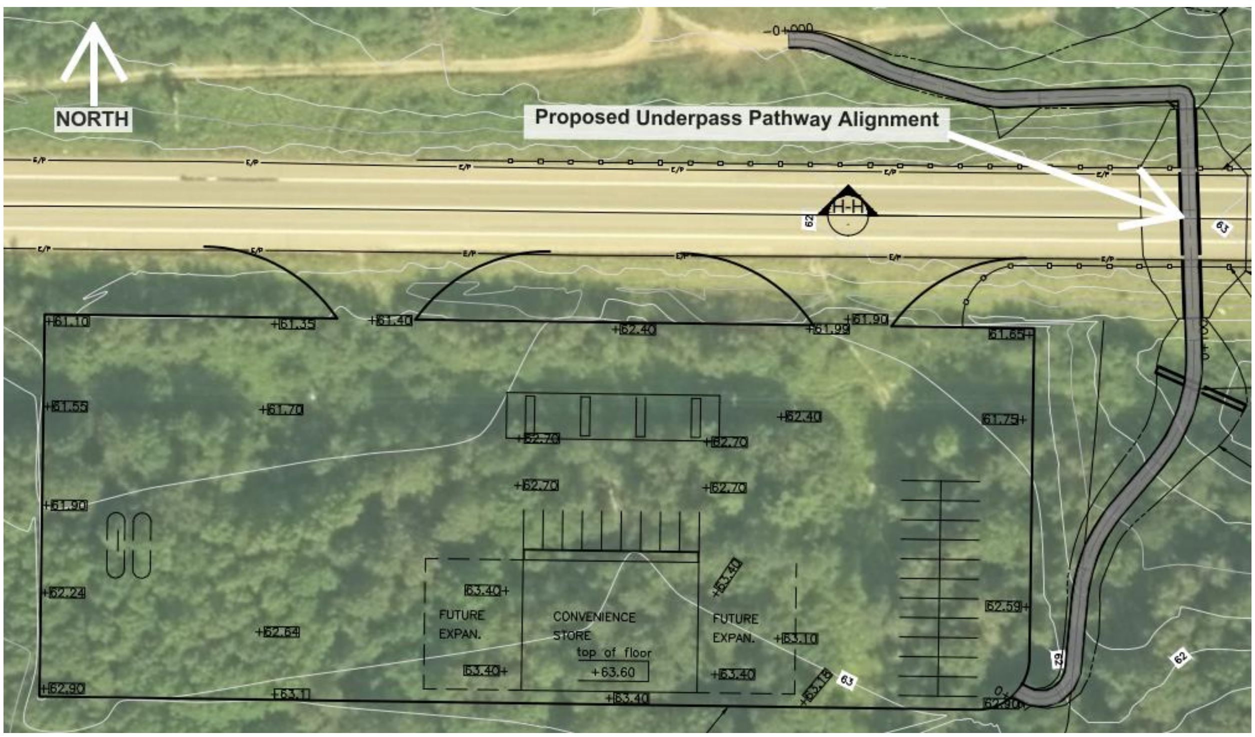

Figure 16 – Plan View of Conceptual KFN Underpass Alignment

The concept forming the basis for the detailed design had already been evaluated qualitatively against other Highway NB-102 crossing options; due to the approximately 5m high embankment the highway is on, providing an overpass was immediately ruled out and therefore, a buried precast concrete box structure was proposed. Unfortunately, due to property constraints, the concept had a subpar horizontal alignment with a nearly 90-degree pathway corner entering the underpass structure on the north side.

3.3 Detailed Design and Construction

The Project Team based its detailed design on the conceptual solution but attempted to optimize both the vertical and horizontal alignment for the facility. Generally, the final design consisted of a buried 3.0m x 3.0m (clear opening) precast concrete box structure pedestrian-cyclist underpass complete with aesthetically attractive precast concrete modular block wingwalls. The final facility plan alignment, with a crossing now skewed to Highway NB-102 to maximize sightlines, is shown in **Figure 17**. An approach path network with maximum gradients less than 5%, land drainage improvements, attractive landscape lighting bollards and soffit mounted underpass lightpacks, and a four-camera security system were also included in the final design.

Ultimately, the project was delivered as a pseudo Design-Build where-in designers coordinated with KFN's contracting company through all stages of the project to ensure feasibility of the design meeting the aggressive timelines. The project was completed in its entirety (regulatory approvals, design, procurement and substantial construction completion) on schedule in three (3) months utilizing significant community labour (over 40%) and was officially opened to pedestrian-cyclist traffic December 23, 2018. The total project value including engineering and construction costs was approximately $1.6 Million (2018 Dollars). Pre- and post-construction photos taken from drone video are shown in **Figure 18** and **Figure 19** respectively.

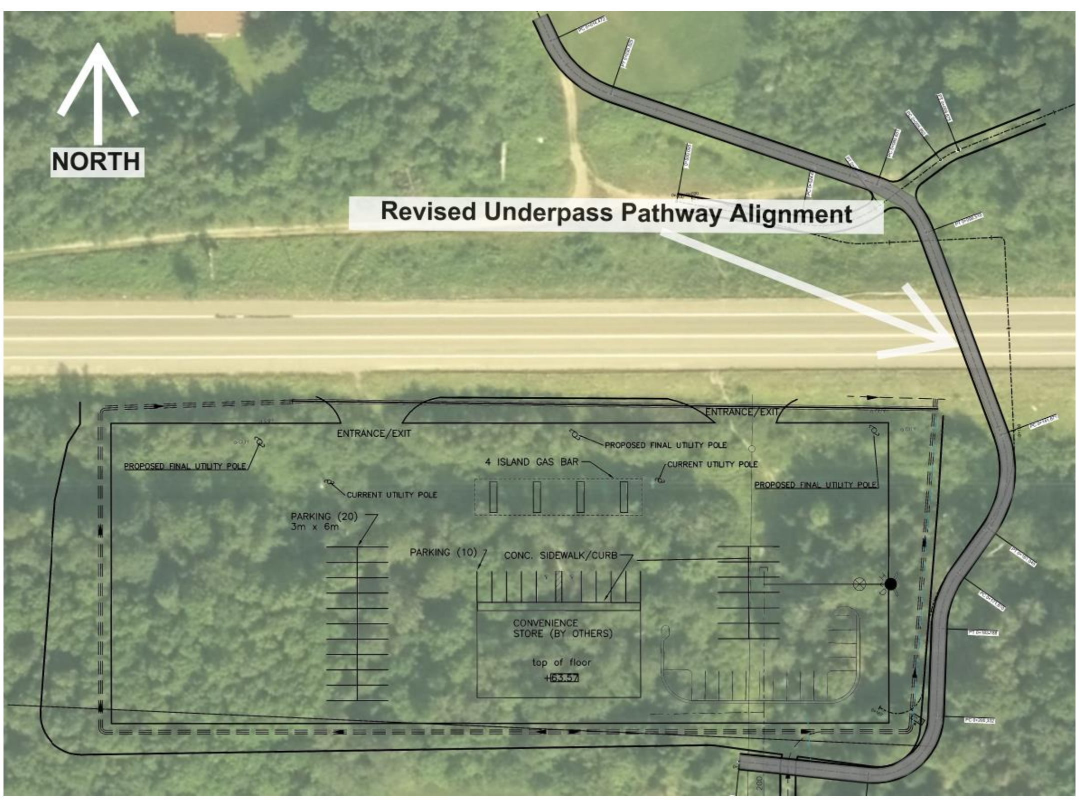

Figure 17 – Plan View of Revised KFN Underpass Alignment

Figure 18 – Pre-Construction Aerial Looking South (September 2018)

Figure 19 – Post-Construction Aerial Looking South (April 2019)

3.4 Community Impact

The newly constructed underpass provides a link between two sections of KFN's community previously divided by a high-speed roadway. The project was identified and initiated by KFN and Dillon's project team in unison, who were committed to preventing another needless tragedy from taking place along the section of highway, regardless of the availability of outside funding sources and typical project timelines. Aside from the practical use of the underpass to provide a means of transportation, the quick action and commitment of the parties involved has added confidence within the community that the parties involved take the concerns and safety of residents seriously and are willing to act appropriately to support them. The newly constructed tunnel is planned to be dedicated in the memory of Alyssia Paul during an official ribbon cutting ceremony in the summer of 2019.

The trail network associated with the underpass also allows added possibilities for expansion of an existing plan for a trail network throughout the community. The proposed network will not only provide community members with a means of transportation throughout the community to essential services and between dwellings, but also provide a means to connect with nature through walking and hiking to the nearby Indian and Murray Brooks and the Wolastoq (Saint John) River. The underpass and associated trail links completed during this project are also accessible for wheelchairs and strollers, providing a solution that is inclusive of all community members.

Lastly, the underpass provides the community with a conveniently located central link from the Band Administration Hall, Child and Family Services Office and Wulastukw Elementary School to the Wulastukw Convenience store. Community members that do not have a means of transportation other than walking or cycling often rely on Wulastukw Convenience for grocery items in times where they cannot travel to Fredericton. The majority of community members also frequent the Band Administration Hall for reasons ranging from community engagement sessions to employment and beyond. The underpass helps to ensure that these community members can safely travel from their homes to these essential services without the risk associated with crossing a high speed travelway.

4.0 Conclusion

In conclusion, the two case studies present highlight the benefit of underpass structures as part of our urban active transportation network. Both overpasses and underpasses are especially beneficial in situations requiring AT connections across high-speed roadways, railways, or other natural barriers. The underpass option utilized to provide the north-south connection across Fermor Avenue was preferred over a possible underbridge pathway and overpass structure due to the underpass's direct route and ease of use. The underpass option utilized to provide the north-south connection across Highway NB-102 in KFN was deemed the only feasible option given the significant topography relief in the area. In either case, provision of an aesthetically pleasing and well-lit structure with long sightlines and comforting design was desired to ensure that users would choose to utilize the facility rather than continue to make risky at-grade crossings. In the case of the KFN structure, additional safety measures were taken including the provision of a four-camera security system directed along approaching pathways and into the underpass as well as provision of a chainlink fence along Highway NB-102 to direct users towards the underpass structure.

5.0 References

[1] American Association of State Highway and Transportation Officials, *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*, 1st Edition [2004]