1 City of Edmonton Quesnell Bridge, Roads and Associated Structures Assessment

1.1 Background

Within the First National Engineering Vulnerability Assessment, the Public Infrastructure Engineering Vulnerability Committee (PIEVC) identifies roads and associated structures among the four priority classes of infrastructure to assess for vulnerability and adaptability to climate change.

The Quesnell Bridge in Edmonton was selected as a case study in the roads and associated structures category. CH2M HILL conducted the case study. The consultants used the Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment (the Protocol) and various information sources, including City of Edmonton personnel, historical weather event information, and climate-model projections. PIEVC and affiliated stakeholders participated in a workshop and bridge tour to review and provide input on applying the Protocol to the infrastructure.

1.2 Where, What and How

The Quesnell Bridge crosses the North Saskatchewan River Valley in the west part of the City of Edmonton, population approximately 730,000. Built in 1968, the bridge, which is a critical element of Whitemud Drive, a major multi-lane arterial roadway running east-west and forming part of Edmonton’s inner ring road system. The six-lane bridge is a key crossing over the North Saskatchewan River, linking the northwest and southwest areas of Canada’s fifth largest city. Owned, operated and maintained by the City of Edmonton, it carries about 120,000 vehicles per day, as well as cyclists and pedestrians. It is located within the steeply sloped and relatively intact North Saskatchewan River Valley, which is nationally recognized as an environmentally sensitive area. The 315-metre structure consists of three lanes in each direction, a 4.5-metre sidewalk, and a superstructure of ten lines of parabolic prestressed and post-tensioned concrete girders with a cast-in-place deck.

One reason for selecting this case-study site is that Edmonton represents a geographic location that experiences a northern continental climate with a variety of extreme climate conditions and weather events. Edmonton is located south of the permafrost region at 53 degrees north latitude and 113 degrees west latitude. The average monthly minimum temperature in January is -18°C and the average maximum monthly temperature in July is 22°C. As the bridge is a heavily used water crossing, the site provides further opportunities to explore climatic impacts. Unique climatic and geographic considerations include extreme cold temperature and its effect on the durability of concrete, frequent snow (sometimes heavy), ice build-up on the river, and the impact of increased rainfall on erosion, due to the long, steep river valley banks.

Coincidentally, the bridge is currently undergoing rehabilitation and upgrading to meet increased traffic loads and to extend the life of the structure for 50 years. This work adds a further
dimension to the study, as resulting recommendations may find immediate practical application. The upgrades, which are to be completed in 2010, include replacing the concrete deck and widening the bridge to accommodate two additional lanes. The goal is to achieve serviceability with minimum maintenance and no major rehabilitation until 2060.

All components of the bridge are considered in this study, including operations and maintenance; deck; expansion joints; bearings; girders; abutment; piers–columns; drainage system; accessories (e.g. pedestrian railing, lamp posts); the riverbank and adjacent infrastructure (upstream dam).

The case study identified two infrastructure components as showing signs of vulnerability: the wearing surface of the deck and the drainage system, including the deck drainage and the retention pond. As these components are being replaced in the bridge rehabilitation program, the vulnerability is assessed in terms of potential proposed alternatives, in particular whether they should be designed according to current standards and typical climatic data.

Climate data used for climate modeling is based on observed weather data and may not capture all the extreme events that are of interest in this study. For that reason, local extreme climate events and their impacts are also considered, based on City of Edmonton sources and other local knowledge. OURANOS reported that the following categories were the most difficult to predict via climate models and observed data are insufficient to validate the model outputs for these particular events:

- increased wind and “storm-type” effects including tornadoes, thunderstorms and wind gusts;
- increased ice build-up, ice accretion and freezing rain; and
• rapid snowmelt, leading to potential flooding.

1.3 Technical Summary

Climate Modeling

The Quesnell Bridge case study of infrastructure vulnerability and adaptability to climate change draws on climate modeling by OURANOS and uses the Canadian Regional Climate Model. The years 2020, 2050 and 2080 were selected as the time horizons for analysis.

It should be noted that OURANOS was unable to satisfactorily model several of the climate elements that were requested for this study. These include the precipitation frequency indices (both rain and snow) for 5 mm, 10 mm and 20 mm cutoffs. Changes modeled appear erratic in some cases and are not statistically reliable. This is most likely due to the fact that the Edmonton area experiences very low levels of precipitation in general (approximately 480 mm of precipitation and 124 cm of snowfall every year). This significantly reduces the available sample size. OURANOS recommends that if all requested indices are necessary for vulnerability assessment, further in-depth modeling and analysis be done.

However, OURANOS can make some general projections about changes in wind, ice and rapid snowmelt events although these projections are among the least reliable since the climate model cannot reliably capture them. These projections were considered relevant because extreme events have occurred in the past and are likely to occur again in the future. They are also the ones most likely to contribute to infrastructure vulnerability, particularly if they occur in combination or sequentially. It must be emphasized that these types of events are difficult to model as they are either localized or involve complex, inter-related processes.
Climate models applied to the North Saskatchewan River Drainage Basin, within which the Quesnell Bridge is located, suggest the following:

1) Wind (hurricanes, tornadoes, thunderstorms, wind gusts)
   Increased instability in mid-latitude regions, such as Edmonton, may increase the magnitude and frequency of “storm-type effects”, including tornadoes and hurricanes.

2) Ice (ice build-up, ice accretion, freezing rain)
   Although it is expected that winters will become warmer, ice build-up (in waterways) and ice accretion (on structures) may increase due to possible increases in freeze/thaw cycles.

3) Snow (rapid melt events)
   Although difficult to predict, OURANOS notes that there is a concern that rapid snowmelt followed by extreme rainfall may load the infrastructure system, leading potentially to flooding events.

OURANOS concludes that the unpredictable nature of these three categories required a more qualitative vulnerability assessment. For that reason, it suggests taking a “what if” approach to assessing the impact of future events, with consideration to local historical events and local knowledge of extreme climate events.

Probability Scales

The case study employs two probability scales (Method A – Climate Probability Scale Factors and Method E – Response Severity Scale Factors) from the Protocol for Climate Change Infrastructure Vulnerability Assessment to gauge vulnerability of the Quesnell Bridge, roads and associated structures to climate change.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Method A Climate Probability Scale Factors</th>
<th>Method E Response Severity Scale Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Negligible or not applicable</td>
<td>Negligible or not applicable</td>
</tr>
<tr>
<td>1</td>
<td>Improbable/highly unlikely</td>
<td>Very low/Unlikely/Rare Measurable change</td>
</tr>
<tr>
<td>2</td>
<td>Remote</td>
<td>Low/Seldom/Marginal Change in Serviceability</td>
</tr>
<tr>
<td>3</td>
<td>Occasional</td>
<td>Occasional Loss some capacity</td>
</tr>
<tr>
<td>4</td>
<td>Moderate/possible</td>
<td>Moderate Loss of some capacity</td>
</tr>
</tbody>
</table>
The climate effects that were considered included average daily high temperature, average daily low temperature, extreme temperature range, rainfall and snowfall frequency and intensity, freeze/thaw cycles, ice accretion, ice force (force of river on the piers), extreme wind, flooding of the North Saskatchewan River, and fog.

In addition, the combined impact of individual weather effects was considered, including:

- temperature and relative humidity;
- heavy winter snow, early spring and heavy rain, resulting in major flooding and debris; and
- snow/ice, rain, and freezing temperatures, resulting in heavy snow.

The table below shows the probability levels and potential losses:

<table>
<thead>
<tr>
<th>Probability Level</th>
<th>Likely Regular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often</td>
<td>Loss of Capacity and Loss of Some Function</td>
</tr>
<tr>
<td>Probable</td>
<td>Major/Likely/Critical Loss of Function</td>
</tr>
<tr>
<td>Certain/Highly probable</td>
<td>Extreme/Frequent/Continuous Loss of Asset</td>
</tr>
</tbody>
</table>

**Figure A-18 Quesnell Bridge**
Climate Change Impacts

Operations and Maintenance

The work of the regular maintenance crew and snow removal personnel is crucial to the performance of the infrastructure. Extreme climate effects may affect their ability to function, increasing emergency response risk, public health and safety.

Deck System – Wearing Surface

The deck system will be entirely replaced during rehabilitation scheduled for completion in 2010. Although a final decision on the system has not yet been made, it will likely consist of a cast-in-place concrete deck, topped by a water-proofing membrane and then an asphalt wearing surface. While the membrane is not expected to be compromised if installed correctly, concern exists about the integrity of the wearing surface, which is exposed directly to weather elements as well as regular vehicle loads and maintenance vehicle loads. As this involves the direct interface between vehicle tires and bridge surface, this could become a safety issue for road users. This component could be vulnerable to two climatic factors: snow intensity/frequency and major flooding.

Snow intensity/frequency
  • More frequent use of snowplows and other de-icing measures may result in more rapid degradation of the wearing surface.
  • Driving hazards may increase, along with more likelihood of delays in clearing snow off driving surface.

Major Flooding
  • Recent climate change trends point to an increase in the frequency of major flooding following a heavy snowfall, followed by an early spring and subsequent heavy rain.
  • Climate loads suggest the wearing surface may be vulnerable to such events in the 2020 timeframe. (In this event, it is assumed that heavy snow/ice has blocked the catch basin of the drains.)

Drainage System – Drainage and Retention Pond

The drainage system diverts water away from the bridge deck and the water is proposed to be stored in holding areas near the structure to avoid discharge into the river system.

Rainfall Intensity

  • Rainfall intensity is expected to increase by about 4% in 2020 and 7% in 2050.
  • This suggests a high probability that the deck drainage will be affected toward the end of the 50-year life cycle of the infrastructure, although the minor increase by 2020 may be insignificant.
Major Flooding

Early warming, followed by heavy rain, may result in drains not functioning properly.

1.4 Policy Makers Executive Summary

General Climate-Change Impact

Climate changes anticipated in the Edmonton region include an increase in the magnitude and frequency of “storm-type” effects such as tornadoes, thunderstorms and wind gusts. Although winters are expected to become warmer, the amount of ice may increase due to more frequent freeze/thaw cycles. This includes ice build-up on the North Saskatchewan and other water bodies, as well as on bridge and road surfaces, sidewalks and other structures.

There is also concern about a potential increase in combination events, such as a rapid snowmelt followed by extreme rainfall, which could cause major flooding. Such events are extremely difficult to predict. However, they have happened in Edmonton’s past and are likely to occur again. More frequent snowfall could result in increased use of de-icing salts, leading to increased maintenance costs, while heavy snowfall or rainfall could affect emergency response times and affect public safety. Rising river levels could reduce clearances for marine traffic, while ice accumulation along the river could increase pressure on the bridge infrastructure.

The two components of the Quesnell Bridge that have the highest vulnerability ratings are the wearing surface of the deck system and the drainage system. The vulnerability of these components would not lead to catastrophic failure of the bridge, but could impact vehicle performance, public safety, maintenance and related issues.

Plans to rehabilitate the bridge by 2010 provide an opportunity to include climate adaptation measures in the design.

Some of the climate data used in the current bridge design standards date back to 50 or 60 years. This suggests a need to review the relevant data used in affected codes to assess how it may be updated to reflect not only more current data collection, but also potential climate-change impacts.

Specific Impacts on Quesnell Bridge Infrastructure

Deck System – Wearing Surface
The deck system will be entirely replaced during rehabilitation, although a final design decision has not yet been made. The design likely will consist of a cast-in-place concrete deck, topped by a waterproofing membrane and then an asphalt wearing surface. Although the membrane is not expected to be compromised if installed correctly, concern exists about the integrity of the wearing surface, which is exposed directly to weather elements as well as regular vehicle loads and maintenance vehicle loads. As this involves the direct interface between vehicle tires and bridge surface, this could become a safety issue for road users. This component could be vulnerable to two climatic factors: snow intensity/frequency and major flooding.

This could be noticeable through the following.

1) **Greater snow intensity and frequency** resulting in:
   - more rapid degrading of the wearing surface due to snowplowing and de-icing; and
   - increased driving hazards and delays related to snow removal from driving surfaces.

2) **Increases in frequency of major flooding**, following heavy snowfall, early spring and heavy rain, may leave wearing surfaces vulnerable in the 2020 timeframe if the heavy snow and ice block catch basins of drains.

3) **Effects on the drainage system and retention pond** may be felt with rainfall intensity anticipated to increase by about 4% in 2020 and 7% in 2050. There is a high probability the deck drainage will be affected by the end of the infrastructure’s 50-year life (minor increases by 2020 may be insignificant). Early warming, followed by heavy rains resulting in drains not functioning, may also impact the drainage system.

**Key Recommendations**

Based on these findings, the consultant makes the following recommendations:

- Review and conduct further study of a number of applicable design procedures and designs, so that design of these components will consider changing or extreme climatic events.

- Review the relevant data used in affected codes to assess how it may be updated to reflect 1) more current data collection, and 2) potential climate change impacts.

The consultant also notes that although only two areas of potential vulnerability were identified for the Quesnell Bridge, other general areas of concern were identified that may be applicable to bridges of other types and in other locations. The consultant states that to obtain a more comprehensive assessment of bridge infrastructure across the country, it would be prudent to undertake further assessments to capture a range of bridge types and locations across Canada.
In general, the infrastructure data set was considered to be complete and adequate, and was readily available from City of Edmonton records. The consultant points to the value of complete maintenance records and in particular notes that a complete maintenance record of specific frequency, approach and quality of snow removal used during each winter season would have been of interest in this assessment.

Figure A-19 Quesnell Bridge - underside