Deerfoot Trail Extension – Innovative Approach Leads to Geometric Innovations

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ABSTRACT

The Deerfoot Trail Extension is 11 km of new freeway, which was completed in 2004. The project cost $100M, and extends south from Hwy 22X to the existing Hwy 2 / 2A interchange south of Calgary. This completes a previously missing direct link in Hwy 2, which is part of the North / South trade corridor through Alberta.

In 1998, Alberta Infrastructure and Transportation (AIT) developed an innovative RFP that:

- Combined what previously would have been four large projects into one very large project.
- Encouraged consultants to propose innovative approaches.

In response, the “Partners in Excellence” Team was formed, including UMA Engineering Ltd., AMEC Infrastructure Ltd., AMEC Earth & Environmental Ltd., and Associated Engineering (Alberta) Ltd. The team developed an innovative approach, incorporating a “Board of Control”, “Partnering” and “Value Engineering” to foster collaboration and drive innovation through all project phases.

This approach resulted in:

- two geometric innovations that saved $8M while improving safety.
- environmental innovations that exceeded requirements, at no additional cost.
- a project which has been receiving accolades since opening.

This paper will provide an overview of the project, the process that led to innovation, and the two major geometric innovations, the “two lane loop ramp”, and the “major fork”.

The existing “Okotoks Interchange” connects Highways 2, 2A, and 552 at the south end of the project. Previous functional planning found that the existing single lane loop ramp, which carries eastbound to northbound traffic, was nearing capacity, and proposed a short term conversion to a diamond interchange style dual left turn, and ultimately a directional ramp. Our team proposed a two lane loop ramp, which would significantly defer the requirement for the costly directional ramp, while removing the safety concerns with the dual left turn across opposing traffic.

About 1 km north of the Okotoks interchange, Hwy 2 splits into MacLeod Trail and Deerfoot Trail, in a “Y” configuration. Conventional design has the “minor” roadway exiting on the right, even though the roadway eventually goes to the left. The resulting grade separation structure would have a minimum radius, with maximum super-elevation, leading to potential bridge icing related safety concerns.

In this case, although Deerfoot Trail is the “new” Hwy 2, functional planning indicated both roadways would have similar volumes.

A “major fork” was developed, resulting in a tangent section over a much shorter grade separation. MacLeod Trail traffic now veers left at the “major fork” rather than exiting right, then curving left over Deerfoot Trail.

Both the two lane loop ramp and the major fork were significant innovations for AIT, and resulted in a better, safer project, while reducing project life cycle costs.

TEXT

Background

High world oil prices have fuelled the growth of Calgary, capital of the Canadian oil and gas sector. New residents have pushed the city’s population to over 900,000, and prosperity has given it the highest per-capita vehicle ownership in North America.

The result: slowdowns on the city’s network of “Trails,” the name given to its multi-lane expressways, particularly the Deerfoot Trail. Six lanes for most of its length through the city, the Deerfoot is an important link in the North-South Trade Corridor (Highway 2) through the province and into the United States.

Growing transport traffic added to the effect of morning and afternoon drive times as commuters from the bedroom communities south of Calgary swelled traffic volumes. Much of the resulting slowdown occurred at the southern end of the Deerfoot where it jogged west on the two-lane Highway 22X before continuing southeast toward Okotoks (See **Figure 1**)

The Province of Alberta wanted a solution. It would need to be cost-effective, because while provincial royalties from oil and gas have been impressive, so have demands on the provincial coffers to pay for infrastructure to support the increased population. The solution would also have to factor in rising environmental concerns and demand for safety – and meet the pressing need for results sooner rather than later.

The plan: extend the southern end of the Deerfoot by 11 km, including four new interchanges. One of the key challenges was meeting rising environmental obligations in crossing the Bow River, which rises from a glacier in the Rocky Mountains and is one of the premiere trout-fishing rivers in North America.

UMA Engineering Ltd., based in Vancouver, British Columbia and a member of the AECOM Group of Companies, proposed that it lead a group of engineering firms for the entire provincial portion, rather than having it divided up among different consultants as was the Province’s usual practice. This idea was accepted by the client, Alberta Infrastructure and Transportation. Being in charge of the entire project allowed our team to come up with cost-saving ideas and the work flowed more smoothly. The major sub-consultants on UMA’s team included AMEC Infrastructure Ltd., Associated Engineering Ltd., and AMEC Earth & Environmental Ltd.

The five-year, $100 million project involved moving 16 million cubic yards of earthworks, 860,000 tons of granular material and 234,000 tons of asphalt.

Opened to traffic in November 2003, the extended Deerfoot has proven popular with users. The new portion has attracted about 60 percent of traffic away from the old Highway 2 (also known as Macleod Trail). Deerfoot Trail traffic is now about 20,000 vehicles per day on the extension, growing to approximately 160,000 closer to the city center.

PROCESS

In 1998, Alberta Infrastructure and Transportation (AIT formerly AT) challenged engineering consultants to develop innovative proposals for the Deerfoot Trail Extension.

In response, the "Partners in Excellence" team of consultants was assembled for the provincial section which included 5 km of new freeway, the Bow River bridges, Dunbow Interchange, south connection to existing Highway 2, upgrades to Highway 2/2A interchange and widening 2 km of existing Highway 2 to eight lanes. This team was led by UMA Engineering Ltd., and included AMEC Infrastructure Ltd. (formerly Torchinsky), AMEC Earth and Environmental Ltd., (formerly Agra) and Associated Engineering Ltd.

<u>Original Team Logo</u>

UMA
TORCHINSKY
AGRA
ASSOCIATED PARTNERS IN HIGHWAY EXCELLENCE

<u>Updated Team Logo</u>

um amec ASSOCIATED
PARTNERS IN EXCELLENCE

Through numerous brainstorming sessions, the team developed a project process which had never before been utilized for an Alberta highway project. This process included three main elements:

- a "Board of Control"
- formal "Partnering" workshops
- formal "Value Engineering" workshop

The "Board of Control" (BOC) included project independent senior representatives from each of the four consulting firms who met with the project director and the four team leaders approximately every three months. Every second meeting also included senior personnel from AIT including their project director, Assistant Deputy Minister, Deputy Minister, and occasionally the Minister of Transportation. Meetings focused on project schedule, budget, and potential problems. A site tour was often included as well. Although rarely used as such, a primary function of the BOC was to resolve any disputes between the four firms over the course of the project.

Andrew Johnson and Associates Ltd. facilitated <u>**five formal partnering workshops**</u> over the course of the project.

The first, a two-day workshop, brought together key personnel from the consultant team, AIT, Alberta Environment and the City of Calgary. The process included a project introduction, identification of goals, objectives, obstacles, development of action plans to facilitate reaching these goals, and a process for contacting appropriate individuals to resolve issues in a timely manner.

Subsequent one-day partnering workshops were held with each of the four contractors at the start of each construction contract.

Lewis and Zimmerman and Associates Inc. facilitated a two-day formal **Value Engineering** workshop. This workshop included many of the same individuals as the first Partnering workshop, and was held before the consultant team started design work. This allowed team members to have an open mind to consider innovative ideas. The "two lane loop ramp" and "major fork" were a direct result of this workshop.

The incorporation of the "BOC", "Partnering", and "Value Engineering" were instrumental in establishing communication and trust between the consultants, AIT, Alberta Environment and the City of Calgary, that fostered a culture of collaboration and innovation throughout the project.

Double Loop Ramp

The Okotoks Interchange is the southerly most point of the Deerfoot Trail Extension project. Commuter traffic from Okotoks to Calgary access Highway 2 at this interchange. Separate from this project, Alberta Infrastructure and Transportation was planning to twin Highway 2A from Okotoks to Highway 2. This upgrade would improve commuter congestion on Highway 2A, but traffic would bottleneck into a one lane loop ramp with a 900-1000 veh/h capacity. Within the 20 year time frame the anticipated growth in Okotoks was projected to double to a population of 29,600. At this stage (2016) the projected traffic volumes from the functional study were 1300 veh/h in the AM rush, well exceeding the single lane capacity. At the ultimate stage the projection for this movement is 2500 veh/h.

It was identified that some form of dual lane ramp would be required within the 20 year horizon to meet the traffic volume forecasts. Various options were considered at a value engineering session including:

- a freeflow dual lane directional ramp
- dual lane diamond interchange like left turn
- double loop ramp

Alberta Infrastructure and Transportation supported further investigation of the dual lane loop ramp alternative as it would it would economically improve the short term congestion and meet the ultimate horizon of accommodating 2500veh/h at a level of service C. Long term savings of $ 7 to $ 9 m would be realized.

The design team explored the double loop concept by researching the use of double loop ramp designs in other jurisdictions and consulting transportation and safety experts on the functionality of the double loop in this scenario. The team also visited locations in Canada and the NW United States to observe the operation of existing double loop ramps.

Findings of research (Ref. 4).

- There is little research information on the design and operation of two-lane loop ramps.
- The first two-lane loop ramp was constructed on Hwy 401 at Weston road in Toronto in 1966.
- Generally, directional or semi -directional ramps are preferred for high-volume, 2-lane ramps.
- However, if space is insufficient, the two lane loop ramp is a reasonable compromise solution.
- With proper exit, entrance, and speed transition zones, a 2-lane loop ramp can carry up to 2,000 veh/h.
- Volumes of up to 2,500 veh/h have been observed.
- Cities studied - Vancouver: Hwy 99 & 17 - 2,600 veh/h.
  Vancouver Hwy 91 - 1,700 veh/h.
  Toronto has 2 ramps: 1,200 and 1,800 veh/h.
  Ottawa: 1,200 veh/h.
  Edmonton has 2 ramps.
  A number of US cities were checked as well.

The primary concerns of the double loop ramp were volume, capacity, and safety. The safety concerns involved lane configuration (i.e. widths and shoulders), median design between lanes, proper signage, as well as the radius of the curves. The first item to be reviewed was the radius. Available land posed the greatest constraint on the radius size. The existing single loop ramp had a radius of 72m with an average width of 8m. Through the design process our team evaluated various radii where it became apparent that the most cost effective solution was to maximize the inside radius to the point where no additional land would be required. This also minimized the impact to the existing Highway 2 exit ramp. This resulted in a radius of 77.5m. A larger radius with the double lane width configuration would push the northbound to westbound exit ramp outside the existing right-of-way (see **Figure 2**).

To accommodate the dual ramps merging with Highway 2, the number of lanes was increased from 3 lanes to 4 under the interchange. The inner and outer loops became the outside two lanes with the existing Highway 2 northbound becoming the inside two lanes. The inside lane was dropped 1500 m from the interchange.

The most critical safety issue was to determine how to keep traffic separated on the parallel loops and prevent lane changing within the interchange. Various alternatives were considered which included an open graded ditch, various guardrails and a painted median with grooved rumble strips. The open graded ditch required reduction of the radius to stay within the existing right-of-way. The guardrail or barrier option was not acceptable alternative because of the potential for snow drifting. The painted median with grooved (milled in) rumble strips was selected as the most viable option.

The 14.4m wide design and the 16.4m wide as-constructed configurations are presented in **Figure .3**. Lane widths are 4m for the outside loop and 4.8m for the inside loop with shoulder widths of 2.4m outside and 3.4m inside. An extra meter on each shoulder was added during construction to provide an extra level of safety and to accommodate the thrie beam guardrail on the outer shoulder.

Special signing was installed in advance of the interchange and at the top of the ramps to advise motorists of the double loop configuration (**Figure 4**).

Approaching the double loop, traffic in the left lane has the option of proceeding straight through, or turning right onto the outside lane of the double loop ramp. Traffic in the right lane approaching the double loop "must exit" onto the inside lane of the double loop ramp.

The double loop has been operating since November 28, 2003 with no incidents, collisions or complaints reported to date.

The Major Fork

The Major Fork (also known as a Bifurcation) was developed to connect the original Highway 2 to the new Deerfoot Trail Extension south of Calgary, essentially in a "Y" configuration (See **Figure 1**).

The Major Fork was derived from various alignments and concepts that were attempted during the design phase, to reduce the crossing angle and length of the bridge structure. The original functional layout for this crossing was a traditional two lane right exit flyover ramp over an ultimate 6 lane freeway at a 56 degree LHF angle. This functional design required a 3 span bridge, 13.9m wide and 174 m long, with an estimated construction value of $4.8 million. The bridge was on a 1000m radius curve requiring the maximum allowable super-elevation rate of 6%. This was an undesirable situation on a high speed highway in rural Alberta due to the potential for icing in the winter. Restrictions in achieving optimal geometrics were caused by the availability and cost of acquiring substantial new right of way and the impact on existing country residential developments.

The design team looked at various horizontal and vertical geometric options to determine the best fit for the functional design. The skew angles attempted created greater land requirements. The design team found that by modifying the skew to 53 degrees, the bridge length was reduced to 165m. This was only a nominal cost savings but still required additional land.

The traditional approach would take the northbound lanes for Highway 2A over the northbound and southbound lanes of Highway 2 with a "minor" two lane exit right. This was opposite to what was required, as the Highway 2A movement was to the left and Highway 2 to the right. During the value engineering process, the alternative of splitting the traffic by having the Highway 2 (Deerfoot Trail) traffic veer to the right and the Highway 2A (Macleod Trail) traffic veer to the left was put forward as an option. The traffic volumes reported in the functional report anticipated a 50/50 split making both equal from strictly a traffic volume perspective. This alternative had previously been dismissed at the Functional Planning Stage and rejected as it was in essence deemed to be a left hand exit that was contrary to the existing Alberta Infrastructure and Transportation planning policy. All of the benefits of this configuration were brought forward and evaluated, including a shorter bridge, better geometrics (including placing the bridge on tangent), and less impact to the adjacent properties. After a thorough review, Alberta Infrastructure and Transportation approved the revised interchange configuration. This resulted in a 100m long single span bridge, at a net cost savings of $ 2m.

The resulting "Major Fork" was researched through the TAC and ASSHTO design guides (Reference 1 and 2) to find any design that created an equal priority to both expressways. Both guides had the Major Fork design guidelines. The designs were similar but the TAC layout was adopted due to its Canadian recognition. In addition, the design team checked with other Hwy departments in the US regarding operations and found that some major forks carry up to 200,000 ADT. Initially the team had created a four lane option with two, two lane splits. The four-lane option was identified in the safety audit as not having proper lane balance and Alberta Infrastructure and Transportation wanted a design whereby anyone traveling from the south would not have to change lanes to continue through on Highway 2 north.

The design team put together a three lane version consistent with the TAC design. With the fork not being symmetrical, the previously noted right-of-way restrictions, and the tight radius curves required north of the fork, it was a challenge to produce a design that had the middle lane transitioning where the cross slopes on each alignment were 2% or less to achieve a maximum allowable grade differential of 4%. With the tight curves north of the fork, the transition to 5.7% super-elevation was rapid for each alignment. The highway crown approaching the fork is between the middle and outside lanes. Increasing the spiral length, as well as introducing a large radius curve ahead of the fork on one alignment, created the necessary lane configuration, through widening of the centre lane ahead of the fork, to accommodate the super-elevation transitions (See **Figure 5**).

As this was a design concept never before used in rural Alberta, signing was critical, to ensure the traveling public understood the interchange layout and which lanes to be in as they approached the fork. The decision was to place diagrammatic signs well in advance of the fork (See **Figure 6**). Both internal and external safety audits were undertaken as the design progressed.

The major fork was opened to traffic on November 28, 2003 (see **Figure 7**). To date there have been no collisions reported at this location. The only complaints were from a couple of first time users who ended up on Highway 2 (Deerfoot Trail) when they really wanted to take the left fork to Highway 2A (MacLeod Trail).

Environmental Issues

Rising environmental concerns were particularly noticeable in the crossing of the Bow River.

One issue was a seemingly-minor side channel which is dry much of the year. However, in the spring it forms a crucial low-current spawning area and habitat for juvenile fish. Interfering with the channel would have required creating compensating fish habitat elsewhere, at significant cost. There was a net savings in shifting the highway alignment 120 yards upriver to avoid impact on the side channel.

Allowing wildlife safe passage across the roadway is very important, so the bridges were designed to not just cross the river, but provide 30 m wide wildlife passages under the bridge, along both river banks. To allow this, the bridge uses 64 m girders, which were the longest pre-cast concrete girders in North America at the time, allowing conventional rather than hammerhead piers. This significantly reduced the amount of berming needed in the river.

Wildlife is further protected by corridors along both sides of the south highway embankment between the river and the south escarpment. Wildlife fencing was placed along both sides of Deerfoot Trail for about 3 km south of the Bow River, keeping animals off the highway and directing them to the corridors. To encourage wildlife use, the team calculated the area of trees that would be disturbed by construction, and then planted equivalent areas in the corridors.

Wildlife can also cross the highway through an underpass about 1 km south of the river, along the escarpment. This 85 m long steel-plate underpass is about 7 m wide by 4 m high. A 2 m diameter skylight, in the centre of the highway median, allows natural light to enter the tunnel. Deer and other animals were crossing the roadway through the underpass even before construction was finished, and this has continued.

To reduce environmental impacts and financial costs from transporting aggregate material, gravel was excavated from beside the construction site. The resulting pits were contoured and landscaped as ponds for wildlife habitat, and planted with local species.

The bridge was designed with future recreational use in mind. As the area may become part of a municipal park, the “X” design of the piers allows for adding a pedestrian walkway across the river, under the bridge.

To avoid fish-threatening sedimentation of the river water, a five-acre settlement pond was designed to catch runoff from the bridge deck and roadway as it climbs out of the valley south of the river.

Because the pond's overflow is taken from some depth below the water's surface, oil and other spills on the road are easier to clean up. Pollutants can be skimmed off of the pond before they reach the river.

Another environmental measure is found in the street lights on the roadway, which use flat lenses to minimize light pollution escaping upwards. They also minimize glare. To provide enough lighting on the roadway, the light standards are 18 m high, compared to the usual 15 m.

Throughout the project, extensive use was made of erosion control matting, environmental ditch dams, and other measures to promote quick growth of ground cover, and minimize erosion.

Contractors also were required to develop erosion control and operations plans. The first such plans on the Deerfoot Trail extension became the model for "ECO plans" now required on all Alberta Infrastructure and Transportation projects.

Safety Measures

Light standards were designed with break-away poles to reduce the severity of any collisions with them.

Also, all guard rail for the project is thrie-beam rather than the usual W-beam, to improve collision performance more frequently and consistently.

The highway's paved shoulders are 11 feet wide, forming a full lane for use of disabled or emergency vehicles. Beyond the paved shoulder, the roadway grade was built wide enough to allow for a six lane cross section when future traffic demands it.

Summary

In addition to completing the "missing link" in the north/south trade corridor through Alberta, the Deerfoot Trail Extension has made life easier for many Calgary commuters, who say that it has taken some 20 minutes off their drive to work each day. It has also been of benefit to the motor transport industry as it eliminates stop and go traffic, and is a much more direct route.

Since it opened, collision rates have been very low, and driver reports have been very positive and complementary. Drivers have adapted very well to the two lane loop ramp and major fork, and environmental agencies are very satisfied that this project has met its goal to "mitigate impacts through good design and construction practices."

Drivers are particularly appreciative of the fact that the project was built with all interchange structures in place on opening day, so that no traffic lights were required to stop through traffic.

All of the above Geometric and environmental innovations are the direct result of the innovative approach developed by the project team at the beginning of the project.

This approach resulted in a very successful project which has received numerous compliments from the public, the City of Calgary and Alberta Infrastructure and Transportation, as well as environmental excellence awards from both Alberta Roadbuilders and Heavy Construction Association (ARHCA) and Association of Professional Engineers Geologists and Geophysicists of Alberta (APEGGA).

REFERENCES

1. TAC GDC, 1999
2. AASHTO Green Book, 2000
3. UMA Deerfoot Extension Report, 2000
4. Walker, Ross, J. "Two-Lane Loop Ramps: Operation and Design Considerations", Transportation
   Research Record 1385, Transportation Research Board.

TABLES

None.

FIGURES

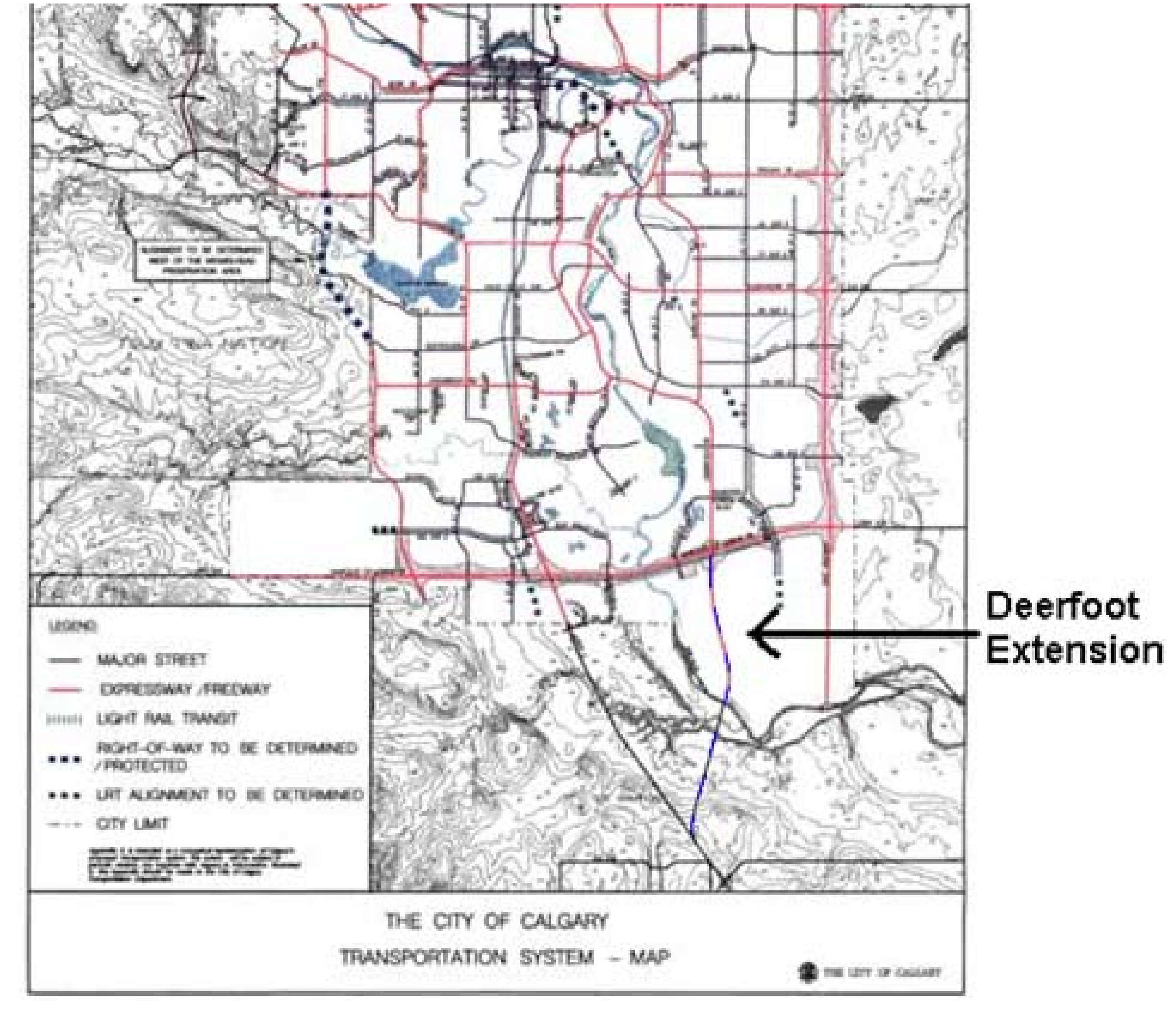

Figure 1: City of Calgary Transportation System – Map

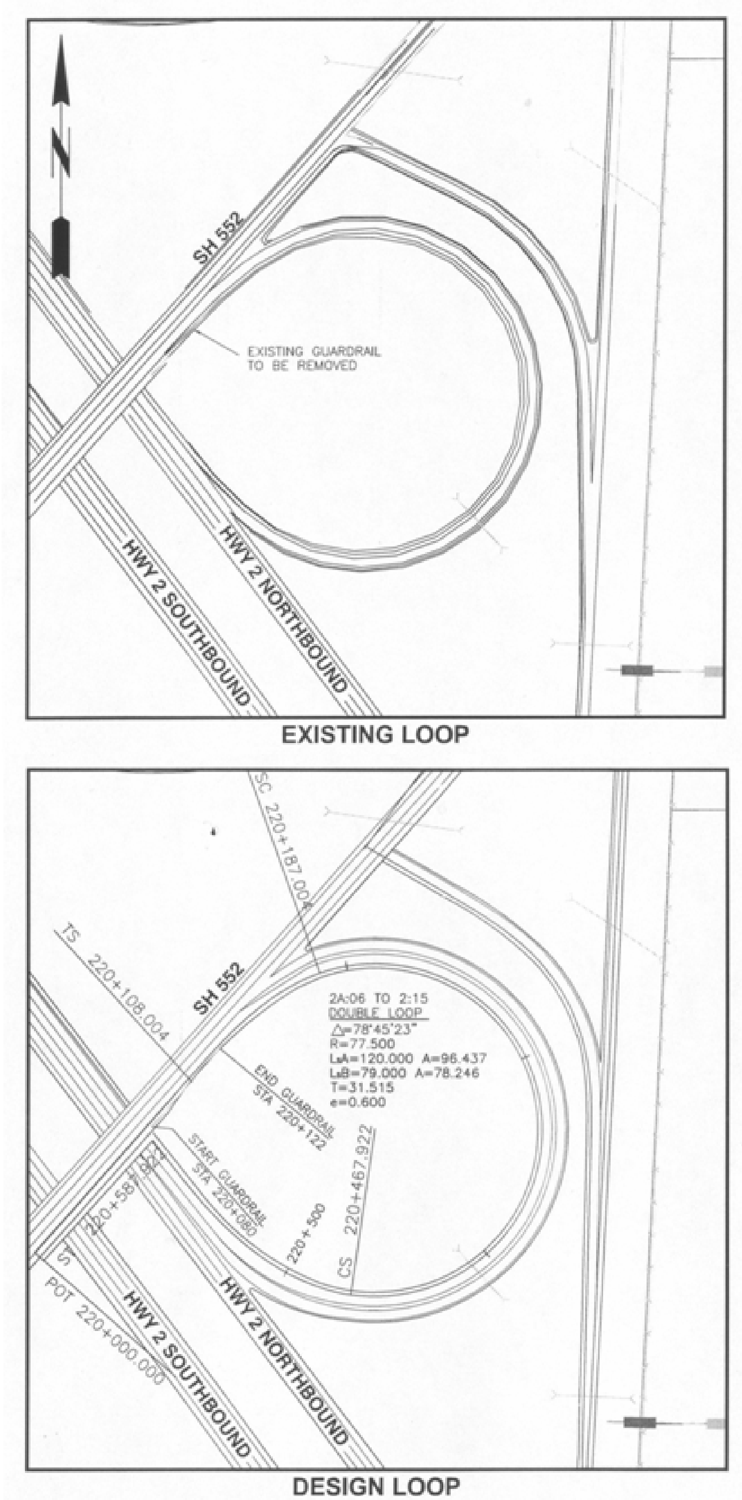

Figure 2: Double Loop Plan Views

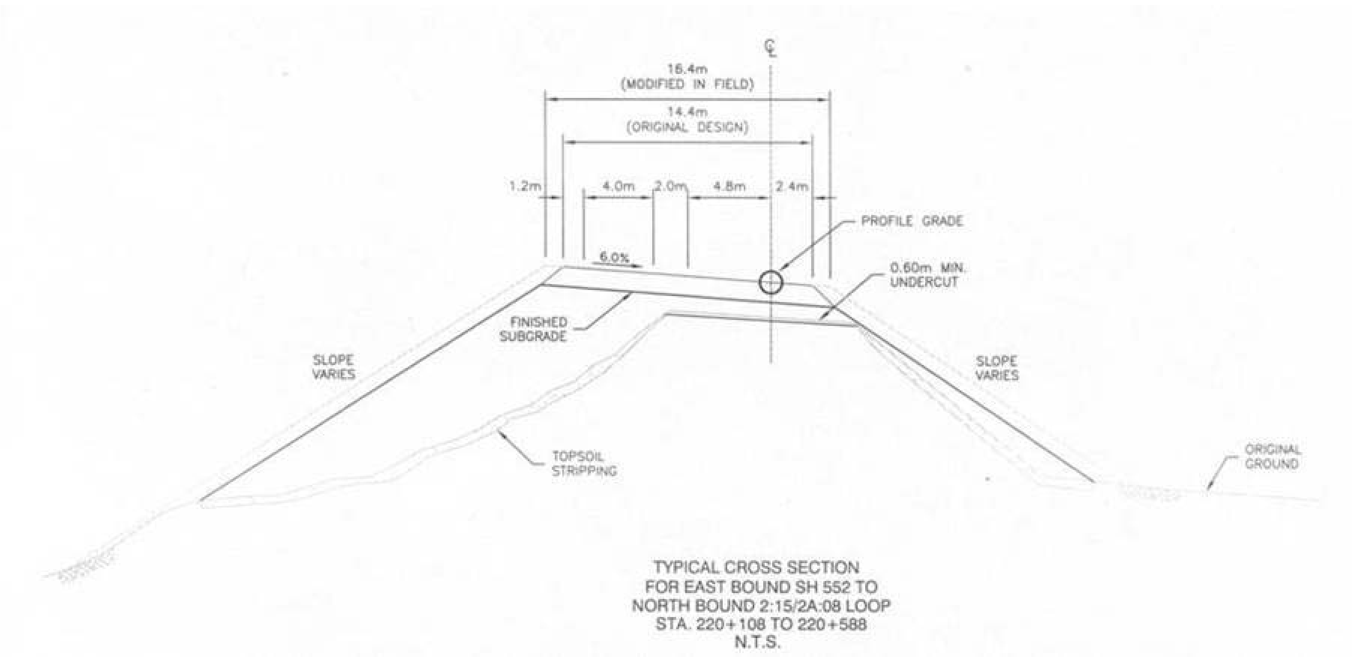

Figure 3: Double Loop Typical Cross-Section

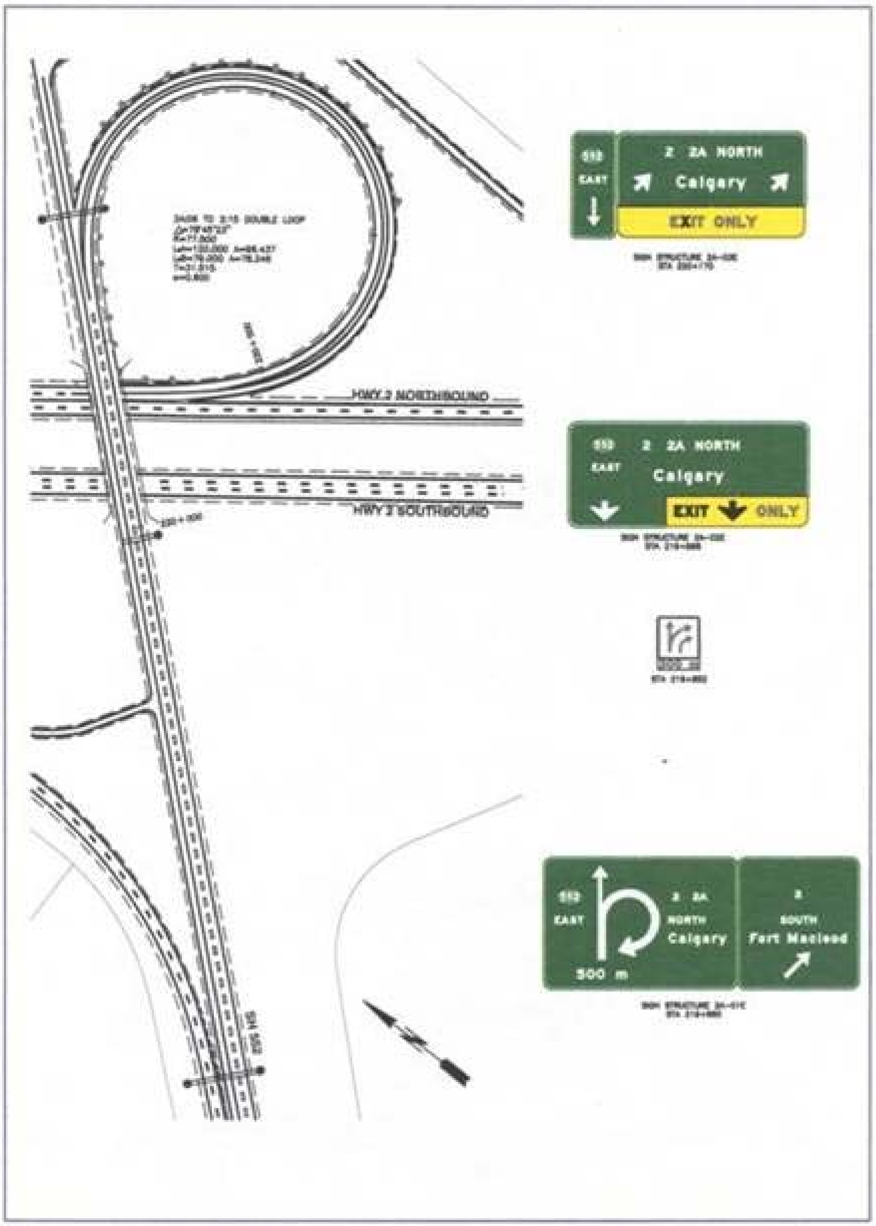

Figure 4: Double Loop Ramp Signing

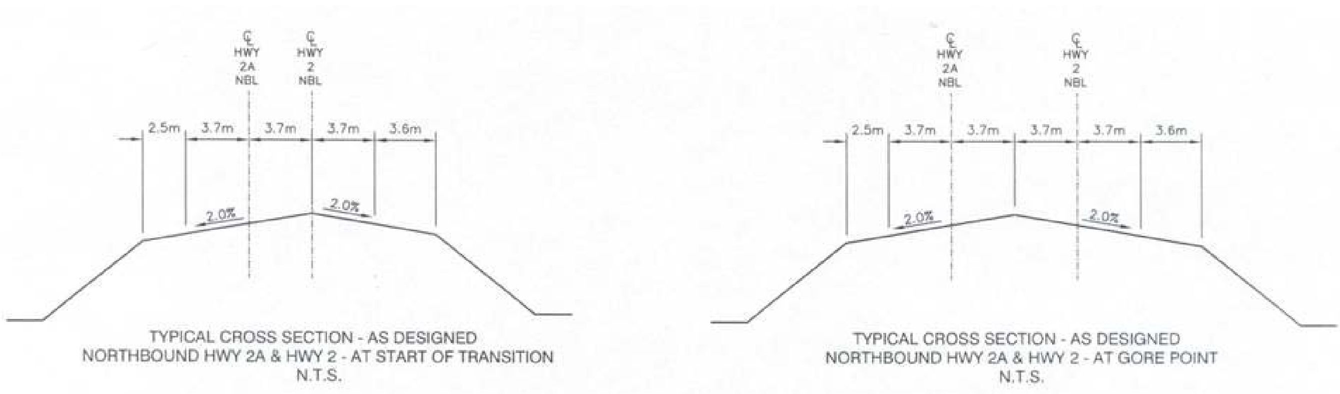

Figure 5: Detailed Cross-Section

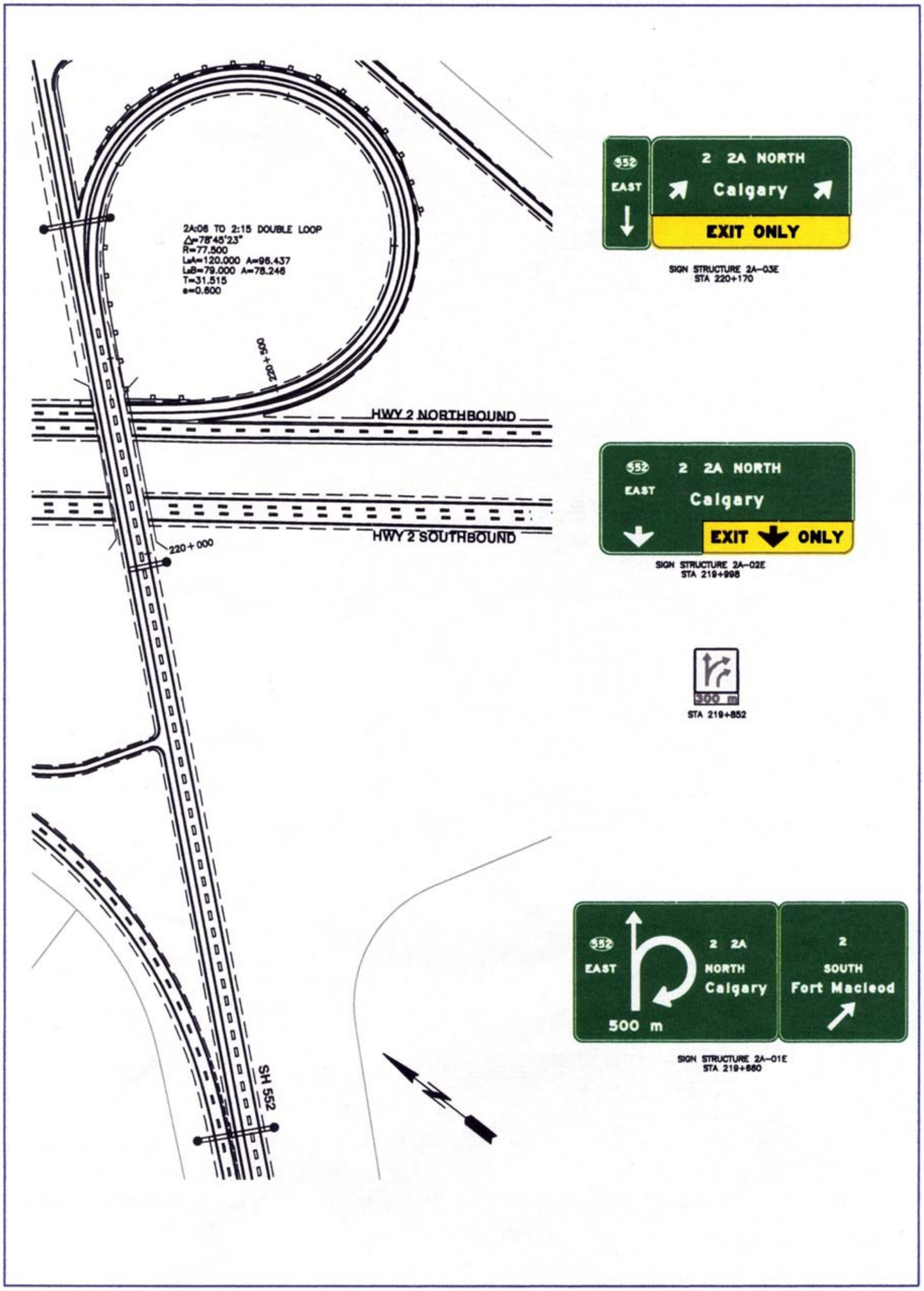

Figure 6: Major Fork Configuration and Signage

Figure 7: Photo of Major Fork – Looking South

Figure 8: Photo of Bow River Bridges

Figure 9: Photo of Deerfoot Trail Extension Crossing Bow River Valley