CONSTRUCTION OF HIGH TENSION MEDIAN CABLE BARRIER ON ALBERTA HIGHWAY 2: A CASE STUDY OF COST-EFFECTIVE INNOVATION

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ABSTRACT

Purpose of paper. In July 2010, Alberta Transportation completed the installation of133 km of high tension median cable barrier (HTCB) on Alberta Highway 2, possibly the largest single such project to date in North America. EBA, A Tetra Tech Company, provided the design and construction supervision services and Alberta Highway Services Ltd. (AHS) was the construction contractor selected through competitive bidding. This paper presents an overview of the HTCB installation and with the help of photos, describes the relevant details of the innovations employed during construction which resulted in substantial cost savings and a record-breaking completion time.

Note that the PowerPoint presentation of the paper at the conference included videos of the innovations.

Summary of the innovations. The innovations utilized include the following:

- Use of driven steel (instead of concrete) for post and anchor foundations for the majority of the project length.
- New tools and techniques:
    - Vibratory post driver rather than the usual drop hammer technique.
    - Straight line production facilitated by hauling 20 cable spools per customized delivery truck rather than the usual four spools.
    - Special guide post attached to the front of a mini excavator to guide the cables off the truck.
    - Special tension-holding post to help take the slack out of the system.
    - Tensioning of cable with an electric winch attached to a mini excavator, instead of using a block and tackle arrangement.
    - Meticulous and detailed planning and execution of traffic accommodation.

Positive results of the innovations. The positive results of the innovations included:

- The innovations allowed AHS to reduce the time required to install the entire 133 km of high tension cable barrier in 45 days compared to an estimated 150 days it would have taken with conventional methods and use of cast-in-place concrete foundations.
- There were no (zero) construction-related incidents within the construction zone during the installation on the busiest highway in Alberta carrying up to 80,000 vehicles per day.
- The contractor’s profit margin was significantly higher than the initial estimate.
- The client (Alberta Transportation) was highly satisfied with the process and the results.

PURPOSE OF PAPER

Since May 2007 Alberta Transportation (AT) has completed six installations of high tension cable barrier (HTCB) in the median of 138 km of divided provincial highways (see Table 1 for details). The largest of these projects, 133 km of HTCB on 122 km of Highway 2 between Airdrie and Red Deer and in the vicinity of Leduc, was completed in July 2010, and is believed to be one of the largest HTCB projects in North America. Figure 1 shows the location of this project.

EBA, A Tetra Tech Company, provided the design and construction supervision services and Alberta Highway Services Ltd. (AHS) was the construction contractor selected through competitive bidding. This paper describes the relevant details of the innovations employed in material handling and construction (preparation, installation of posts and cables, tensioning of cables) which resulted in substantial cost savings and a record-breaking completion time.

OVERVIEW OF HIGH TENSION CABLE BARRIER

Advantages and Limitations of High Tension Cable Barrier

In comparison with rigid concrete and semi-rigid steel barrier systems (i.e. Concrete, W-beam, Strong post, Thrie beam, Modified Thrie beam, Box Beam etc), the advantages of HTCB include the following:

- Significantly reduced collision severity (fewer fatalities and injuries); high tension cable barriers deflect and thus cushion the force of the hitting vehicle and are therefore more forgiving than concrete and steel beam.
- Reduced damage to vehicles; a significant proportion of vehicles which hit HTCB are able to drive away.
- Cost to install is much less than concrete or steel barrier systems.
- If impacted, relatively fast and easy to repair.
- Can retain much of its tension after a hit and can take additional hits until repaired.
- Reduced snow drifting.
- Improved sight distances in problem areas.
- Aesthetic appeal, visually non-intrusive.

Other HTCB benefits include:

- Although not designed to stop semitrailers, there have been numerous instances where semitrailers were successfully restrained.
- As discussed with reference to published research in reference EBA, 2010, HTCB is not any worse than other barrier types for motorcycles.

Limitations of HTCB include:

- HTCB has not been tested and approved for installation as a median barrier on median side slopes steeper than 4H:1V.
- HTCB is not suitable for very narrow medians (less than approximately 6 m) because the cables need space for deflection and must have sufficient distance from the nearest travel lane in both directions.
- HTCB is not suitable on small radius horizontal curves (less than approximately 200 m).
- HTCB requires hand mowing around the post foundations.

A summary of the experience with cable barriers in the US, where over 5,000 km median cable barriers have been installed, is provided in Ray, et al, 2009. Churchill et al, 2011, report the results of a before-and-after analysis of the 11 km HTCB installed in 2007 on Deerfoot Trail, Calgary, Alberta.

Testing and Approval of High Tension Cable Barrier Systems

HTCB consists of three or four 19 mm (3/4 inch), 3x7 strand, galvanized steel cables held at the desired height by light "clips" or "hangers" attached to weak steel posts (line posts) placed in sleeves/sockets which are contained in concrete or steel foundations. The cables are individually connected to end terminals anchored in steel or concrete foundations. Four terminal posts (in case of the Gibraltar HTCB) help transition the cables from the line posts to the ground level anchor. Photos 1 and 2 illustrate selective aspects of HTCBs.

Cables are pre-stretched and are post-tensioned after installation to a value depending upon ambient temperature, e.g. 25 kN (5,600 pounds) at 21 C (70 F). The posts are designed to yield on impact and the tensioned cables deflect and cushion the force of the hitting vehicle. Cables are supplied in 1,000 ft. (303 m) spools and are connected by turnbuckles and acorns.

The HTCBs installed on major highways in the US and Canada are generally selected from the products approved by the US Federal Highway Administration (FHWA) on the basis of tests conducted by independent laboratories. A brief description of the required testing procedures, test levels, and the FHWA approval process is provided in Hassan et al, 2007. Approved HTCBs for Test Level 3 (tested for a pickup truck) and Test Level 4 (tested for a single-unit truck) are available from five manufacturers: Brifen, Gibraltar, Nucor, Safence, and Trinity. Table 2 shows selective test data, including the maximum test deflection at the given post spacing, for the five cable barriers approved by FHWA for installation on 6:1 and 4:1 median side slopes. The data in the table are summarized from the FHWA acceptance letters.

Although the physics/dynamics involved in the workings of all high tension cable barriers is similar, the actual designs are proprietary, thus differing in, for example, the number of cables, maximum test deflection, post spacing, design and dimensions of posts (spacing, height, cross-section, clips or hangers holding the cable to the posts) and end treatments/anchors, etc. Photo 1 shows some of the differences in line post cross sections and post-cable connecting mechanisms.

Photo 2 shows the Gibraltar terminal anchor and the four terminal posts used to transition the cables from the line posts to the anchor.

The parts are not interchangeable between various HTCB systems. A given cable barrier installation must use components from the same manufacturer.

New products, new tests and new FHWA guidelines may be introduced any time. It is therefore essential that thorough research be undertaken regarding available products before designing new HTCB installations.

RELEVANT DETAILS OF THE HIGHWAY 2 CABLE BARRIER PROJECT

The following selective details of the Highway 2 HTCB installation are relevant to the discussion of the construction innovations described in the subsequent sections of the paper.

- AT's tendering policies require competitive bidding. The specifications (e. g. maximum test deflection of 2.7m and maximum post spacing of 6.1m) for the Highway 2 HTCB were therefore set with a view to enabling multiple manufacturers to bid on the project.
- Since only one median HTCB is normally installed to protect both directions of traffic, sufficient deflection space consisting of the maximum specified deflection plus a safety margin must therefore be provided between the HTCB and the median side painted yellow shoulder lines in both directions; and also between the HTCB and a median hazard if the HTCB is relied upon to protect the hazard. The preferred HTCB location from a soil strength viewpoint is generally is at the top of the median side slope near the shoulder, as long as the above conditions and other FHWA guidelines can be met.

  The ditches are often uneven, with weak soil conditions and may require extra grading, compacting and review of the overall drainage patterns. These factors tend to make the ditch installation of HTCBs more expensive. HTCB should be installed in the ditch only when shoulder installations are not able to meet the desirable deflection space requirements. For all HTCB installations, the soil strength must be taken into account when designing the line post foundations and end anchor foundations.
- As shown in Table 2, some HTCB manufacturers offer both three-cable and four-cable HTCB systems, while others offer only four-cable systems. Both three and four cable HTCBs have equivalent FHWA approval. However, the recent trend is to specify four cables (as in BC), as research has shown that a four cable HTCB may stop a larger variety of vehicles. AT had stipulated that a four-cable HTCB be specified for the Highway 2 installation.
- The foundations for the end anchors and for line posts can be either driven steel or concrete, provided both have FHWA approval for a given HTCB manufacturer's system.
- As a result of competitive bidding, Highway 2 HTCB project was awarded to Alberta Highway Services (AHS) with Gibraltar as the manufacturer/supplier of the four-cable HTCB system. The project was awarded in September 2009. AHS used the time from award of contract to start of construction work in April 2010 for surveying, pre-casting foundations and other planning activities. Site work began in April 2010 and was completed in July 2010.

- Some relevant statistics are:

Traffic volume	Up to 80,000 vehicles/day (AADT)
Length of Highway 2 with HTCB	122 km
Length of cable barrier installed	133 km (55 km near the shoulder on the northbound or southbound side, 56 km in the middle of the median ditch, and 11 km on both northbound and southbound side)
Number of cable barrier segments	53 (Average length = 2.5 km)
Number of end terminals	106
Number of line posts	20,000

CONSTRUCTION INNOVATIONS

The major innovations employed by AHS during the construction of Highway 2 HTCB are briefly described below and illustrated by photos from the project site.

Innovation #1. Use of Driven Steel (instead of concrete) Post and Anchor Foundations for the Majority of the Project

The design had specified either concrete or driven steel foundations for the line posts and end anchors. The design had also required that the subsoil information provided in the tender documents be used to prepare foundation design which must be certified by an Alberta-registered Professional Engineer. Gibraltar is one of the HTCB manufacturers with FHWA approval for concrete or driven steel foundations.

AHS used driven steel for line post foundations on the entire length of the project. Of the total of 106 anchors and the associated terminal posts, approximately 60 percent had driven steel foundations and 40 percent had pre-cast concrete foundations. Driven steel and pre-cast concrete foundations are assumed to be less expensive than cast-in-place foundations; the exact comparative costs are not publicly available for the Highway 2 project.

Photo 3 shows two examples each of concrete and driven steel foundations.

Innovation #2. Utilizing a Vibratory Post Driver Rather than the Usual Drop Hammer Technique

The drop hammer technique is the usual procedure for pounding the driven steel sockets into the ground. For the majority of the Highway 2 project, AHS used a vibratory post driver mounted on a mini excavator to install the line post sockets. Depending on local soil conditions this allowed AHS to install line posts at an average rate of one post every 1 to 2 minutes. The vibratory driver was sufficient at most locations to install line posts quickly. In locations where soil conditions provided difficult during installation, AHS switched to a backhoe mounted pneumatic driver or pre-drilled each location before installation.

Because of difficulties (time and amount of effort required to install an anchor) encountered during the first installations at some driven anchor locations, AHS elected to pre-auger at each driven anchor location to reduce the installation time. While a pneumatic hammer was still required to drive the anchor to the specified depth, the amount of effort required was reduced as the displaced material would be forced into the hollow middle of the anchor instead of being compacted as would be the case without pre-auguring.

Photo 4 shows the use of vibratory driving of steel sockets.

Innovation #3. Straight Line Production Facilitated by Hauling 20 Cable Spools per Customized Delivery Truck rather than the Usual Four Spools

Normally the delivery truck that brings the 1,000 ft (303 m) spools to the work site carries four spools. AHS utilized a customized truck and trailer for cable stringing work. During installation of the Highway 2 HTCB, AHS utilized two delivery trucks with each carrying 20 spools (approximately 12.0 linear km of cable or 2.5 km of 4-cable barrier per truck). This allowed AHS to install approximately 5 km of 4-cable barrier per full day of production. This configuration allowed workers to continue stringing until each truck was exhausted of cable instead of having to wait for delivery in a four spool configuration, resulting in less total downtime.

Photo 5 shows the customized spool delivery truck.

Innovation #4. Special Guide Post Attached to a Mini-Excavator to Guide the Cables off the Truck

AHS used a custom built attachment to assist workers with installation of the cable barrier. Mounted on a mini-excavator, the guide post ensured that cables were kept separated and untangled. This configuration also assisted workers by keeping the cable at a constant height above ground, thus reducing fatigue and potential worker injury from repetitive lifting motions at each line post, which is the usual procedure.

Photo 6 shows the use of the special cable guide post.

Innovation #5. Special Tension-Holding Post to Help Take the Slack out of the System

Every 303 m AHS was required to install a splice in the cable by using a set of turnbuckles. In order to maintain consistent turnbuckle placement, AHS developed a customized post to maintain some tension in the system during splicing. At each splice, workers would pull cables taut using the mini-excavator mounted winch; cables were then held in place, in tension, while the splice and turn buckles were installed. Once the splice was completed the tension was released (until the post-tensioning of an entire HTCB run), and work continued.

Photo 7 shows the use of the special cable guide post, dubbed the “Christmas Tree”.

Innovation #6. Tensioning of Cable with an Electric Winch Attached to a Mini-Excavator, Instead of Using a Block and Tackle Arrangement

Normally a block and tackle arrangement is used at the end anchor to tension the cable barrier. However, AHS discovered that this method required too much time, and opted to use a mini-excavator-mounted winch, which was parked in place at the end terminal. This method resulted in fewer setups per end terminal and allowed workers greater precision during tensioning. The set up was also useful during splicing work, as additional equipment was not required for the tension holding post mentioned above.

Photo 8 shows the use of the mini-excavator-mounted winch.

POSITIVE RESULTS OF THE INNOVATIONS

The positive results of the innovations included:

- The process described above allowed AHS to reduce the time required to install the entire 133 km of high tension cable barrier in 45 days compared to an estimated 150 days it would have taken with conventional installation methods and use of cast-in-place concrete foundations.
- There were no (zero) construction-related incidents within the construction zone during the installation on the busiest highway in Alberta carrying up to 80,000 vehicles per day within the project limits.
- The contractor’s profit margin was significantly higher than the initial estimate.
- The client (Alberta Transportation) was highly satisfied with the process and the results.

This type of work was new to AHS as a contractor, and they turned this challenge into an opportunity for innovations that proved to be highly effective in technical and financial terms.

REFERENCES

Churchill, T., Barua, U., Hassan, M., Imran, M., and Kenny, B. (2011). Evaluation of safety and operational performance of high tension median cable barrier on Deerfoot Trail, Calgary, Alberta. Paper prepared for presentation at the “Canadian Applications of the AASHTO Highway Safety Manual” Session of the 2011 Annual Conference of the Transportation Association of Canada, Edmonton, Alberta. 2011.

Hassan, M., McGregor, R., and Lahey, O. (2007). Design of a TL-4 median cable barrier For Deerfoot Trail, Calgary. Proceedings of the Transportation Association of Canada Annual Conference, Saskatoon, Saskatchewan, 2007.

Ray, M., Silvestri, C., Conron, C. and Mongiardini, M. (2009). Experience with cable median barriers in the United States: design standards, policies and performance. Journal of Transportation Engineering, v 135, n 10, 711-720, October 2009.

TABLE 1. High-Tension Median Cable Barrier Installations in Alberta

Row No.	Highway No.	Location	Completion Date	Estimated Highway Length with cable barrier (km)	Estimated Cable Length including double-sided sections (km)	High-tension Cable System Supplier
1	Hwy 2	Deerfoot Trail, Calgary	May 2007	10.8	10.8	Gibraltar 3-cable, Test Level 4
2	Hwy 2	In Airdrie south of Hwy 567	July 2010	3.9	7.8	Gibraltar 3-cable, Test Level 4
3	Hwy 2	N. of Airdrie to Red Deer and near Leduc	July 2010	122.0	133.0	Gibraltar 4-cable, Test Level 3 Test Level 4
4	Hwy 2	Deerfoot Trail/Stony Trail Interchange north of Calgary *(It separates Deerfoot Trail northbound lanes from Stony Trail ramp lanes, and is therefore not strictly a median barrier)*	2010	0.9	0.9	Trinity 3-cable, Test Level 4
5	Hwy 16	Hwy 16/21 interchange east of Edmonton	October 2009	0.3	0.4	Trinity 3-cable, Test Level 4
6	Hwy 63	Hwy 63 & Parson Creek Aggregates Rd. intersection, north of Fort McMurray	2010	0.1	0.1	Trinity 3-cable, Test Level 4
			TOTAL LENGTH	138.0	153.0	

TABLE 2. Selective characteristics of the five FHWA-approved high tension cable systems as of March 2011*

Item	Brifen	Gibraltar		Nucor	Safence		Trinity	
	4-cable only	3-cable	4-cable	4-cable only	3-cable	4-cable	3-cable	4-cable
6:1 OR FLATTER SIDE SLOPE, (FHWA-approved as TL-4)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test deflection, m	2.4	2.4	Assume same as 3-cable	2.55	3.7	2.1	2.3	2.3
Test Post Spacing, m	3.2	6.1		6.1	10.0	4.0	6.1	6.1
Selective FHWA guidelines for installation on 6:1 or flatter side slope	May be placed in the median ditch; when placed on the median side slope the cable barrier should not be between 1 ft and 8 ft (0.3 m and 2.4 m) from the ditch bottom.							
4:1 SIDE SLOPE, (FHWA-approved as TL-3)	Yes	Yes	Yes	Yes	Yes	Yes	?	Yes
Test deflection, m	2.7	2.6	Assume same as 3-cable	2.93	5.0	FHWA letter pending	?	2.28
Test Post Spacing, m	3.2	6.1		6.1	4.9		?	6.4
Selective FHWA guidelines for installation on 4:1 side slope	May be placed in or near (+/- one foot or +/- 0.3 m) the centre of a 4:1/4:1 median ditch; when placed on the median sideslope the cable barrier should be no more than 4 ft (1.2 m) down a 4:1 slope and no closer than 8 ft (2.4 m) from the ditch bottom.							
FHWA-approved End Anchors	TL-3, TL-4	TL-3	TL-3	TL-3	TL-3, TL-4	TL-3, TL-4	TL-3	TL-3

(Source: FHWA approval letters)

* Rather than relying on this summary table, designers should consult the original FHWA approval letters for these products and search for the latest versions of the products. Note that new products or new tests on existing products may be introduced any time, e.g. as of March 2011 Safence has FHWA approval letters pending based on new tests.

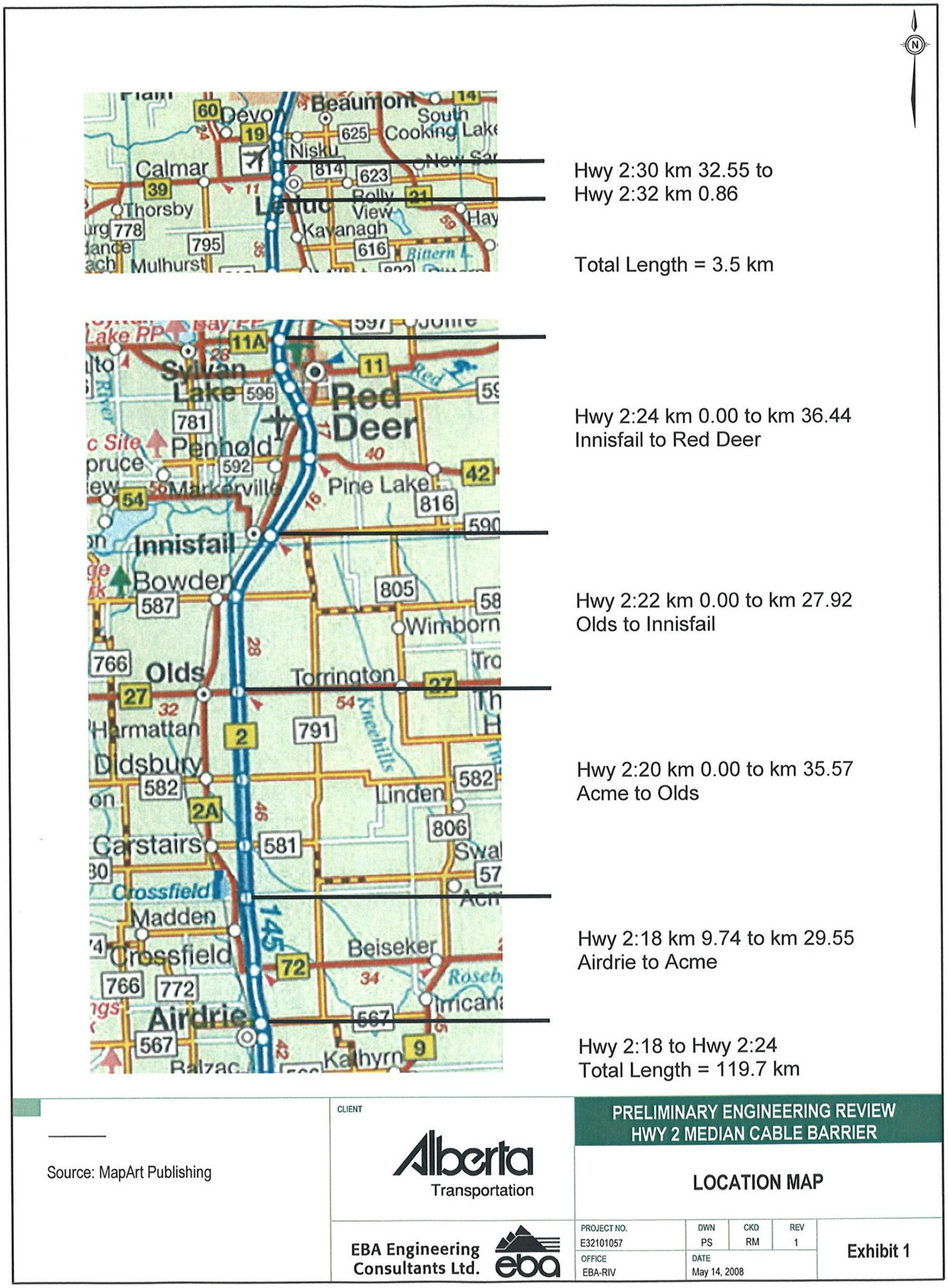

FIGURE 1. Location of Alberta Highway 2 high tension median cable Barrier project.

PHOTO 1. Photos of the five FHWA-approved high tension cable barrier systems.

PHOTO 2. Gibraltar end terminal (cable-release type) and terminal posts.

PHOTO 3. Top to bottom: Installing pre-cast concrete anchor foundation in bored hole; Backfilling pre-cast concrete anchor foundation in bored hole; Installing driven anchor post using pneumatic driver; Driven line post socket.

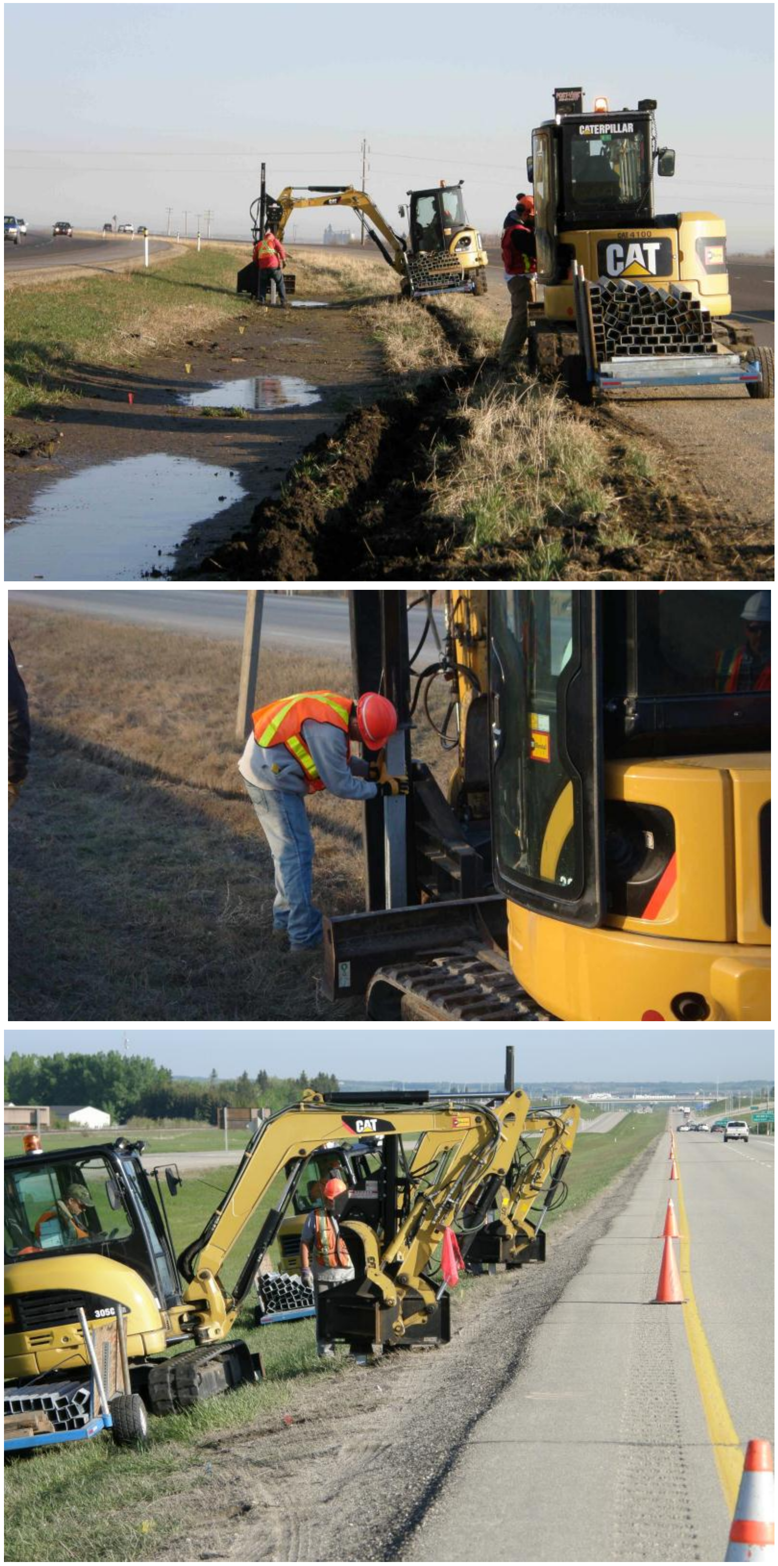

PHOTO 4. Top to bottom: Installing driven steel sockets; Checking angle of post during vibratory driving of steel sockets; Vibratory driver attached to mini-excavators.

PHOTO 5. Top to bottom: AHS's customized spool truck carrying 20 spools of cable barrier (approx. 12.0 linear km of cable or 2.5 km of 4 cable barrier per truck); Worker unraveling new spool of cable barrier during start of stringing work.

PHOTO 6. Top to bottom: AHS custom built cable guide mini-excavator attachment; Cable guide untangling cable to ensure proper installation; Cable guide and mini-excavator maintaining cable at constant height to reduce worker fatigue from repetitive lifting motions.

PHOTO 7. Top to bottom: Using the “Christmas Tree”, workers taking up excess slack in barrier before beginning splicing and install of turnbuckle; Custom post holding tension in system during splicing and installation of turnbuckles.

PHOTO 8. Top to bottom: Mini-excavator mounted winch for use during tensioning and splicing work; Worker directing winch operator to increase tension to a specified amount by taking up excess slack; Workers attaching cable to terminal anchor once specified tension has been reached.