# Thickwood Interchange and Highway 63 Tangent Pile Wall

By:

Ferhan Bhanji, P.Eng. – Project Manager, Transportation
Author
AECOM
17007 – 107 Avenue
Edmonton, AB, T5S 1G3
ferhan.bhanji@aecom.com

And

Leon Seto – Project Manager, Transportation
Co-Author
AECOM
17007 – 107 Avenue
Edmonton, AB, T5S 1G3
leon.seto@aecom.com

Paper prepared for presentation at the Design Session of the 2012 Annual Conference of Transportation Association of Canada
Fredericton, New Brunswick

# ABSTRACT

The Thickwood Boulevard Interchange is being constructed in conjunction with the Highway 63:11 Corridor improvements through Fort McMurray to accommodate extremely high volumes of local and commuter traffic, in addition to overdimensioned vehicles going to the oil sands through this very constrained corridor. The Hwy 63:11 corridor improvement involves a combination of grade widening and new construction of 9.5km of freeway, from 4 to 6 lanes, and the construction of C-D lanes (1 to 3 lanes) from downtown to Confederation Way. When complete there will also be 3 new bridges constructed across the Athabasca River which will provide a total of 10 lanes of traffic.

AECOM was retained by Alberta Transportation to provide preliminary engineering, detail design, tender preparation, construction supervision, contract administration and post-construction services for the Thickwood Boulevard Interchange in Fort McMurray. This involves converting the existing at-grade signalized intersection to a "trumpet" interchange to facilitate the high volume northbound left turn movement which is currently handled by a 3-lane dedicated left turn bay.

Innovative design solutions were required to address:

- Hillside geotechnical stability due to an abundance of weak compressible clays and layers of oil sands in the subsurface;
- Restricted right-of-way with Highway 63:11 wedged between a steep hill to the west and the Athabasca River to the east;
- Horizontal and vertical sight distance issues from the north side of the river bridges up to the Thickwood Boulevard Interchange;
- Congested utilities within this narrow right-of-way;
- Accommodation of over-dimensioned transport trucks;
- Incorporation of oil sand and weak compressible materials overlying bedrock found on site in embankment construction;
- Permitting from major pipeline companies, municipal infrastructure, storm pond and outfall facilities, existing fish bearing creek; and
- Tender schedule to meet the overall staging plan of the entire Highway 63 corridor for 6-lane conversion.

Innovative designs solutions that AECOM incorporated into the project included:

- A two level MSE wall retaining system to accommodate the over-dimensioned vehicles traveling to the oil sands sites to the north, with the wall system designed to address huge ice flows during spring break-up;
- Large scale multimillion dollar utility relocations and installations throughout the length of the project limit to tie-in to various infrastructures, allowing the corridor to be cleared of utilities prior to the road construction;
- Construction of extensive secant and tangent pile wall systems both at the base of the steep slope below the Thickwood subdivision and along the Athabasca River to mitigate slope failures and enable the realignment of Highway 63 into the valley slope;
- Develop and provide an adequate width to accommodate the highway widening and a new C-D roadway;

- A Vulcan Gate interlocking movable centre median barrier system to accommodate over-dimensioned transport trucks maneuvering between Thickwood Boulevard Interchange and the next interchange north at Confederation Way should over-dimensioned transport trucks not be able to access the highload bypass;
- An Open Bottom Arch culvert of deep corrugated structural steel designed for Conn Creek to span 90m across 10 lanes of traffic while minimizing disturbance to the natural channel – preserving or improving fish habitat.
- An automated anti-icing system incorporated into all bridges to increase safety for road users.

## Background

The Highway 63:11 corridor through Fort McMurray, at one time, was a two-lane rural undivided highway. With the economic boom came rapid population growth and the emergence of residential communities north of the Athabasca River outside of downtown Fort McMurray. In 1981, the increased traffic congestion along the two-lane highway prompted Alberta Transportation (AT) to twin Highway 63:11 to a four-lane rural divided highway with signalized at-grade intersections.

**The Highway 63:11 corridor is highly constrained as it is situated on the Athabasca River terrace which is wedged between an unstable river valley slope to the west and a steep river bank to the east. The highway also crosses over Conn Creek, which is fish bearing, and is surrounded by major utilities servicing the Oil Sands developments to the north in addition to the City of Fort McMurray itself.**

In 2005, AECOM was retained by Alberta Transportation (AT) to provide engineering services to design and construct an interchange at the junction of Thickwood Boulevard and Highway 63:11.

In 2005, a consortium involving Stantec, AECOM and CH2M Hill was also retained by AT to provide engineering services to design and construct 9.5 km of six-lane grade widening of Highway 63:11, with interchanges at Confederation Way and Beacon Hill. This project also included superstructure replacements of Steinhauer and Grant MacEwan River Bridges.

In 2005, McElhanney undertook a functional planning study for the Regional Municipality of Wood Buffalo (RMWB) that revisited the six-lane grade widening and explored the concept of core / collector-distributor (C-D) roadways to manage congestion by separating local from non-local traffic that would better suit the upgrade of Highway 63:11. The concept was later accepted by AT and added to the consortium's project scope.

This paper focuses mainly on 2.4 km of Highway 63:11 corridor between the Athabasca River and Thickwood Interchange. See **Figure 1 - Key Map of Fort McMurray** in the Figures Section.

## Functional Planning

*Thickwood Interchange*

The at-grade intersection at Thickwood Boulevard and Highway 63:11 operated for many years as a signalized intersection with a double bay left turn slot for northbound (NB) to westbound (WB) traffic, double left turn for eastbound (EB) to northbound (NB) traffic, single right turn with raised island for southbound (SB) to westbound (WB) traffic and double right for eastbound (EB) to southbound (SB) traffic. The SB-WB and EB-SB movements operated as free flow whereas the NB-WB and EB-NB movements were protected. With increased queuing occurring for NB-WB movement during the peak hour, AT added a third turning lane as a temporary measure until an interchange was constructed.

The functional plan for the interchange evolved from a traditional **Diamond** (developed by ISL in 2001) with signals having single entrance and exit tapers for all movements except for the double entrance taper for the EB-SB movement, to a **Trumpet** (developed by McElhanney in 2005) having a double lane loop for the NB-WB movement on the east side and Half Diamond on the west side. A high-load bypass

ramp was provided that would merge with the EB-NB movement. The critical movements, NB-WB and EB-SB, were free-flow.

**AECOM's scope was to validate the functional plan and undertake detailed design of the Thickwood Boulevard Interchange.**

*Highway 63:11 Grade Widening*

The grade widening of Highway 63:11 involved widening of four lanes to six lanes to the median and adding C-D lanes to the outside that widened the cross section. The core lanes comprised the Highway 63:11 six laning with three lanes in the NB and SB directions. The C-D lanes comprised two to three lanes in the NB direction and one to three lanes in the SB direction. A transfer lane was developed to provide access from core lanes to C-D lanes along the NB direction.

With basic understanding of the constraints when working in a very tight corridor, AT still preferred the core/ C-D concept as it improved traffic operations significantly by eliminating weaving. During the peak hour, most residents living in Thickwood and Timberlea will either commute SB to downtown Fort McMurray or NB to the Alberta Oil Sands with the dominant movement being to downtown Fort McMurray.

**AECOM's scope was to validate the functional plan and undertake detailed design of the portion of Highway 63:11 from north of the Athabasca River to north of Confederation Way.**

## Preliminary Engineering

In previous experience working on Highway 63 in the Fort McMurray area, AECOM encountered many challenges during the engineering and construction phases which added substantial unforeseen costs to the projects. The challenges encountered included taking measures to stabilize the sensitive valley slopes which were subject to minor disturbances; meeting stringent environmental requirements when working near water bodies such as creeks and rivers; working around major oil pipelines, telecommunication cables and municipal services; and working around traffic to effectively stage construction.

**The most challenging issue in this project involves working in a very constrained highway right-of-way.** Highway 63:11 is situated on a river terrace bench that was formed by years of down-cutting. The river valley slope abuts the west side of the highway corridor. There is a sharp drop off along the east side where a branch of the Athabasca River has eroded into the east side of the terrace bench. The narrowest part of the terrace bench is about 60m wide, which creates a pinch point/space constraint for the proposed highway grade widening and C-D lanes.

Within this very constrained highway right-of-way, consideration must be given to:

- **Working around or within the unstable valley slopes.** The general soil conditions consist of clay shale over oil sand over limestone. The valley slopes have been subject to past and ongoing slope erosion and landslide, which has resulted in the presence of weak, unconsolidated colluviums soil draped over the valley slope with the thickest accumulations occurring at the base of the valley slope;

- **Working in close proximity to utilities.** Major oil pipelines (Enbridge, Suncor), RMWB infrastructure (storm, sanitary), telecommunication copper or fiber cables (Telus, Shaw, Bell) and overhead powerlines (ATCO) run adjacent to, cross, or run within the highway right-of-way. The timely relocation and protection of these utilities to accommodate the construction is essential;

- **Accommodation of Over-dimensioned Transport Trucks during design and construction.** Highway 63:11 is a highload corridor whereby combination units hauling various load sizes are transported daily to the Alberta Oil Sands;

- **Native Soils.** The native soils within the highway right-of-way and at the borrow sites are not typical. The clays consist of low to medium to high plasticity, lean oil sand having <6% bitumen content and clay shales. The NE and SE quadrants of the Thickwood Interchange footprint contain an abandoned sewage lagoon, which over the years was backfilled with random waste not suitable for fill. In general, the native clays have varying characteristics which must be worked and mixed strategically to optimize strength and benefit fill placement criteria;

- **Environmental Permitting.** Conn Creek is considered a fish bearing stream, and the existing culvert is a barrier to fish passage due to its extensive length, lack of daylighting, and potential for high velocities. The Department of Fisheries and Oceans will not entertain compensation mitigation until the fish barrier issue is resolved.

*Implementation of Core/ C-D*

AECOM implemented the core/ C-D concept between the Athabasca River and Thickwood Interchange only to encounter immediate challenges that involved cutting into the unstable valley slope to the west, and encroaching very close to the Enbridge pipelines and the Athabasca River flood plain to the east.

The centerline median established along the existing highway alignment shifted 12.0m to the west as grade widening beyond the existing NBL to the east would make the river bank unstable. The cut into the valley slope resulted in massive retaining walls that extended 17m in height over a 400m section through the pinch point. AT had varying opinions regarding the massive retaining wall. One view was that any failure to the retaining wall would have a direct affect on the Thickwood subdivision located at the top of the slope bank if the upper portion of the slope became unstable; could shutdown Highway 63:11, which is the only direct route the Alberta Oil Sands and Fort McMurray; and would adversely affect the major utilities. The other view was that if proper engineering could stabilize the valley slope with appropriate retaining walls and meet geotechnical recommendations, then the core/ C-D concept should be considered at any cost improve traffic operations to meet future demands.

AECOM also explored other core/ C-D combinations in comparison to the McElhanney functional plan through the pinch point that did not involve cutting into the valley slope. The four alternatives developed for evaluation were as follows:

– McElhanney Plan. See **Figure 2 – McElhanney Functional Plan** in the Figures Section.

- Follows the McElhanney planning study;

- Provides for rural expressway standard with adequate separation for transfer lane (86.9m basic width);
- Tangent pile wall up to 17m in height and 400m long is required at pinch point. The estimated cost of the tangent pile wall is $15M (2008 dollars). The wall would be designed to resist earth pressures to avoid a major slope failure below an existing subdivision;
- Aesthetics of the large wall would have to be addressed;
- Tie backs for the retaining wall would require access for maintenance and periodic tightening;
- Weaving distance on NB C-D is approx. 500m and would require a design exception;
- Decision sight distance on NB C-D is not met and would require a design exception;
- LOS is acceptable;
- Storm drainage would be handled using a combination of rural ditches for the NB roadways and piped drainage for the SB roadways;
- Snow clearing could be accommodated along the NB core and C-D lanes in the 17m median. Barriers between the core lanes and between the SB C-D and SB core lanes would require snow removal;
- Common excavation of approx 40,000$m^3$ would be generated, with a potential saving of $400,000 (2008 dollars) over import material; and
- The wide road cross section would result in the need for a 3-span bridge at Thickwood interchange, the need for MSE retaining walls along the C-D roads to deal with the flat (7:1) side slopes, and longer bridge file extensions at Conn Creek.

– Cantilevered Roadway. See **Figure 3 – Alternative 1** in the Figures Section.

- Follows the McElhanney planning study;
- Provides for rural expressway with adequate separation for transfer lane (86.9m width);
- No cut is made into the valley slope (reduced risk of slope failure);
- A significant soldier pile wall 560m long and 15m to 20m high would be required to retain fills and/or support the cantilever road deck. 150m of this wall would be constructed within the Enbridge pipeline ROW. Cost of the soldier pile wall would be in the range of $11M (2008 dollars);
- A cantilever structure with an area of approx 7700$m^2$ would be required to accommodate the roadway cross section. The cost of the structure is estimated to be in the range of $30.8M (2008 dollars);
- A significant length of the Enbridge pipeline ROW outside the cantilever roadway structure would have new roadway over it, and as a minimum Enbridge would require a parallel pipe to be constructed at substantial cost;
- The soldier piles would need armoring protection to avoid potential damage from ice;
- The roadway geometric alignment would have lower radius curves resulting in a lower design speed;
- Large fill volumes would be required for the section of road between the Athabasca River and the hill;
- The option would require DFO approvals; and
- The wide road cross section would result in the need for a 3-span bridge at Thickwood interchange, the need for MSE retaining walls along the C-D roads to deal with the flat (7:1) side slopes, and longer bridge file extensions at Conn Creek.

– Elevated SB C-D. See **Figure 4 – Alternative 2** in the Figures Section.

- Follows the McElhanney planning study;
- Provides for rural expressway standard with adequate separation for transfer lane (86.9m width);
- Tangent Pile wall up to 17m in height and 400m long is required at pinch point. The estimated cost of the tangent pile wall is $15M (2008 dollars) plus. The wall would be designed to resist earth pressures to avoid a major slope failure below an existing subdivision;
- The vertical profile for the C-D road required to avoid a cut into the valley slope may not meet standards;
- Aesthetics of the large wall would have to be addressed;
- Tie backs for the retaining wall would require access for maintenance and periodic tightening;
- Not all of the tangent pile wall would be in existing soils which could result in a need to form the piles above grade;
- Weaving distance on NB C-D is approximately 500m and would require a design exception;
- Decision sight distance on NB C-D is not met and would require a design exception;
- LOS is acceptable;
- Storm drainage would be handled using a combination of rural ditches for the NB roadways and piped drainage for the SB roadways;
- Snow clearing could be accommodated along the NB core and C-D lanes in the 17m median. Barriers between the core lanes and between the SB C-D and SB core lanes would require snow removal;
- Common excavation of approx 5,000$m^3$ would be generated, with a potential saving of $50,000 over import material; and
- The wide road cross section would result in the need for a 3-span bridge at Thickwood interchange, the need for MSE retaining walls along the C-D roads to deal with the flat (7:1) side slopes, and longer bridge file extensions at Conn Creek.

– Urban Roadway (with tight cross section). See **Figure 5 – Alternative 3** in the Figures Section.

- Identifies a C-D road similar to the McElhanney planning study;
- Urban expressway with 62.7m basic width;
- The width of road would fit between the toe of the valley slope and the top of bank;
- Cannot be designed properly without 17m separation for transfer lane between NB core lanes and NB C-D road; and
- Minimal separation between roadways will encourage motorists to cross medians.

– 5 Lanes NB (no C-D). See **Figure 6 – Alternative 4** in the Figures Section.

- Utilizes a 5 lane NB roadway with no separate C-D road between the high point at station 14+300 to the Thickwood interchange (uses the same design standards as Deerfoot Trail);
- Urban expressway with 60.7m width;
- No cut into valley slope would be required and the need for the tangent pile wall is eliminated;
- Only a minor soldier pile wall would be required along a 75m length at the pinch point (similar to what would be required for Option 1 for the east side of the roadway);

- The width of road would fit between the toe of the valley slope and the top of bank;
- Curve radius could be maintained so there would be no reduction in design speed;
- A weaving length in excess of 640m could be provided between the crest of the hill at 14+300 and the Thickwood Interchange;
- The weave section would allow NB traffic on the C-D road to enter the Hwy 63 core lanes prior to Thickwood Interchange, reducing the volume of traffic that would have to run on the C-D road north of Thickwood;
- The alignment avoids the Enbridge pipeline in the area of the pinch point;
- A full piped drainage system would be required with an estimated cost of $1.4M based (2008 dollars) on an average cost of $800/m (2008 dollars) of roadway;
- The surface area of the roadway pavement would be reduced by $7m^2/m$ of roadway length relative to options 1, 2 and 3. From the Athabasca River Bridge to the Thickwood interchange, the road is 1800m resulting in a reduced pavement area of $12,600m^2$. The estimate cost of the pavement structure and earthworks is $\$120/m^2$ (2008 dollars). Potential savings of $1.5M (2008 dollars) in roadway structure are possible;
- With the roadway width reduced from 86.9m down to 60.7m, the bridge at Thickwood interchange could be reduced in length and the bridge cost reduced from $12M (2008 dollars) down to approx. $8.4M (2008 dollars) for a saving of $3.6M (2008 dollars);
- With the narrow roadway cross section, it would be possible to reduce the amount of MSE wall area because there would be a greater length to run out the flat slopes required at the interchange; and
- No DFO impacts to deal with except at Conn Creek.

Of the 4 alternatives, AT requested AECOM to undertake a detailed review of the 5 Lanes NB (no C-D) versus the McElhanney plan and do traffic modeling to determine LOS in year 2025. The 5 Lanes NB (no C-D) had the least cost and tightest cross section and was worthy of further evaluation. Variations to this alternative were as follows:

– 5 lanes NB with NB C-D and no SB C-D. See **Figure 7 – Option 1** in the Figures Section.

- LOS C for weaving in NB direction;
- LOS C for weaving in SB direction;
- Lane balance would be met; and
- Retaining wall would be required into the valley slope and east side to stabilize the river bank to accommodate grade widening.

– 3 lanes NB (with NB C-D) and 3 lanes SB. See **Figure 8 – Option 2** in the Figures Section.

- LOS D for weaving in NB direction;
- LOS E for weaving in SB direction;
- Lane balance would not be achieved at exit to NB C-D as core lanes would be reduced from 3 to 2 lanes;
- Retaining wall only required into the valley slope; and
- Much tighter cross section with 3 lanes in NB direction.

– Long Term Recommended with no SB C-D and with CL shift east. See **Figure 9 – Option 3** in the Figures Section.

- Retained the core/ C-D concept in the NB direction only;

- Centreline median would be shifted east to reduce wall height into the valley slope but still required on the east side to stabilize the river bank to accommodate grade widening;
- No weaving in NB direction; and
- LOS D for weaving in SB direction.

Based on this outcome, AT compromised and selected Option 3 with the understanding that in the future, either a SB C-D could be built or a bypass around Fort McMurray would be constructed to accommodate additional traffic. **Option 3 –Long Term Recommended with no SB C-D and with CL shift east became the Recommended Plan.** AECOM was now authorized to proceed with detailed design.

## Detailed Design and Construction

The following are other considerations made in design and construction to optimize right-of-way use:

*Tangent Pile Walls at the Pinch Point*

One of the most physically constrained portions of this project is located north of the Athabasca River to south of Thickwood Blvd. This has been referred to by the project team as the "Pinch Point". Pile walls, both secant and tangent, are one of the key elements employed to gain additional right-of-way for the required highway expansion and utility relocations within this corridor. The west secant pile wall system (hillside) is approximately 430m in length and is approximately 16 meters in combined height (including embedment) at the highest point. The east tangent pile wall system is 320m in length and approximately 16 meters in combined height (including embedment) at the highest point. Pile walls were chosen to accommodate the height required, and allowed the wall to be constructed by drilling down piles prior to the staged excavation to lower the existing highway. See **Figure 10 – Tangent Pile Walls.**

*Working in Close Proximity to the Athabasca River*

MSE walls were incorporated with the Thickwood Boulevard Interchange to retain the fill slopes from extending into the Athabasca River flood plain. The interchange footprint became much larger after AT requested that a 90m loop ramp radius be designed to improve traffic operations from the 70m loop ramp radius in the McElhanney plan. As the interchange shifted further towards the river, the original ground was at a downgrade which required a 12m high retaining wall. In order to improve global stability and reduce cost, a tiered level MSE wall was preferred over tangent pile walls, which would have been more costly to design. No direct construction was proposed within the wetted width of the Athabasca River. See **Figure 11 – Thickwood Boulevard Interchange** in the Figures Section.

*Working with Native Soils*

The earthworks scope involved excavating the colluvium clays at locations designated for gravel shear keys and gravel wedges used to stabilize the interchange headslopes and MSE walls, excavation of waste material , embankment construction utilizing in-situ native clay material on site, importing fill material from a borrow source, and re-working loose fill material left in a stockpile from a previous contract. The contractor had the challenge of having to haul fill material from a borrow source within a very tight timeframe and carry on with excavation. All material excavated on site and imported had to be sorted. The good clay material was used for the fills under the roadway and marginal fill material was used for

the sideslopes as there was a shortage of good clay material. The site became very congested with the various operations.

Embankment construction was very slow since work was done under tight geotechnical constraints as the original ground and valley slopes in the immediate area were considered unstable. Mitigation measures consisted of monitoring and restricting the fill placement and maintaining flatter slopes than normal within the right-of-way available as it was not practical to excavate all the colluviums soil.

*Shared utility facilities versus separate facilities*

Rather than having each individual utility placed within multiple individual alignments, a utility corridor was established on the west side of Highway 63:11 to enable the construction staging of the proposed works. The utility stakeholders involved are Bell, Telus, Shaw, ATCO, Enbridge, Suncor and RMWB. Utility stakeholder meetings took place early in the design process to get buy-in so that all utilities could co-exist within a single utility corridor. The utility corridor is comprised of a common utility duct which would incorporate all shallow utilities (not including Enbridge, Suncor or RMWB) into separate conduits within a confined area and done by open excavation and trenchless excavation. At the tangent pile wall section, the utilities are installed behind the wall but away from the tie-back and wall footing and installed on the pile cap.

In anticipation of the future decommissioning of the existing RMWB forcemain located on the east side of the existing highway, AECOM installed a new forcemain within the utility corridor that the RMWB will tie into at a later time.

There was no need to relocate the Enbridge and Suncor pipelines. The roadway was designed in such a way that the pile walls retaining the NB C-D are situated adjacent to the Enbridge pipeline right-of-way and the MSE walls at Thickwood Boulevard Interchange retaining the highload bypass are setback 5m from the right-of-way.

*Implementation of the design of long life pavement to save overlay widths.*

To avoid constructing additional subgrade widths to accommodate conventional future pavement overlays, long life pavement was used on the core lanes, C-D lanes and Thickwood Boulevard Interchange ramps. Future pavement rehabilitation would only involve mill and fill and would not result in adjustments to gores and ditches or affect setback distances to other infrastructure within the roadway cross section.

*Tender Strategy and Construction Staging*

Due to the limited space available, the project was split into separate tender and construction packages to minimize potential disruption to motorists. The initial contracts focused on rough grading the abutment and interchange fills away from the existing highway. The utilities were also relocated at this time to strategically accommodate the lowering of Highway 63 through the pinch point. Once the rough grading was completed, subsequent contracts worked to complete each section in phases including lowering Highway 63 through the pinch point.

## Conclusion

Optimizing right-of-way within the Highway 63:11 corridor throughout Fort McMurray becomes very challenging when having to expand a roadway network to improve traffic operations to sustain population growth. The corridor between the Athabasca River and Thickwood Boulevard Interchange is very unique as it has many constraints with all levels of risk. Optimizing the roadway cross section through the pinch point and at Thickwood Boulevard Interchange with the tiered wall concept was significant as it provided for a low risk, cost effective design that meets both geometric and operational requirements for the long term.

Lessons learned included that working around shallow and overhead utilities during construction can be somewhat of a hindrance, however, seeking the opportunity to establish a utility corridor and undertaking the relocation work in one contract and carry-on with the remainder of the proposed works in a following contract will be more cost effective with less risk to the contractor and minimizes potential delays to the contract.

The design and construction of this project demonstrated the necessity of balancing highway, utility, and stakeholder needs against the land and space available, risks and costs.

## References

Design Memorandum #2 – Thickwood Boulevard Interchange Preliminary Geotechnical Recommendations. Thurber Engineering Ltd. (February 24, 2006)

Design Memorandum #6 – Hwy 63 – CD Lane Alignment at Pinch Point North of Athabasca River Crossing Preliminary Recommendations. Thurber Engineering Ltd. (June 1, 2006)

## Figures

**Figure 1 – Key Map of Fort McMurray**

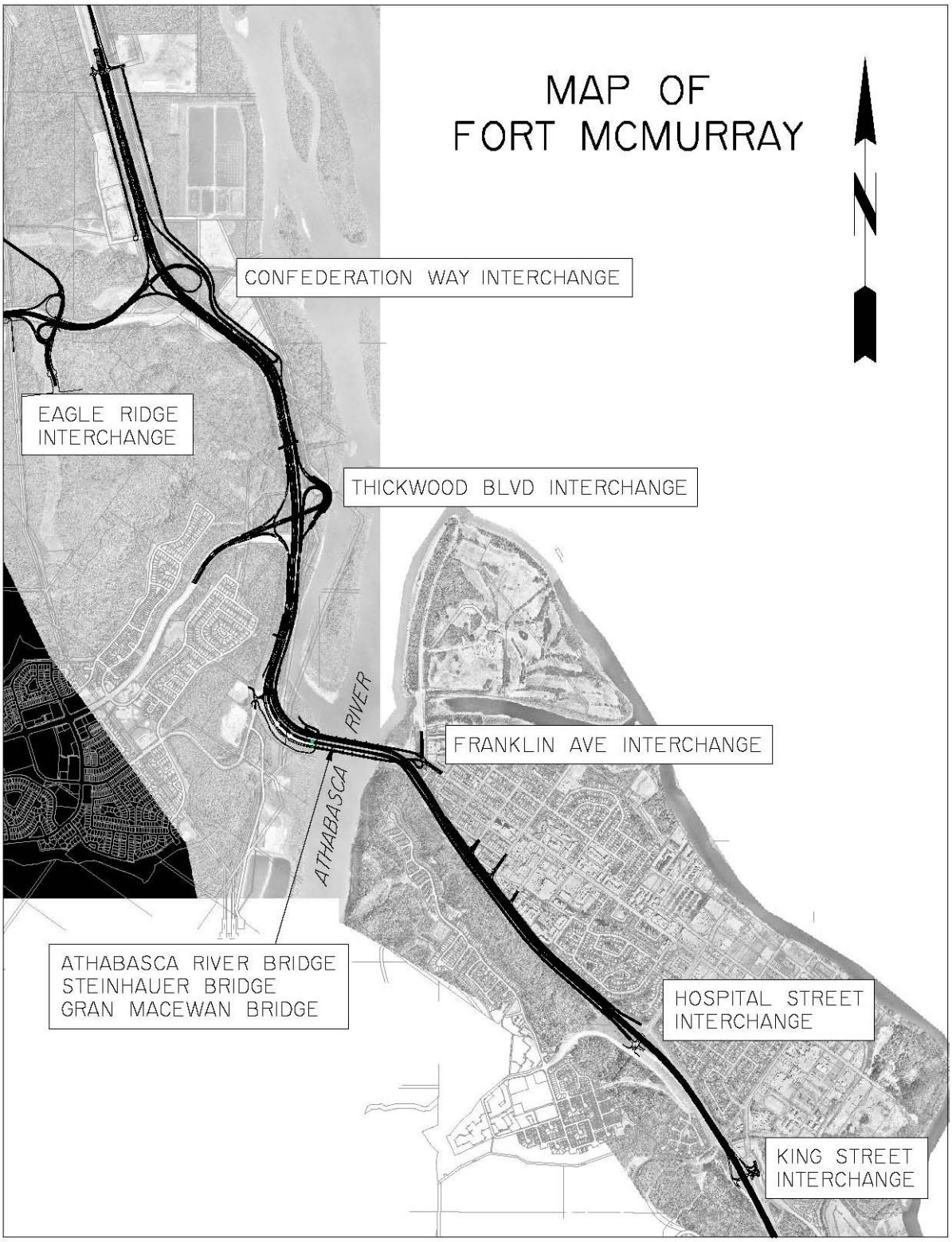


**Figure 2 – McElhanney Functional Plan**

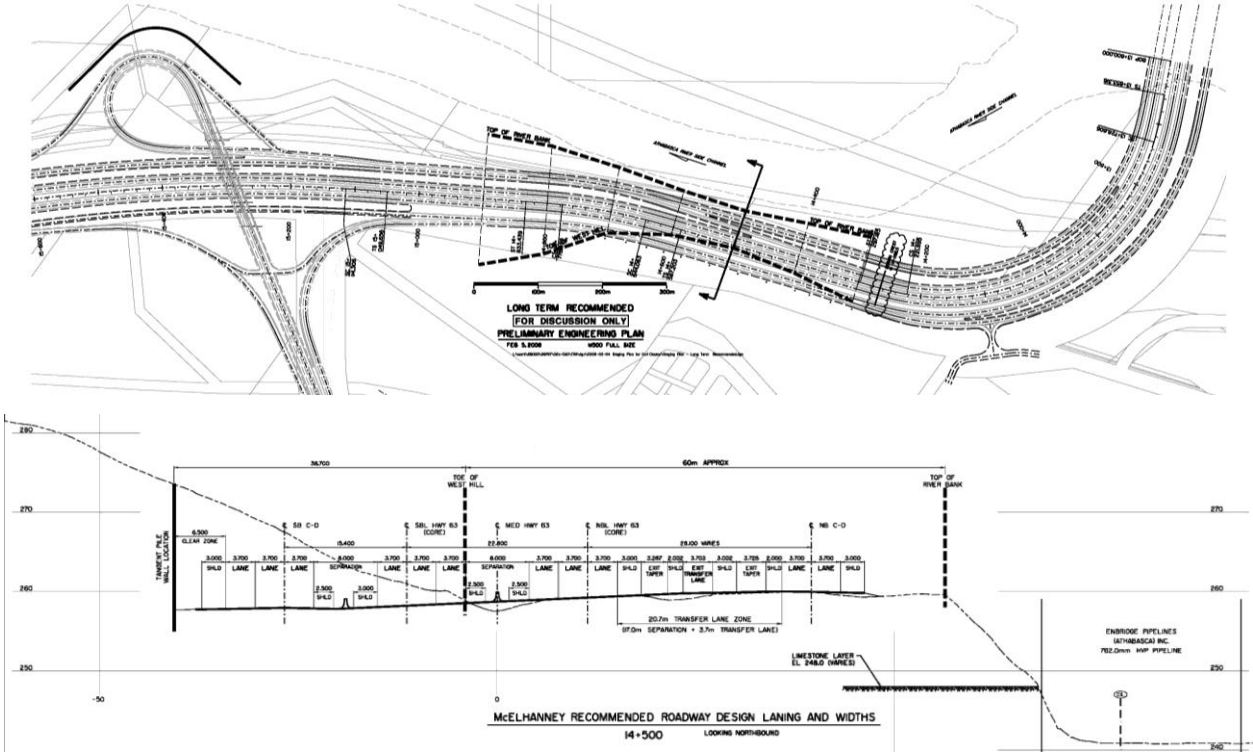



**Figure 3 – Alternative 1**

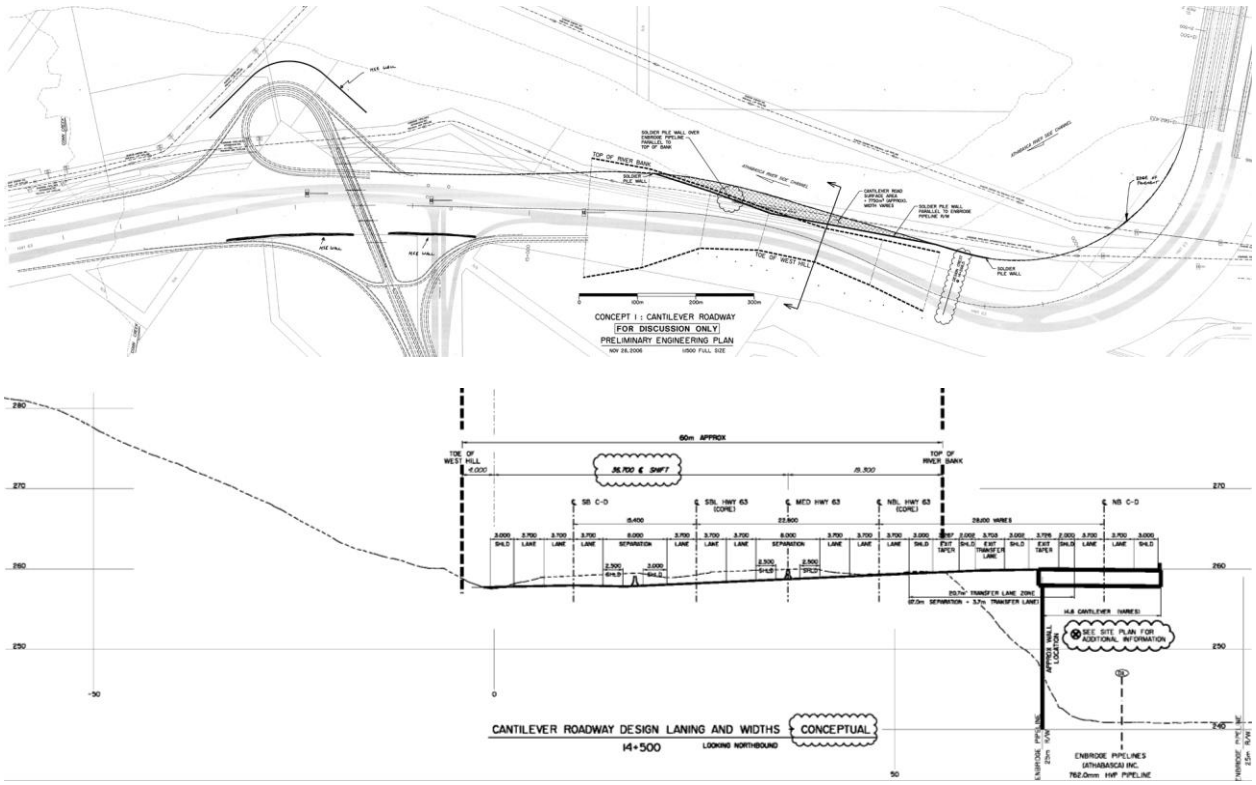


**Figure 4 – Alternative 2**

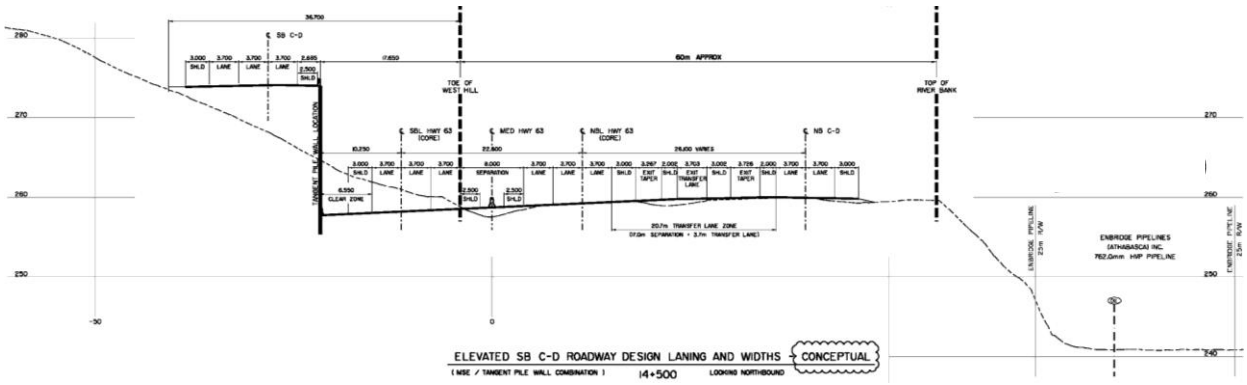



**Figure 5 – Alternative 3**

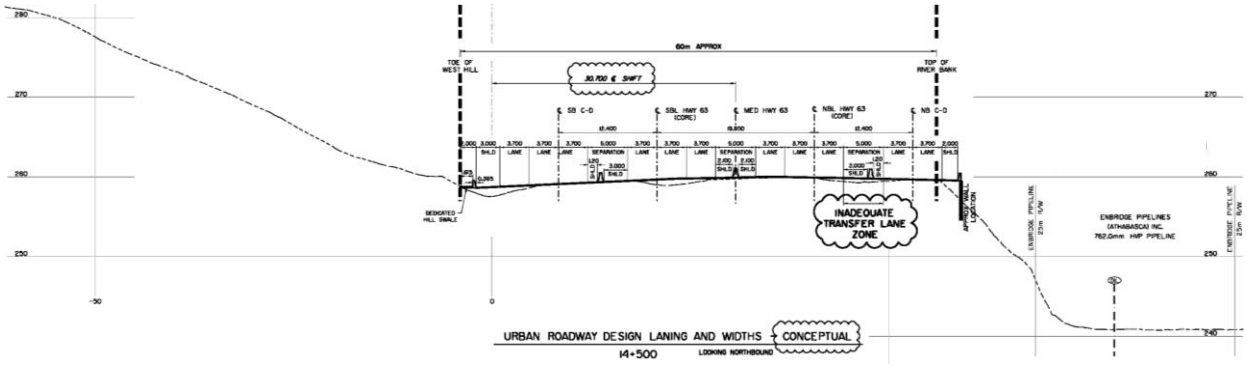
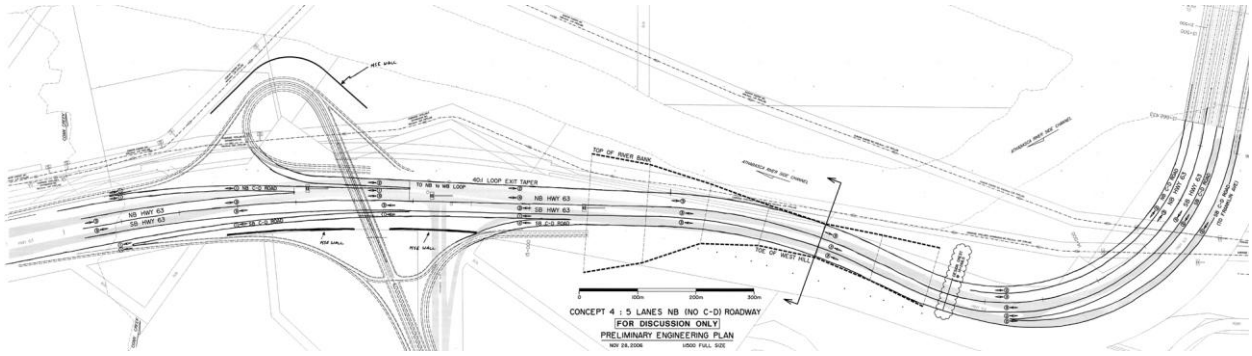



**Figure 6 – Alternative 4**



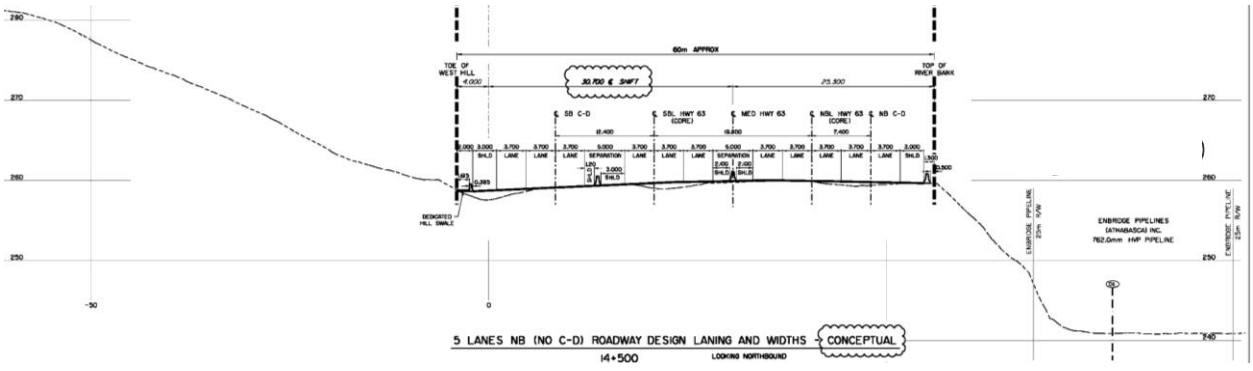



**Figure 7 – Option 1**

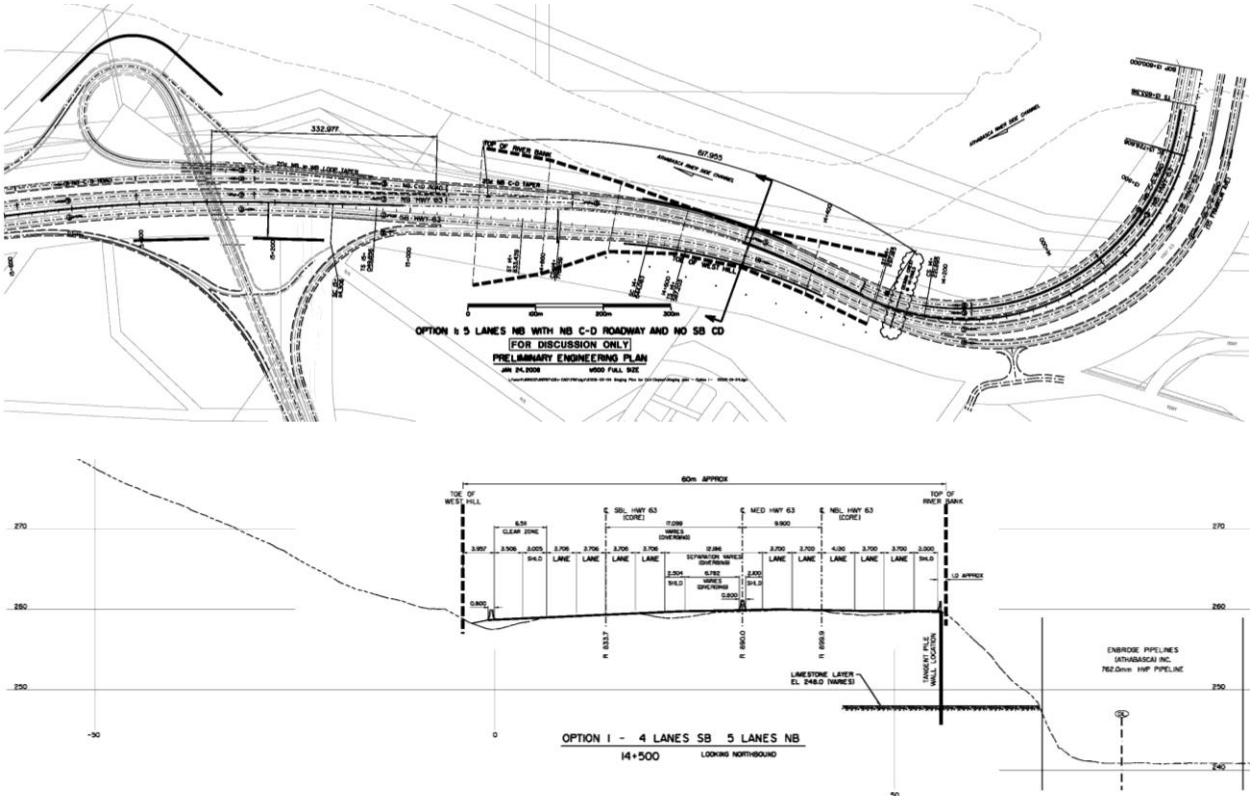



**Figure 8 – Option 2**

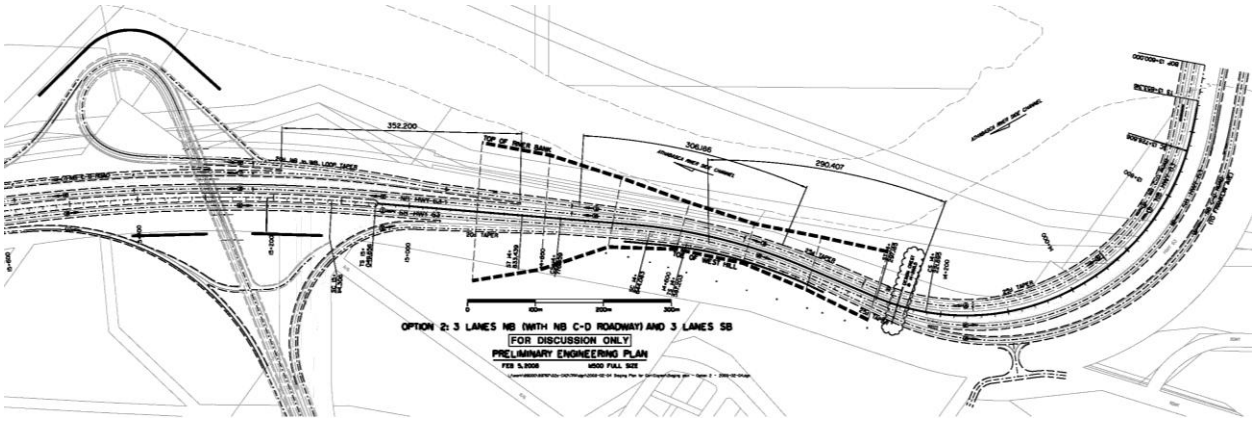


**Figure 9 – Option 3**

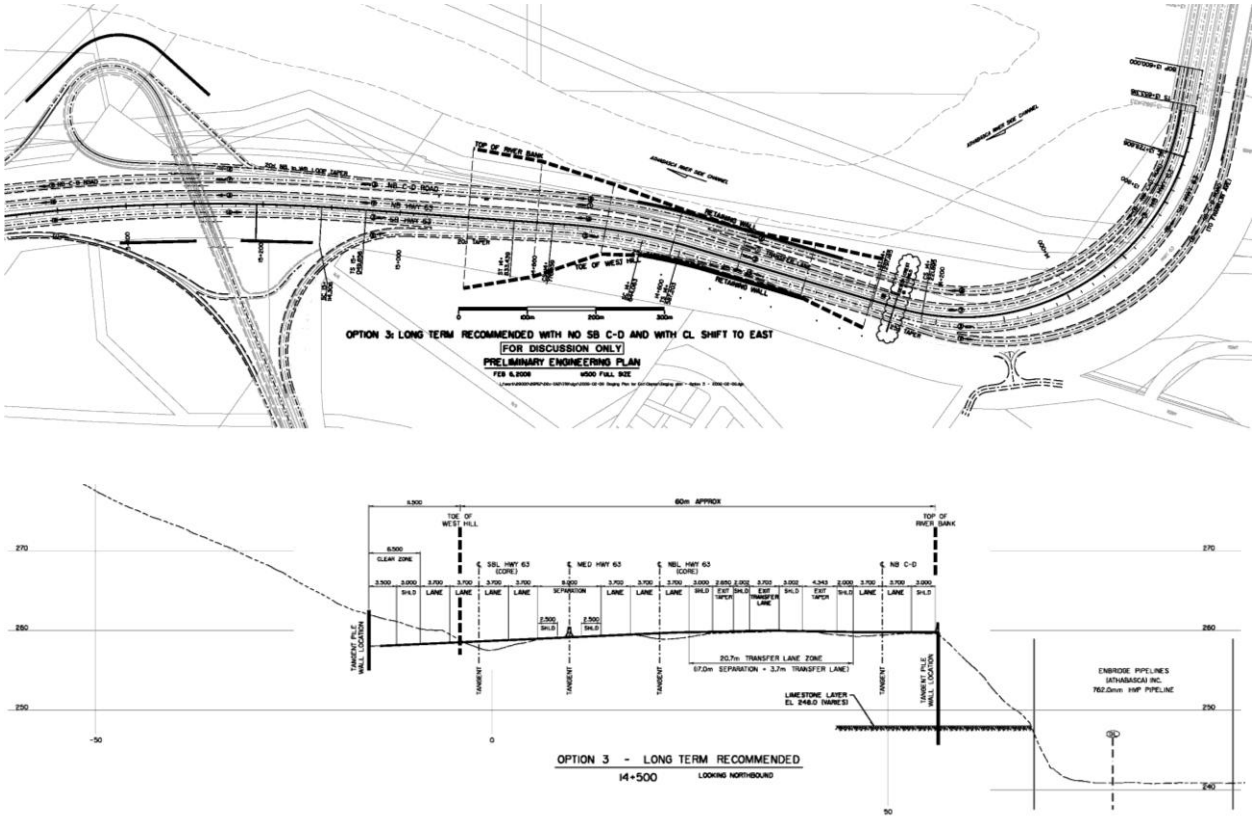


**Figure 10 – Tangent Pile Walls**

**Figure 11 – Thickwood Boulevard Interchange**