ELBOW RIVER BRIDGE CROSSING
ON THE SOUTHWEST CALGARY RING ROAD (SWCRR)

BRIDGE PLANNING
CONCEPTUAL DESIGN REPORT

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Introduction

TransTech Engineering and their sub-consultants were retained by Alberta Infrastructure and Transportation (AIT) in 2005 to carry out an advanced functional planning study to locate the alignment and other preliminary details for the Southwest Calgary Ring Road (SWCRR). As part of this process, Terrace Engineering was retained by TransTech to carry out conceptual and preliminary engineering for the crossings of Fish Creek and Elbow River. TransTech also retained the services of geotechnical, environmental, wildlife, roadway and other experts which we have relied upon in preparing our analysis and conclusions. The purpose of this report is to address the bridge planning and river engineering conceptual design issues for the Elbow River crossing.

Site Description

The proposed crossing of Elbow River is located on Tsuu T'ina lands near an existing local road bridge. It is located immediately upstream from the Weaselhead natural area. The affected Tsuu T'ina lands that would be transferred to provincial jurisdiction if the ongoing negotiations are successful. In the ultimate configuration, four new bridges would be built for the SWCRR, and the existing bridge local road bridge would be replaced with a new bridge immediately upstream from the SWCRR bridges. The existing channel of Elbow River will be relocated since the existing river flows parallel to and under the proposed roadway fills for the SWCRR.

Hydrotechnical

The hydrotechnical issues of the site were examined to provide input into the design of the bridge opening and to ensure that it is large enough to handle the design flood event, and to ensure that lateral erosion does not adversely affect the bridge or roadway. Due to the location of the proposed roadways, a realignment of the creek is required since the creek flows parallel to and under the roadway fills, thus the parameters for this channel realignment were also examined.

The key hydrotechnical issues are the flow alignment (and the related lateral erosion) and the design high water level (and the related discharge). The Elbow River has significant on-going lateral erosion and realignment of its main channel caused by natural causes. This issue needs to be addressed so that the bridge crossing remains stable. With regards to the design high water level and discharge, the bridge opening needs to be large enough to handle these flows. The key component of this analysis is the determination of a design high water for the existing conditions and the development of a bridge opening which does not significantly constrain the flows. With the selection of an appropriate bridge opening, the design high water level at the bridge compared to the natural channel is not overly sensitive to changes in the design discharge.
Flow Alignment and Lateral Erosion

The alignment of the Elbow River has naturally eroded and relocated over the years with occasional major realignments of the creek, based on an examination of air photos dating back to 1920. The creek alignment can be considered to be unstable and over the millennia, the river alignment has covered the entire valley floor. It is expected that the new SWCRR crossings and the associated channel realignment will require significant bank protection to control the instability in the immediate area of the bridge crossing. It should be noted that this is only a localized control and that the instability will continue to occur both upstream and downstream from the crossing. Essentially the effect that the bridge and roadway structures will have on the river is to provide a localized control of the lateral instability. The bank protection should consist of engineered structural riprap bank protection and/or spurs in the vicinity of the crossing and road fills where lateral erosion needs to be strongly controlled. In select locations along the channel realignment, bio-engineered bank protection solutions can be considered where some lateral erosion control is desired but where control of the lateral erosion is not as critical. It is our understanding that the structural riprap requirements are to be identified as part of the bridge preliminary engineering and that all other bank protection requirements will be designed as part of the environmental mitigation for the channel realignment.

As noted previously, a realignment of the river channel is required since the existing river channel flows parallel to and under the roadway fills. In order to minimize impacts on the stream the channel realignment is to have curves which mimic the existing channel curvatures, and a cross-sectional flow area and an overall length similar to the channel that is being replaced in order to keep the overall channel slope and related stream characteristics unchanged. The channel realignment ties smoothly into the existing channel alignment both upstream and downstream. The conceptual channel realignment location together with the structural bank protection is shown on Figure 1. Structural riprap guidebanks have been used to control lateral erosion of the channel as it passes between the bridge fills and at the start of the channel realignment where the river is turned away from the high valley wall. Several earth spurs with riprap at the nose have been shown upstream of the crossing to limit future lateral erosion from attacking the road fills. These spurs can be built set back from the river realignment and would only begin to function if/when the river channel shifts towards the roadway fills in the future. Details for this concept will be shown on the Design Data drawings being produced as part of the preliminary engineering for the bridge crossing.

Design Discharge

The flows on the Elbow River have been recorded since 1908 at several gauges operated by Water Survey of Canada and Alberta Environment. The longest operating gauge is located near the mouth of the Elbow River downstream of the Glenmore reservoir. The Glenmore reservoir has impacted the flows on the Elbow River since 1932. Floods which have occurred since 1908 with discharges in excess of 250 m$^3$/s at the proposed bridge site upstream of the Glenmore reservoir are shown in the following table:
<table>
<thead>
<tr>
<th>Year</th>
<th>Max. Daily. Q (m$^3$/s)</th>
<th>Max. Inst. Q (m$^3$/s)</th>
<th>Estimated Time that Q &gt; 250 m$^3$/s (days)</th>
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<tr>
<td>1915</td>
<td>239</td>
<td>380</td>
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<td>700 *</td>
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<tr>
<td>1967</td>
<td>199</td>
<td>419</td>
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<tr>
<td>1995</td>
<td>(190) **</td>
<td>(377) **</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>2005</td>
<td>312 *</td>
<td>460 *</td>
<td>1</td>
</tr>
</tbody>
</table>

*estimated based on reservoir inflow calculations by others
**recorded at Bragg Creek - may not be applicable

The 1932 flood is the largest known event on the Elbow River since 1908 or earlier. There are 99 years of recorded flow data and a historic presence that includes the establishment of Fort Calgary and the construction of bridges over the Elbow River. The 1932 flood occurred as the Glenmore reservoir was nearing completion and the reservoir was empty. The flood filled the reservoir from empty to within 0.5m of the crest over a period of 1 to 2 days and significantly reduced the flood flows downstream of the dam. The flood was calculated based on stage elevations at the Glenmore reservoir and these calculations resulted in a very sharp peak in the hydrograph with a top hourly flow of 725m$^3$/s, and which exceeded 600m$^3$/s for only three hours. These calculations are very sensitive to the accuracy of the stage observations. Averaging the top three hourly readings (which may be inaccurate individually) results in a peak flow of 700 m$^3$/s. The length of time that the flows exceeded 250 m$^3$/s in 1932 was only one and a half days.

The waterway opening requirements of the bridge were examined using AIT’s design methodology. AIT’s current hydrotechnical design guidelines incorporate the channel capacity technique, historic observations, and runoff potential. It is expected that historic observations will govern on most major streams with long and well documented historicis. The channel capacity was checked using cross-sectional data of the existing channel that was obtained from ground survey undertaken by others in fall 2005 and spring 2006. Based on this information, a representative stream cross-section was developed that correlated with the existing stream and that could be input into AIT’s channel capacity calculator. The representative section has a bedwidth of 20m, a bank height of 2.1m, and a top width of 50m. The ground survey also measured the stream thalweg for a distance of 3.2km in the vicinity of the crossing and a stream slope of 0.0015 to 0.0019m/m was determined. Using the representative section results in a flow depth of 1m above bank height and a resultant discharge of 250m$^3$/s. When comparing with the recorded flood information it is obvious that the historical floods exceed the results of the channel capacity methodology. This is likely due to the influence of the Glenmore reservoir and
its effect on the overall river slope and channel cross-section as the channel rapidly transitions from a steep stream to the reservoir.

The extensive recorded flows allow us to determine a design discharge based on the largest known flood that has occurred. The 1932 flood appears to be an extreme event that can be considered design worthy. It is by far the largest flood event in over 100 years and is significantly larger than a normal flood. Only 6 years in 99+ years have had flows greater than 250 m$^3$/s and the next closest flood in 2005 had a peak discharge of 2/3 the peak of 1932.

It should be noted that others have used various statistical methods to try and determine a design worthy flood event on the Elbow River. Frequency analysis of the available data is difficult and is based on a number of assumptions and a limited amount of data on which to base these assumptions. At this site, frequency analysis results vary from 475 m$^3$/s to 850 m$^3$/s for a statistical 1:100 year event. AIT does not endorse this statistical approach as it ignores the physics of the site and is based on many assumptions that cannot be verified.

Others have suggested that a Probable Maximum Flood (PMF) discharge should be used for the bridge similar to the design criteria for the reservoir. It must be remembered that reservoir design is concerned with potential failure of the dam leading to a catastrophic loss of life in downstream communities and thus creates a higher standard of design than any other type of river structure. Thus, for dam safety purposes, the PMF discharge is extremely conservative and is based on the theoretical combination of the worst possible events. To the best of our knowledge, no recorded or observed flood on a major stream in Alberta have approached the magnitude of PMF flows.

For the SWCRR, the bridge and highway can be closed to traffic during a PMF type event thus eliminating any loss of life risk. The only issue here is whether the damages that would occur at the bridge during PMF conditions would create increased risk to the reservoir and dam located downstream from the bridge. The road is being designed so that the roadway will be overtopped prior to PMF flood conditions. Prior to reaching the low elevation of the roadway, there may be some minor ponding of flows with a chance that a small surge wave would be created as the roadway and bridges fail due to overtopping. However there is very limited potential storage upstream of the bridge which will limit the amount of water that can form a surge in the event of a failure. Also, if this surge wave were to occur, it would likely be absorbed by the reservoir prior to reaching the dam and any surge formed as the roadway fails would have a discharge and water level lower than the design PMF at the dam. Thus, the bridges and roadway do not appear to create an increased risk to the reservoir and dam and the PMF design criteria would not apply.

In conclusion, it is recommended that a design discharge of 700 m$^3$/s representing the 1932 flood be used as the design discharge for establishing the bridge opening and bank protection system.
Design High Water Levels

High water elevations for the channel are best determined using information from previous floods. Information about the high water elevation for the 1932 flood event is limited to the recordings at the Glenmore reservoir and the downstream WSC gauge. The twin bridges on Highway 8 west of Calgary were noted as being above the flood levels, but no recorded flood elevations or depths were found in the bridge correspondence files.

For the 2005 flood, stage elevations have been obtained for the Sarcee bridge gauge which is located in the immediate vicinity of the proposed bridges for the SWCRR. Reservoir level and discharge calculations by others using WSC and City of Calgary information have also been obtained. Alberta Environment did not obtain any highwater elevations for the Elbow River upstream from the City of Calgary during the June 18th event. There is a chance that the City of Calgary may have useful high water elevation data, but this has not been provided as of this date.

Air photos were taken of the Elbow River within the City of Calgary on June 19th, 2005, 20 hours after the flood peak. The air photos nearest the proposed crossing are shown on Figure 2. The calculated discharge at the time of the air photo is approximately 250 m³/s with a geodetic survey elevation of 1081.9m at the Sarcee bridge gauge. The flood peak discharge was 460 m³/s with a gauge elevation of 1082.4, which is 0.5m higher than shown on the photo. Examination of this air photo shows that the high conveyance flow area is located along the main channel of the Elbow River, with only minor conveyance, if any, along the valley floor. In support of this statement, it can be seen that the entire flow at the time of the photo is channelled under the Weaselhead pedestrian bridge. Also, just off the edge of the photo, the local road crossing the valley is mostly at elevation 1082.0 or higher which would indicate that at the time of the photo, most or all of the discharge was passing through under the 43m long existing local road bridge.

The question remains about what is happening at flows higher than 250 m³/s. Due to the tree and bush coverage adjacent to the main channel of the Elbow River, and the ability of the main channel to attract and carry flows, it would appear that the majority of flows are being conveyed by the main channel. The main channel has the capacity to convey observed flows and that floodplain paths offer limited conveyance due to much higher relative roughness (depth to roughness ratio) and lack of continuity of flow path (vertically and horizontally) in the downstream direction. Also, if a somewhat preferential floodplain path begins to attract a significant portion of the flow, it would likely be eroded into an alternate channel flow path with the previous main channel being slowly abandoned due to deposition with the total discharge being carried by the river channels remaining unchanged. This process is how many channel relocations and cut-offs occur. It is also important to note that discharges over 250m³/s are very rare and short-lived events. Over a 100 year time span there have been less than 8 days over the course of 6 flood events where the flows have exceeded 250m³/s, which is less than 0.02% of the time. For 99.98% of the time, the discharge and the related water level are lower.

The design high water level for the existing conditions includes consideration of the existing local road bridge at stream station 2+742. The 2005 peak water level at the Sarcee bridge gauge
was measured at elevation 1082.5 on the downstream side of the bridge and corresponds to a discharge of 460 m$^3$/s. Consideration for the design discharge of 700 m$^3$/s requires additional flow depth.

The surveyed cross-section at channel station 3+350 was used for analysis of flow levels since it is where the proposed channel realignment re-enters the existing channel. It also appears to be a representative cross-section on a straight section of channel away from the high valley wall. As seen in the 2005 flood airphoto, the channel width between the vegetated banks is approximately 45m to 50m at the recorded flow of 250 m$^3$/s. One important characteristic of this stream is that during high flows, the channel bed gravels will be scoured and the available main channel cross-section will be enlarged, prior to gravels being re-deposited as the flood recedes. The ground survey of the existing channel cross-sections is representative of the channel after deposition during the flood recession. Another characteristic of the stream is that during extreme flood events, additional effective flow width will be available adjacent to the main channel as the vegetation is removed during the high velocity flows in the main channel. There may also be some minor conveyance away from the main channel, but this is not expected to carry a significant discharge. Much of the velocity experienced in the valley away from the main channel is expected to be caused by equalization of water levels and lateral interaction with the main channel flows.

Based on a simplified analysis, the following high water elevations apply at 3+350 and represent existing conditions. It should be noted that all elevations except the design flood are based on measurements at the Sarcee bridge gauge in 2005.

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Discharge</th>
<th>Est. Avg. Velocity</th>
<th>Comments</th>
</tr>
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<td>1080.0</td>
<td>100 m$^3$/s</td>
<td>--</td>
<td>bank full</td>
</tr>
<tr>
<td>1080.9</td>
<td>250 m$^3$/s</td>
<td>2.1 m/s</td>
<td>2005 flood - air photo</td>
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<tr>
<td>1081.4</td>
<td>460 m$^3$/s</td>
<td>2.6 m/s</td>
<td>2005 flood - peak</td>
</tr>
<tr>
<td>1082.1</td>
<td>700 m$^3$/s</td>
<td>3.0 m/s</td>
<td>design flood</td>
</tr>
</tbody>
</table>

These elevations will need to be transferred onto the channel realignment and adjusted to account for the slope of the river and any impacts from the bridge opening dimensions when designing the bridge opening.

In conclusion, it is recommended that the crossing be designed for a downstream design HW elevation of 1082.1m at channel station 3+350 near the downstream end of the proposed channel realignment with the elevations modified when looking further upstream to adjust for the channel slope and channel realignment location.

*Elbow River Bridge Crossing on SWCRR - Bridge Planning Conceptual Design Report*
*Terrace Engineering Ltd., September 2006*
Geotechnical

Recommendations for the bridge headslopes are being prepared by Thurber Engineering on behalf of Transtech. We have not yet received any recommendations from Thurber, so we have assumed that the headslopes will be in the order of 2:1.

Wildlife

It has been determined by the wildlife specialists on the Transtech team that the proposed Elbow River bridge opening is appropriate for wildlife passage. Special design features for wildlife include the covering of the flat riprap apron and the flat top of riprap with smaller gravels and/or soils to allow wildlife to walk over these portions of the riprap. Wildlife habitat enhancement measures associated with this crossing are further described in the Environmental Assessment Screening. No pedestrian movements are to occur under the Elbow River bridge crossings due to the proximity of the wildlife corridors and the desire of the Tsuu T'ina nation.

Roadway Design

Early in the functional planning process it was recognized that the Tsuu T'ina requirements, the north interchange ramps and the south roadway curvature would strongly limit the roadway alignment and bridge crossing location options at the Elbow River crossing. Based on a detailed analysis undertaken by TransTech it was determined that the new bridges would be located at the east edge of the Tsuu T'ina lands and immediately west of the Weaselhead area. The bridges will be located on tangent to the north of the horizontal roadway curve and south of the interchange ramps at the north valley wall. The bridges are to have a 1.8%+/ gradient rising to the north to meet the roadway requirements.

Conceptual Bridge Layout

On the basis of the previously discussed information, the conceptual bridge layout can be determined. For purposes of this report, all elevations given below will be at the proposed centerline median. All elevations offset from the centerline median, except for the roadway, will need to be adjusted to account for the slope of the stream. To relate the elevations determined for channel station 3+350 at the end of the channel realignment to the centreline median of the roadway, subtract 0.7m from the centreline median elevations to obtain the respective elevations at 3+350. The elevations at the Sarcee Road gauge need to be reduced by 0.3m to relate to the centreline median elevations.

An appropriate bridge opening will provide adequate room for the passage of both water and wildlife. A bridge opening with an out to out of fills of 93.5m that meets these criteria is shown on Figure 3. This sketch shows a three span bridge with a minimum centre span length of 30m,
but it should be noted that the exact span arrangement has not yet been determined. It should also be noted that the proposed bridges are significantly longer and higher than the existing local road bridge and will have a centre span opening that is less restrictive than the existing local road bridge which has a 15.5m +/- centre span. To protect the new bridge fills, class 3 structural riprap is to be placed on both headslopes and at the toe using launching aprons. The bridge opening incorporates wildlife passageways on top of the riprap apron and to the inside of the riprap by placement of gravels similar to the gravel bars found naturally. These gravel bars will wash out during extreme floods but will be replaced by natural deposition gravel bars as the flood recedes. The design flood will scour and the flow area available during a design flood will include the scoured area, similar to what happens on the natural channel processes. The cross-sectional area that can be scoured between the riprap boundaries exceeds what is required to pass the design flood discharge without ponding.

When examining the existing flow conditions in the previous section it was determined that the majority of flows are being conveyed by the main channel. For the new bridges at the proposed SWCR bridge crossing, channelizing the minor flows carried along the valley through the bridge opening may slightly increase the high water levels upstream of the bridge for discharges in excess of 250m³/s compared to existing conditions. However, this will have no significant impact on the discharge passing through the bridge opening or the water levels downstream from the bridges. Only minor ponding of water is expected behind the bridge fills. An allowance of 0.2m of ponding has been incorporated in setting the design high water level through the bridge opening. The estimated design average velocity for the bridge opening is 3.1m/s during design discharge conditions, which is similar to the 3.0m/s existing main channel velocity away from the bridge. The minor difference of 0.1m/s between the average velocity through the bridge opening versus the natural channel during design discharge conditions will dissipate as the guidebanks taper out downstream of the bridges. The average velocity in the channel will be at existing pre-bridge condition prior to reaching the downstream end of the proposed channel realignment.

The bridge opening will incorporate 1.0m of freeboard between the design high water level and the bottom of the bridge girders at the low end of the bridge. This allows for drift/debris and local variability in flow etc. The bridge does allow for flows greater than the design discharge, but some damages can be expected. For example, the 1m freeboard allows the bridge to pass approximately 300 m³/s in addition to the design discharge of 700 m³/s before the water touches the girders at the low end of the bridge. Also, the bridge would be able to pass significant additional discharge after the water touches the girders. Damage to the fills and headslopes can be expected to accumulate once the flows exceed the design discharge.

Some have put forth the opinion that the valley is carrying significant floodplain flows during a rare design flood event. While we disagree, it is prudent to discuss the impacts if this were to be the case. As discussed previously, the air photos from the 2005 flood show that the flows are being carried largely by the main channel and are channelized under the existing local road and Weaselhead pedestrian structures. For flows as shown on the 2005 flood air photo (which are not exceeded for 99.98% of the time historically), the proposed bridges provide a more generous
opening than the existing local road bridge and will therefore will have no negative impacts on the flow compared to the existing conditions, and may actually cause less impediment. For a theoretical situation where overbank flows were to occur at higher discharges they would only exist for a short period of time, and any negative effects of a theoretical concentration of flows would be minor, especially in light of the impacts caused by the smaller opening of the existing bridge. However, in order to prudently address any concerns with this theoretical confinement of flows, it is recommended that the outside bend of the downstream portion of the channel realignment be lined with non-structural riprap to counteract any possible additional erosional impact downstream from the proposed bridge openings. Velocity and high water elevations are still expected to return to pre-bridge existing conditions prior to the end of the channel realignment. The bell mouth structural riprap through the bridge openings and the non-structural riprap along the downstream end of the channel realignment will control and limit erosion. This control of erosion is an important component along the this reach of the river as others have identified erosion along the main channel as the major source or sediment supply. (Hudson, *Hydrology and Sediment Transport in the Elbow River Basin*, 1983). However, the overall impact of the proposed bank protection on a reduction in sediment is expected to be minimal to nil since the Elbow River carries very large sediment loads in the order of 70,000 t/year (Hudson) and the bank protection is only providing erosion control over a very short distance when looking at the overall river system.

Unit costs for bridges are difficult to determine due to the current economic activity. For comparison purposes we suggest using $3500/m² based on a three span bridge within the out to out of fill length. The combined width of the four SWCRR bridges will be 3.7m * 16 lanes + 3.0 * 2 shoulders * 4 bridges + 0.5 curb * 2 sides * 4 bridges = 87.2m. The new local road bridge will have a width of 9.0m clear roadway + 0.5 curb * 2 sides = 10.0m. Based on the above noted unit cost, this results in a cost per linear metre of $340,000. Therefore the costs are for the bridges (excluding bank protection, channel realignment excavation, environmental mitigation and roadway costs):

93.5m out to out of fills = $32 million

TransTech recommends and AIT accepts the proposed 93.5 metre out to out fills length. The preliminary engineering and Design Data drawings are proceeding based on this concept.

**Summary for Environmental Assessment**

The environmental assessment being compiled by AMEC E&E requires information regarding changes to the river including flow parameters such as velocities, discharge and gradients and changes to hydrological factors resulting from confined flows, partial watercourse obstructions and other activities. These items are discussed in previous sections of this report and are summarized below.

The bridge opening and channel realignment has been designed to minimize detrimental impacts on the hydrotechnical conditions of the Elbow River. While creating obvious changes such as a
realignment of the river and the construction of roadway fills and bridge structures, the surficial flow hydrotechnical impacts of this project are minor. The gradient and flow area of the river is unchanged along the channel realignment, the discharge passing through is unchanged, and minor velocity and high water level changes that may occur in the immediate vicinity of the bridge structures during a design flood event are returned to existing conditions prior to the end of the proposed channel realignment. Erosion is controlled with structural riprap bank protection through the bridge opening and along selected portions of the channel realignment, and overall lateral erosion rates through the channel realignment reach are expected to match or be reduced compared to existing conditions. The proposed bridges have a large centre span largely spanning the main normal flow channel of the river and is considerably longer than the centre span of the existing bridge thus improving partial channel obstructions compared to the existing local road bridge.

Closure

This study has been prepared exclusively for TransTech Engineering for purposes of a bridge planning conceptual design report for the Elbow River crossing on the SWCRR. The information and data contained herein represent our professional judgement in light of the knowledge and information available to us at the time of preparation.

Except as required by law, this study and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the client, who is restricted to using this information only for the purpose for which it was intended. We deny any liability whatsoever to other parties who may obtain access to this study for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this study or any of its contents. Any use of this study by third parties, or any reliance or decisions based on it, are the responsibility of such third parties.

Respectfully submitted,
Introduction

The Southwest Calgary Ring Road Project (SWCRR) proposes the initial construction of two new bridges over the Elbow River on a realigned channel to be located immediately west of Calgary and upstream of the Glenmore Reservoir. These works also require the removal and replacement of an existing Local Road bridge over the Elbow River.

On or about June 20, 2013 a significant flood event occurred on the Elbow River including the reach upon which these bridge crossings are located. While the 2013 flood discharge has not yet been published, this flood was larger than any recorded flood event on the Elbow River upstream of Calgary and potentially equal or larger than previously known historic flood events. The purpose of this report is to provide an engineering assessment of possible flood impacts to the previous conceptual waterway opening design for the planned Elbow River bridges on the SWCRR. It is expected that this assessment will be considered, confirmed and refined by others during the future detailed engineering design of the bridge crossing.

The prime consultant for this work is AMEC Environment & Infrastructure (AMBC) under contract to Alberta Transportation (AT), and Terrace Engineering is a sub-consultant to AMEC.

June 2013 Flood Event

During the later part of June 2013 a significant storm event affected much of the south-central foothills of Alberta causing extensive flooding over an extended area of these foothills and the downstream rivers. The peak flood at the bridge site appears to have occurred on or about the evening of June 20, 2013.

Water Survey of Canada (WSC) operates two gauges on the Elbow River upstream from the Glenmore Dam and both identified record water levels. Discharge values for 2013 have not yet been published, and preliminary discharge estimates have varied, due in part because the gauge heights are beyond the applicability of the stage-discharge rating curves. The largest of the estimates is in the order of 1240 m³/s based on water level and storage information for Glenmore Reservoir inflows by the City of Calgary (as provided by email from C. Watt, AT). This peak discharge occurred over a very short period of time, with the 24-hour daily average peak discharge being considerably lower. Based on the largest value for the estimated discharge for the 2013 flood event, the flood was larger than the design flood for the SWCRR bridge design.

High water mark information is available from a variety of sources. Both Alberta Environment and Sustainable Resource Development (AESRD) and WSC have identified high water marks for the 2013 flood event. AESRD identified a high water elevation of 1082.9 m, (as provided by email from C. Watt, AT) which places the highwater onto the existing local road bridge girders but below its bridge deck. The WSC website provides an unverified preliminary high water estimate which appears to be about 0.4 m lower than the AESRD high water elevation when converted to matching datums. For purposes of this assessment we will discuss the higher AESRD value.
Potential Impacts to the Bridge Waterway Opening Design

The flooding that occurred in June 2013 at the Elbow River crossing for the SWCRR was a significant event. The following parameters were examined from an overall perspective.

High Water Elevation
As noted previously in the 2013 flood event section of this report, the estimated high water level at the existing bridge is 1082.9 m based on the AESRD measurements with the flood waters up onto the girders of the existing TsuPLAIN T’ina bridge. The proposed new bridge concept identified a design high water elevation of 1082.8 m which appears to align with the AESRD high water level. The new bridges have a minimum waterway opening elevation (minimum girder elevation) of 1083.8 at the low end of the new bridges which is considerably higher than the existing bridge.

Design Waterway Opening Width
The proposed bridges have a much larger waterway opening width than the existing TsuPLAIN T’ina bridge which survived the 2013 flood event. At flood depth the waterway opening width is about 68 m for the new bridges versus 43 m for the existing bridge. It is recognized that some flood flows passed over the TsuPLAIN T’ina roadway during the 2013 flood event that would not occur with the new ring road facility which is designed to a higher roadway elevation.

Commentary
The design for the new bridges provides a much wider and higher waterway opening as compared to the existing bridge and the existing bridge survived the 2013 flood. The design high water elevation for the new bridges is similar to measured high water elevation of the 2013 flood although the design discharge for the new bridges is lower than the City of Calgary estimate. This apparent discrepancy between discharge and measured high water has not been verified. However, the new bridges were designed with flexibility to accommodate floods larger than the design flood by providing freeboard between the design flood elevation and the bottom of the bridge girders. This additional flow area can be used to pass significantly larger discharges than the design discharge before flood waters touch the bridge girders. In addition, the high water can touch onto the bridge girders to pass additional flow for a period of time without causing undue concern, such as occurred with the existing bridge in the 2013 flood event.

Conclusions
The flooding that occurred in June 2013 at the Elbow River crossing of the SWCRR was a significant event. In general terms, the overall bridge and river engineering concept was not negatively impacted by the 2013 flood and remains a viable and reasonable concept.
Closure

This report (study) has been prepared exclusively for AMEC and AT to provide an assessment of possible implications of the June 2013 flood on the previous conceptual waterway opening design for the new Elbow River bridges on the SWCRR. The information contained herein represents our professional judgement in light of the knowledge and information available to us at the time of preparation, which may be earlier in time than the date of this report. The information made available or gathered during the preparation of the report may not represent all information that is available, and the accuracy of the information provided or gathered may not have been independently verified.

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Respectfully submitted,

Terrace Engineering Ltd.

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