Waverley West Arterial Roads Project (WWARP) Part 3 – From Paper to Pavement

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Abstract

The Waverley West Arterial Roads Project (WWARP) extends Kenaston Boulevard to the Perimeter Highway, relieving congestion on adjacent arterial routes, servicing the new Waverley West neighbourhoods, and creating a new north-south arterial route in southwest Winnipeg.

Kenaston Boulevard was designated an economic route within the City of Winnipeg, Capital, Region and Province of Manitoba. It also provides access to new residential and commercial zones within the Waverley West neighbourhoods and, as a result, provides service to high volumes of commuter traffic.

This complex, multi-disciplinary project had unique design aspects that were considered in the delivery of this project. The tri-level government funded project was split into three parts to be able to quickly get key pieces of infrastructure built first and to stage design and construction such that the schedule could be met. This paper and presentation will focus on Part III, the largest of the parts.

Geometric design is key to every new transportation infrastructure project, and each has its own challenges. The paper will focus on the specific issues tackled on WWARP Part III, how current standards were applied, designs refined, and innovative ideas used to design and construct a safe, high speed arterial to modern standards.

The WWARP project as a whole is comprised of over 40 lane-kilometres of high speed roadway connecting Kenaston Boulevard to P.T.H. 100, including a 105 m fly-over structure, the first of its kind in Winnipeg. Geometric topics to be covered will include the following:

- Intersection sight distance with curvilinear high speed roadways.
- One-way pair arterial around a planned “Town Centre”.
- Use of Smart Channels versus conventional right turn channelization.
- Challenges of an overpass structure with a vertical and horizontal curve re sight distance.
- Design refinement to move obstructions out of the clear zone.
- The value of Value Engineering and Safety Audits in geometric design reviews.
- Construction staging and temporary pavement – lessons in superelevation.
- Ramp geometry re driver expectation and standardization.

The paper and presentation will provide real world examples of challenges faced when translating standards and guidelines on paper, onto pavement in the field. The safety of road users is of utmost importance and good geometric design is key to building a facility that protects users, yet at the same time allows for efficient movement.

1. PROJECT BACKGROUND

Planning for development of the City of Winnipeg's southwest quadrant began in the early 2000's. The area is typically referred to as the "Waverley West" neighbourhoods. At full build out, it is anticipated that the area will be home to over 40,000 people.

To service an area of this size, and provide improved arterial connections with the greater region, the City of Winnipeg initiated the Waverley West Arterial Roads Project (WWARP). This paper focuses on Part III, which was the largest of the three parts. Figure 1 illustrates the project area, indicating the three parts of WWARP, and the four construction contracts within WWARP Part III itself. Detailed design for the project began in 2012, with construction contracts occurring in 2013 and 2014 and the overall project substantially complete by the winter of 2014.

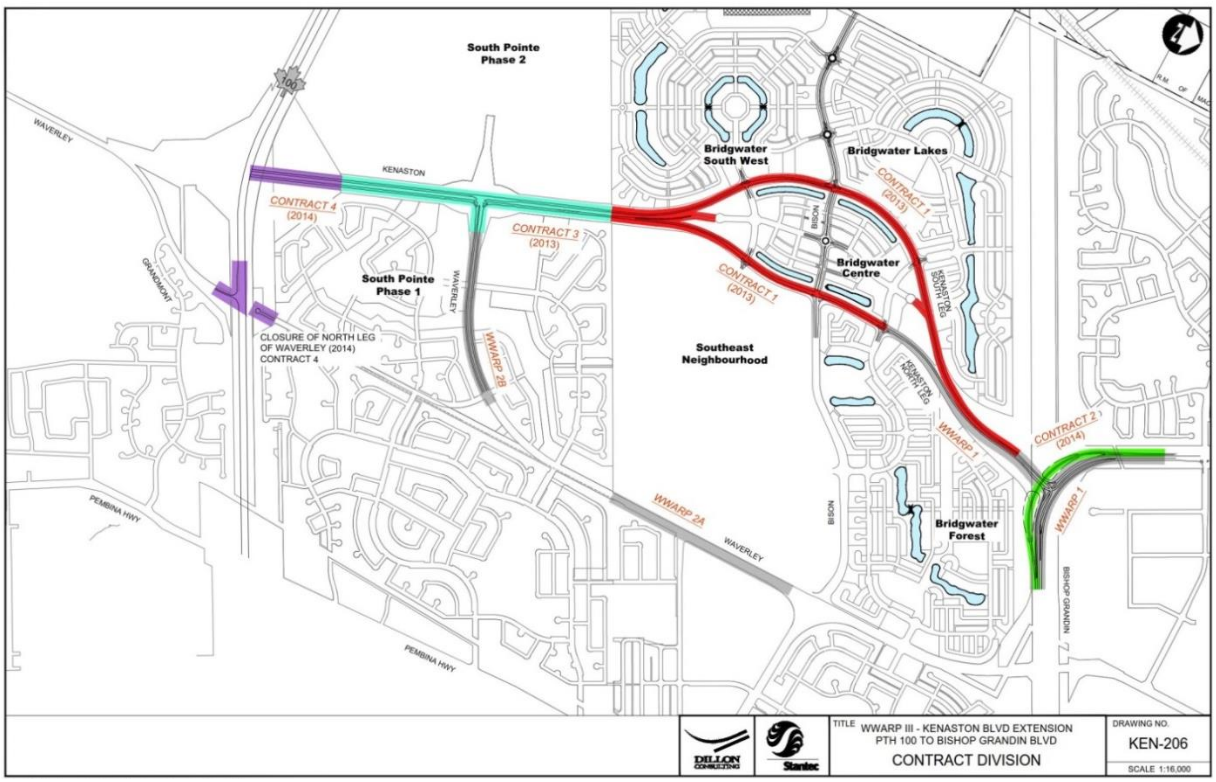

Figure 1 : WWARP III Contract Division.

The WWARP project as a whole is comprised of over 40 lane-kilometres of high speed roadway connecting Kenaston to P.T.H. 100, including a 105 m overpass structure. In addition to vehicular traffic, the project included multi-use pathways along its length to connect pedestrians, cyclists, and other active transportation (AT) users to the existing AT network.

Kenaston Boulevard (Kenaston) was designated an economic route within the City of Winnipeg, Capital, Region and Province of Manitoba. Due to the linkage it provides between major industrial/commercial sites and national/ international trade routes, it handles a large volume of truck traffic that has resulted in significant cost savings for the transport industry. Kenaston also provides access to new residential and commercial zones within the Waverley West neighbourhoods and, as a result, provides service to high volumes of commuter traffic. Lastly, Kenaston functions to provide a corridor for inter-neighbourhood travel, commuter active transportation, and transit networks.

2. GEOMETRIC DESIGN AND ROAD SAFETY

Within the transportation profession, the idea that good design results in safer facilities. In practice, this is not always a straightforward exercise. Designers are routinely faced with built environment constraints, and competing safety issues that require thoughtful application of standards. There is rarely a “one size fits all” for standards. Geometric issues tackled through the WWARP III project are presented in the following sections as examples of applying design standards, and their anticipated impact on safety Quantitative details of the examples are not the focus, rather the design philosophy and how other real world factors impact anticipated road safety.

In general, the project design utilized the following industry and local standards:

- TAC Geometric Design Guide for Canadian Roads (GDGCR).
- AASHTO A Policy on Geometric Design of Highways and Streets (Green Book).
- (Draft) City of Winnipeg Transportation Standards Manual – 2012 update.

3. INTERSECTION SIGHT DISTANCE WITH CURVILINEAR ROADWAYS

The developer’s vision for the Waverley West neighbourhood included a mixed use town centre called “Bridgwater Centre”, which is bounded by splitting and separating the north and southbound lanes of Kenaston Boulevard. The alignment of the public right-of-way and thus roadway when split was done at a conceptual/functional level, with a curvilinear alignment. While aesthetically pleasing, during preliminary design it was decided that an intersection sight distance analysis should be undertaken to verify that adequate sight distances were available at all intersections in the project area. A combination of small radii and a high design speed may result in a situation where a driver cannot see far enough ahead on a roadway to react to an errant vehicle or pedestrian in their path.

Sight distance was analyzed for vehicles approaching an intersection on both the minor cross streets, and on Kenaston itself. As an example, *Table 1* below presents an excerpt of a few intersections analyzed specifically for minor street originating traffic.

Table 1: Intersection Sight Distances for Selected Minor-Street-Originating Traffic Movements.

INTERSECTION	MOVEMENT	AVAILABLE SIGHT DISTANCE	DOES IT SATISFY THESE SIGHT DISTANCE REQUIREMENTS?					
			STOPPING	DECISION		INTERSECTION		
				Minimum	Desirable	A Crossing (Through)	B-1-4-Lane (Left)	B-2b (Left) (Overtaking) (1)
Kenaston SB & South Town	EB Looking north	310m	Yes	Yes	**No**	Yes	n/a	**n/a**
	WB Looking north	250m	Yes	Yes	**No**	Yes	n/a	**No**
Kenaston SB & Bison	EB Looking north	340m	Yes	Yes	Yes	Yes	n/a	**n/a**
	WB Looking north	230m	Yes	Yes	**No**	Yes	n/a	**No**
Kenaston SB & North Town	EB Looking north	660m	Yes	Yes	Yes	Yes	n/a	**n/a**
	WB Looking north	670m	Yes	Yes	Yes	Yes	n/a	**Yes**

(1) Cb (Right-turn vs. traffic from left) has not been analyzed as all right-turn traffic enters via acceleration lane

Figure 2 illustrates the definition of the intersection movements. The designer has to consider the following:

- Available Sight Distance – the distance a vehicle at the minor street stop line can see along the major street in the indicated direction. This also generally corresponds to the maximum distance a vehicle approaching on the major street (Kenaston) can see the intersection, or more precisely, a vehicle/pedestrian at the minor street.
- Stopping – Does the vehicle approaching the intersection on Kenaston have enough sight distance to stop their car in an emergency?
- Decision - Does the vehicle approaching the intersection on Kenaston have the desirable or at least the minimum decision sight distance to make a lane change?
- A, B-1-4, and B-2b – Does the vehicle on the minor cross street have enough sight distance to execute the manoeuvres in *Figure 2* if they are stop controlled, or the signals are in flash mode?

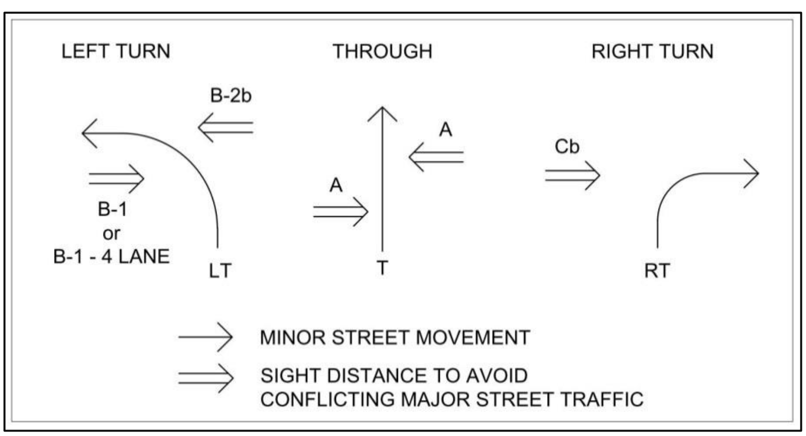

Figure 2: Sight Distance Parameters for Turning Movements from Stop Condition.

The analysis showed that vehicles approaching always had at least the minimum stopping and decision sight distance. This is the most important consideration in terms of safety. In an emergency, drivers can see far enough to react and avoid a collision. However, desirable decision sight distance, and some intersection sight distance manoeuvres were not met.

For example, a vehicle on Bison Drive facing westbound does not have adequate sight distance looking upstream at Kenaston southbound traffic to make a left turn into southbound traffic without being overtaken by a southbound vehicle that may be just around the corner.

With the results of the analysis, recommendations had to be made. Since stopping and minimum sight distance was met, safety concerns are generally alleviated. Not meeting the intersection sight distance for the B-2b movements means that an overtaking vehicle must slow to less than 85% of the design speed. This is more of an inconvenience than a safety issue, at least in good driving conditions. Radical adjustments such as property purchases to enlarge radii, or removal of sound berms could have been recommended, but instead a balanced approach of recommending that signals not be placed into flash mode at low volume times (overnight) was considered acceptable.

4. SMART CHANNELS

A relatively recent geometric design for right turn channels is the aptly named "smart channel". First conceptualized through a Federal Highway Administration (FHWA) Research and Development study for pedestrian facilities, this type of channel has many benefits to vulnerable road users. *Figure 3* illustrates typical smart channel geometry.

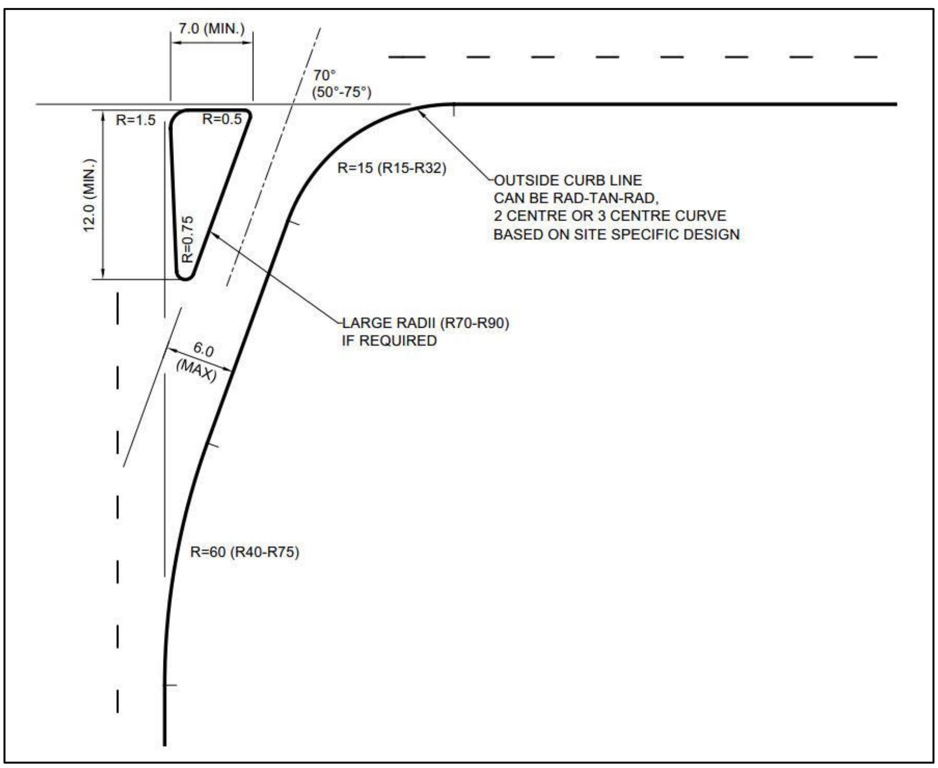

Figure 3: Typical Smart Channel Geometry (Source: City of Winnipeg "(Draft) Transportation Standards Manual – 2012 Update". Drawing No. SI-14).

Typically, right turn channels, or right turn cut-offs are seen at major intersections. They allow right turning traffic to avoid the signalized intersection and make a yield movement. They also provide pedestrian refuge and a reduced crossing distance. Smart channels are an improvement in that the angle for the yielding driver allows them to "look left" with less strain, but slows them further than a typical channel due to the acute geometry. This improves entry angle sight lines and thus visibility of pedestrian crossing movements. The application on this project was for right turns exiting the high speed facility (Kenaston) to the lower speed cross-streets. Figure 4 shows smart channels in the bottom right and top left corners of the Kenaston and Waverley intersection. Note that deceleration lanes are included along Kenaston to get slowing traffic out of the high speed through lanes. At the smart channels, an acceleration lane is not provided on Waverley as it is lower speed and the smart channel geometry is designed to prepare drivers for a low speed manoeuvre onto the lower order facility.

Figure 4: Smart Channels going from Major to Minor Roadway.

Figure 5: Kenaston Boulevard southbound at Southtown Road. Smart channel in foreground.

Conversely, *Figure 5* illustrates that the right turn channels going from the minor to major roadways are more traditional three centred curves with acceleration lanes onto the major roadway. Note for safety, the smart channels have the pedestrian crossing at the downstream end of the island, where vehicle speeds are lowest. The other two islands have the crossings at the upstream end where vehicle speeds are lower before the accelerate to merge. These features increase safety for vulnerable road users.

5. OVERPASS STRUCTURE SIGHT DISTANCE

Kenaston Overpass is the first grade-separated structure, not involving a water or railway, constructed in Winnipeg in over 20 years. Built under Contract 2, the Kenaston Overpass consists of a two-lane bridge structure and ramp lanes that connect southbound Kenaston to eastbound Bishop Grandin. With the realignment of these two lanes over the bridge, modifications and improvements at the Kenaston and Bishop Grandin at-grade intersection were also completed. *Figure 6* illustrates this unconventional intersection/interchange. Prior to the development of the Waverley West neighbourhoods, Kenaston and Bishop Grandin essentially met as a large radii curve. The WWARP Part I project constructed a south leg to Kenaston, and brought the leg in around the mid-point of the curve with the intention of saving right-of-way immediately to the west for a future system interchange. The WWARP III Kenaston overpass is designed as a ramp lane for this future system interchange.

Figure 6: Completed Kenaston Overpass. At grade intersection visible to left.

The single biggest geometric challenge of the WWARP III project was in determining the horizontal and vertical profile of the overpass. The limited right-of-way in the overpass area resulted in design challenges for the final road profile. Constraints encountered by the design team included:

- Immediately to the south of the overpass is a Manitoba Hydro corridor with high voltage transmission lines. While some property acquisition was considered, there was a buffer zone extending 6 metres on either side of any transmission line where the ground elevation could not be altered and must be kept flat. In addition, arcing from the lines had to be considered when constructing a raised roadway within a certain diameter of any one line.
- To the north are the existing lanes of Bishop Grandin and Kenaston and the recently constructed at-grade intersection that connects the south leg of Kenaston.
- The overpass was to be designed to be used as a direct ramp lane for a future system interchange when Bishop Grandin is extended to the west. Therefore the underpass geometry must accommodate the existing south leg of Kenaston and the future westerly extension of Bishop Grandin.
- To the west, proximity of existing noise berms, ditching, and residents with limited right-of-way.
- Along southbound Kenaston north of the overpass, the roadway passes over a box culvert. This box length culvert must accommodate the existing lanes of southbound Kenaston, the two new ramp lanes, and an AT pathway. This made for challenges with the vertical profile due to the low elevation of the box culvert followed by an immediate upgrade to gain height for the overpass.

These constraints, as well as others conspired to require a tight horizontal radius for the ramp and overpass. The design speed for the overpass is 90 km/hr. With an aim to have a maximum superelevation of 4%, the minimum radius noted in Table 2.1.2.3 of the GDGCR is 380 m. Early iterations of the design were based on this radius.

Much of the right-of-way constraints were solved by the addition of vertical mechanically stabilized earth (MSE) walls. This allowed for optimizing (shortening) of the bridge structure and fitting the at grade intersection and AT paths in closer proximity. Therefore, both the MSE walls and bridge deck required F-shape concrete barriers to provide protection to vehicles leaving the roadway (vertical drop off). With these required safety barriers in place, the design team realized that stopping sight distance was not achievable. This is illustrated in *Figure 7*. Table 1.2.5.1 of the GDGCR notes the driver's eye height of 1.05 and a height of 0.38 metres for a taillight for the object ahead that drivers must identify. As the F-shape barriers are over 1 metre in height, a driver cannot see through the barrier on the inside of the curve to see an object at this height, such as a derelict vehicle in the dark.

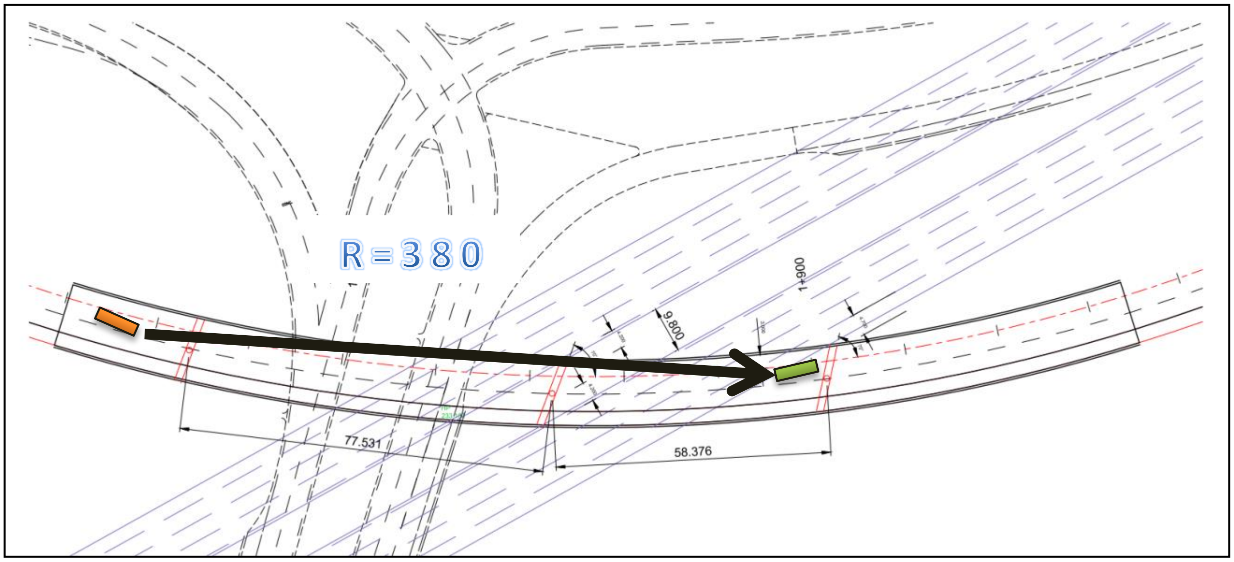

Figure 7: Inadequate stopping sight distance due to visual interference from F-shape barriers.

Multiple design iterations were undertaken to resolve this issue. Safety was the prime concern during this analysis and played heavily into the final design. To achieve a safe facility, the following modifications were made:

- Widening of the inside shoulder/shy distance from 1.5 m to 3.5 m. This effectively pushed the barriers out of the way of the critical sight line.
- Widening the inside shoulder has a negative safety consequence of causing potential off-tracking of vehicles, especially in low light or snow covered conditions. To counteract, rumble strips were added to both lane edges.
- The radius of the ramp on either side of the bridge structure was reduced from 380 m to 340 m, which allowed the bridge structure radius to be increased to 510 m. This again assisted in getting a longer sight distance on the critical section of the bridge.
- The radius reduction necessitated an increase in the maximum superelevation from 4% to 6% (5.2% actual maximum used). This was still deemed safe in terms of deck icing and driver comfort.

These changes effectively allowed drivers to see "across the curve" and eliminate a potentially dangerous situation. *Figure 8* illustrates the final alignment.

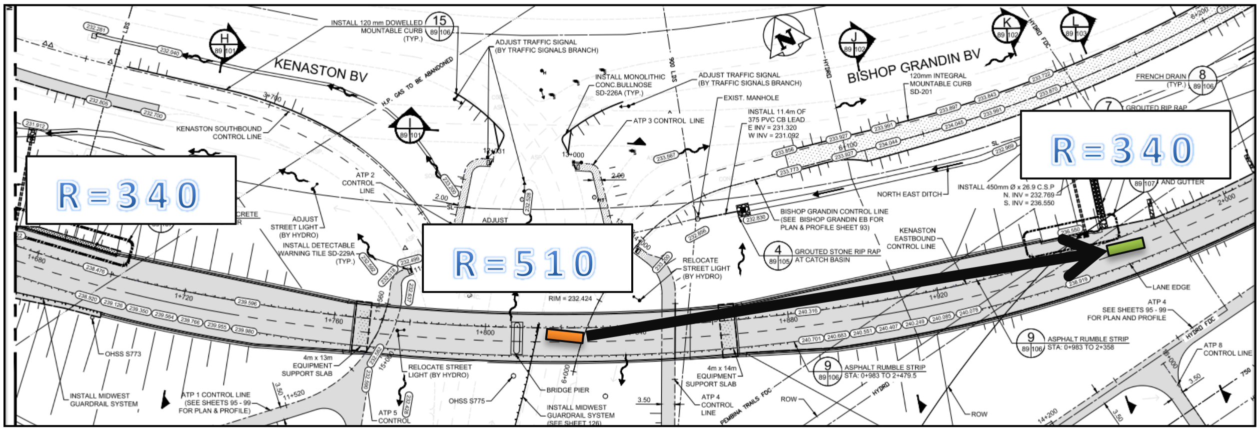

Figure 8: Adequate stopping sight distance achieved through combination of geometric changes.

6. REMOVING/PROTECTING FROM OBJECTS IN CLEAR ZONE

Safe design practice is first to remove objects in the clear zone if possible. If this is not possible, then protection must be provided. Of course, the protection then becomes an object that can be struck within the clear zone, and thus becomes a hazard in itself, requiring proper development and/or end treatments to improve safety.

On the WWARP III project, there were many instances of clear zone issues. Each required a unique solution. Some were discussed within the context of a project Value Engineering session, and a preliminary design Road Safety Audit. A good design has to balance the sometimes competing goals of these sessions. A few examples are noted below.

Numerous overhead sign structures (OHSS) were required throughout the project to provide highly visible driver guidance. Most were cantilever structures, with two full-span structures. Though the Value Engineering session confirmed the construction cost savings through having one design for the cantilever structures, this required that some OHSS on the higher speed Kenaston roadway required guardrail protection. The Road Safety Audit noted that it would be preferred to have a longer cantilever arm to move the OHSS out of the clear zone where possible. This was done in the one-way split area of Kenaston as the OHSS could be moved away from the roadway, without impinging on the clear zone of the opposite direction, and thus needing guardrail protection on the backside. An example is shown in *Figure 9*. This is an example of where the safety benefits outweighed the marginal cost increase of multiple OHSS formats. Eliminating the guardrail also resulted in cost recoveries.

Figure 9: OHSS moved out of clear zone to avoid need for roadside protection (guardrail).

On lower order intersecting collector streets, the OHSS were protected with an architecturally pleasing “safety shape” curb, which blends with the landscaping, yet provides the level of protection warranted for lower speeds. Breakaway signal poles and street light poles were utilized, and AT paths were moved away from the road edge, and in many cases elevated on the noise berms for further protection from errant vehicles

Another example of the relationship between geometric design and safety comes from the side slopes of the overpass embankments. Geotechnical stability required a maximum slope of 5:1. Within road safety, this is considered a recoverable slope where a driver can off-track down the slope, but manoeuvre a vehicle back to the roadway. Slopes steeper than 3:1 are considered drop offs at high speed and would require guardrail protection. For most of the overpass embankment therefore, guardrail protection was not required. One interesting location is on the downslope of the overpass on the right side. Noise and light pollution were a concern of nearby residents, even though studies undertaken showed that local standards were being met. However, it was decided to carry the F-shape barrier all the way along the downslope to cut down on headlight glare and road noise, with the added safety benefit of providing protection from a high voltage transmission tower. As seen in Figure 10, the tower was well out of the clear zone, but it is important for a designer to consider the “softer” aspects of design, such as public and stakeholder perception, and designing for something better than the minimum standards.

Figure 10: High voltage tower out of clear zone, but extending F-shape barrier from bridge provides increased protection as well as other benefits.

As a final example of the relationship between geometric design and roadside hazards, the box culvert area just northwest of the overpass structure is discussed. Figure 11 and *Figure 12* illustrate the final horizontal geometry and vertical cross-section respectively.

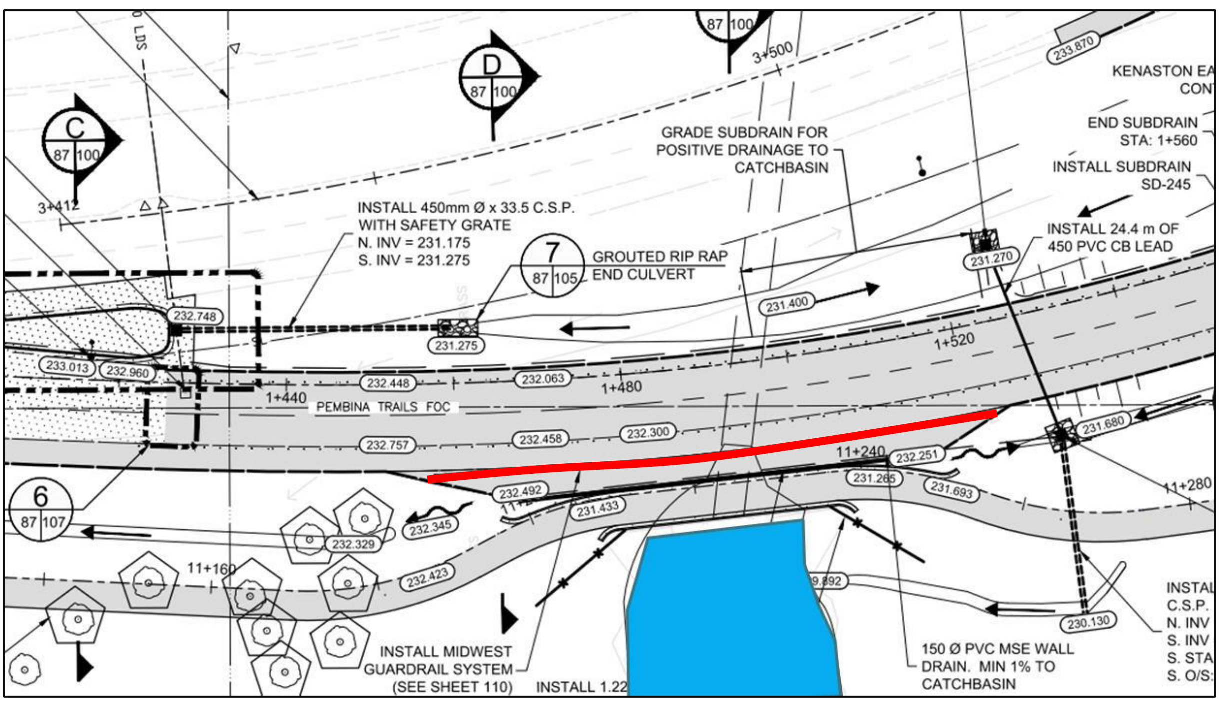

Figure 11: AT path must come in tight over the box culvert. Note “Midwest Guardrail System” highlighted in red for protection from vertical drop.

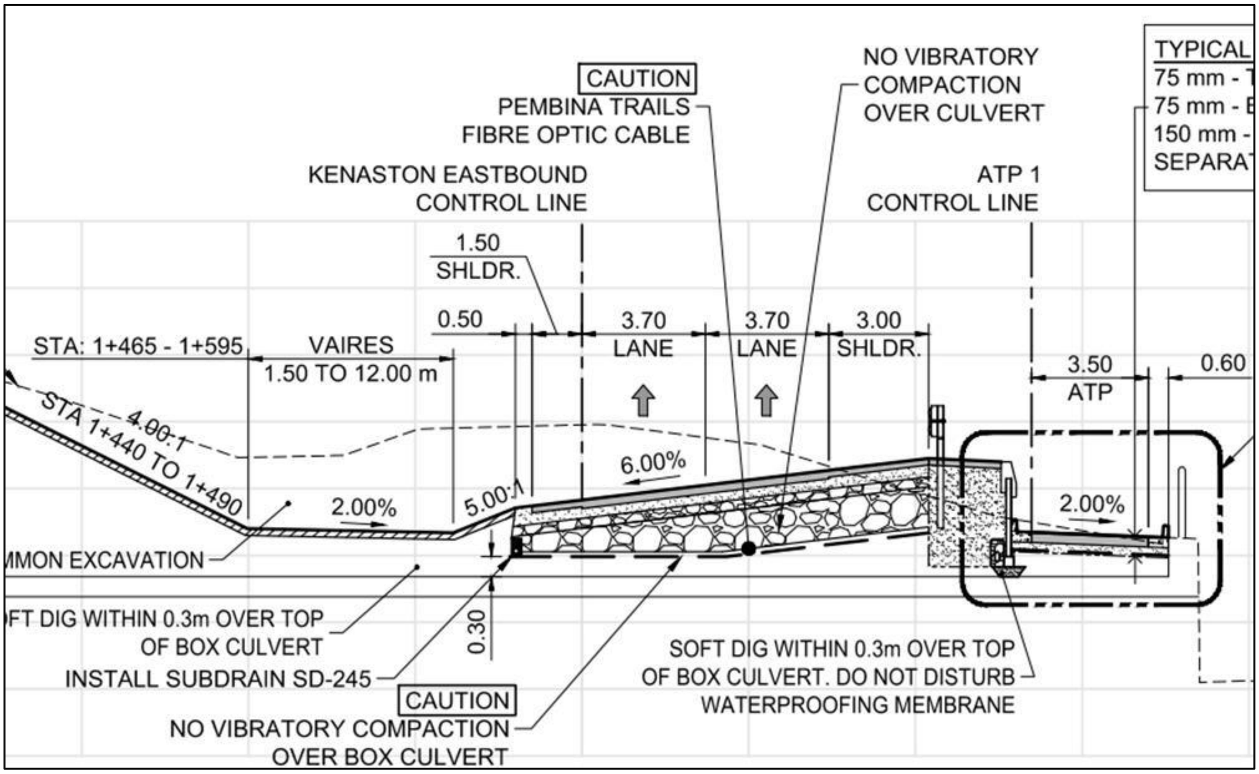

Figure 12: Cross-section illustrates MSE wall required to drop grade to fit AT path on box culvert structure. Guardrail required for protection from drop off.

The horizontal design of the ramp was the primary design feature that could not be altered. The ramp exit geometry defined where the lanes would be in relation to the end of the concrete box culvert. With that set, the vertical profile of the ramp lanes was lowered as much as possible, while maintaining an adequate sag curves and maximum longitudinal grade. This was necessary to fit the AT path on the culvert without overtopping the culvert headwall. Safety considerations included:

- Guardrail at edge of shoulder to protect vehicles from vertical drop-off.
- Guardrail provided double duty as protection for pedestrians that are now well within the clear zone.
- Curbs along either side of path to create a “shy distance” for users away from the vertical MSE wall and chain link fence on the headwall. Both could snag cyclist handlebars if they travel too close.
- Chain link fence extensions from the end of the culvert headwall down the slope of the creek. These were added to prevent cyclists from reaching the water if they leave the path while navigating the chicanes on either side of the culvert.
- A chain link fence was also added to the top of the MSE wall to preclude adventurous pedestrians from jumping down the over 1 m drop, potentially injuring themselves (not shown in Figure 12).

The final product shown in *Figure 13* clearly illustrates the roadside and pathside safety features added due to geometric constraints.

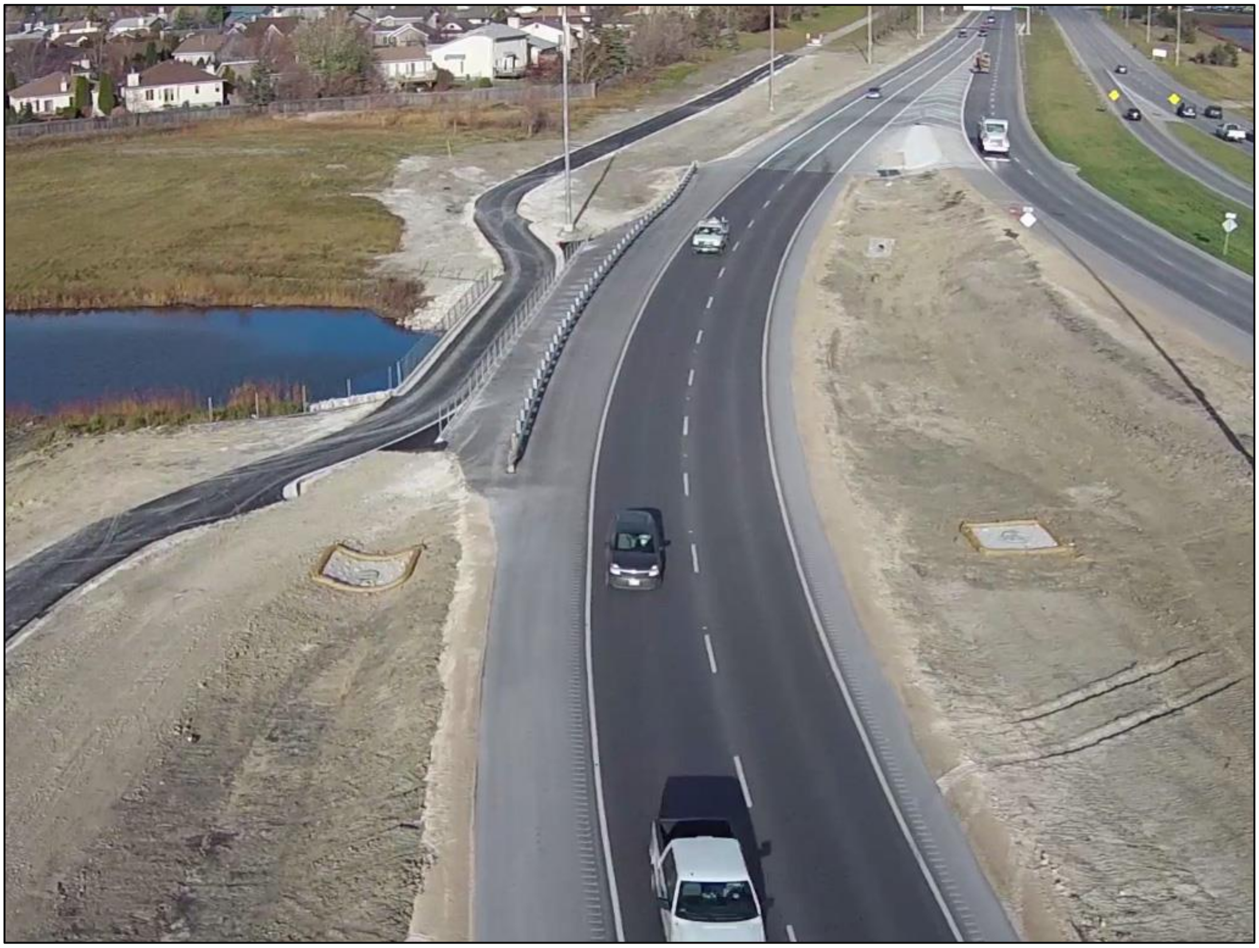

Figure 13: View looking north at road and AT path over box culvert.

7. CONSTRUCTION STAGING AND TEMPORARY ROADS

The final product must meet applicable standards and be designed with best practices in mind. In addition, many construction projects require temporary works, lanes, and roadside objects that must still allow traffic to travel through the construction zone safely. Geometric design is important to confirm that vehicles can navigate the temporary facilities in a safe manner. Software such as Auto Turn is invaluable to optimize narrow temporary lanes and identify pinch points.

Considerations for construction staging include vertical designs that require temporary drop-offs from excavation or road lowering immediately adjacent open traffic lanes. Another typical geometric check is to ensure off-tracking tractor semi-trailers can navigate through lane drops or switchovers. On WWARP, the construction of centre pier of the overpass introduced a roadside hazard. The final design included guardrail, but this could not be installed until all bridge construction was complete and the median backfilled. During construction, this was remedied by lowering the speed limit through the construction zone, which shrank the required clear zone. The median lane in each direction was closed to traffic which provided the necessary distance. This allowed adequate room on the median for construction as shown in *Figure 14*.

Figure 14: View southbound. Median lane closed to traffic to create clear zone to central pier until final guardrail installed.

A unique construction staging situation faced at the intersection of Kenaston and Bishop Grandin was the result of proper geometric design during the previous WWARP I project. Before the underpass was constructed, southbound Kenaston to eastbound Bishop Grandin traffic had to go through the signalized intersection. This was a high speed (80 km/hr posted) superelevated curve. However, once the overpass was constructed two years later, the high speed curve was no longer needed. The designers of the intersection had the forethought to construct a composite pavement. The permanent pavement was constructed in concrete, with normal crossfall to facilitate future low speed turning movements only. On top of this, a sandwich of granular and asphalt pavement up to 0.5 m thick provided superelevation around the curve. As Figure 15 illustrates, the intersection had to be shutdown for a 24 hour period to remove the temporary pavement. Extreme vertical grade changes and drop offs would not permit the passage of traffic. However, had the superelevation been left off in the WWARP I design, there would have been an unsafe condition for two years, likely resulting in vehicles sliding outside the corner, especially in slippery winter conditions.

Figure 15: Removing the temporary granular and asphalt roadway surface that provided needed superelevation for the Southbound to Eastbound curve.

8. RAMP GEOMETRY AND DRIVER EXPECTANCY

As a final example of the interaction of geometric design and road safety, a situation that was not anticipated until after the overpass opened to traffic is presented. Driver expectancy is a term used to describe how a driver tends to respond to situations and information assuming the facility is designed in a similar manner to others. If a particular design violates driver's expectancy, then you can expect longer reaction times, confusion, and driver error.

Drivers travelling southbound on Kenaston are presented with a decision point to either stay on Kenaston Boulevard southbound, or exit to the right to access eastbound Bishop Grandin. While a right side exit is typical on most North American freeways, for Winnipeg drivers it violated expectation to exit right *to turn left*. This was reinforced due to the over 15 years that southbound traffic on Bishop Grandin stayed in the through lanes to make a long curve to the left to continue onto Bishop Grandin. In addition, ramps in an interchange typically have less traffic than the through lanes, whereas in the WWARP III situation the ramp is the primary movement, so most drivers need to take the exit.

Figure 16: Guidance signage southbound Kenaston.

Figure 16 shows the main guidance signage for drivers at the decision point. After opening to traffic, it was observed that many vehicles mistakenly stayed on the Kenaston lanes, and then had to make last minute decisions to take the Bishop Grandin exit. The potential for rear end collisions and sideswipes was elevated for the first few months until regular commuters became used to the change. However, the issue is likely due more to driver *familiarity* than general driver expectancy.

9. SUMMARY

The WWARP III examples presented above showcase the relationship between geometric design standards and road safety. As noted, engineering judgement and innovation must be applied to refine designs to translate standards and guidelines on paper to pavement in the field. The safety of road users is of utmost importance and good geometric design is key to building a facility that protects users, yet at the same time allows for efficient movement.