RIVJAM APPLICATIONS ON THE MIRAMICHI RIVER

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Abstract

The Miramichi River, located in northern New Brunswick, is one of the largest river systems in the province. The Miramichi River has a history of flooding in the Newcastle-Chatham area which is documented back to 1874. The main cause of flooding in the Town of Newcastle and the areas further upstream is ice jamming. A recent study under the Canada-New Brunswick Flood Damage Reduction Program (WMS 1990) concluded that the area was highly prone to ice jam flooding and that any new construction which impinges on the River should carefully consider the implication of changes to the river ice regime and the possibility of ice jamming.

The New Brunswick Department of Transportation proposed to construct a new bridge across the Miramichi River in the vicinity of Newcastle. WMS Associates Ltd. (WMS) conducted the environmental overview for this proposed bridge. The proposed bridge was located at a narrow stretch of the river, (approximately 500 m wide) approximately 2000 m upstream from the location of a major jam in 1970.

The RIVJAM model was used (with a limited number of trials as constrained by the budget for the study, which was an environmental overview) to examine maximum water and ice levels at the bridge location to determine if the proposed clearance was sufficient. The results were compared with those of the simplified methods and empirical methods for determining bridge clearance in ice prone areas.

The analysis showed that the proposed clearance was not sufficiently conservative and it was recommended that the bridge clearance be increased.

This paper presents the methodology used for the examination of the clearance of a proposed bridge across the Miramichi River at Newcastle. It describes the application of the RIVJAM model using the limited amount of data from previous ice jam events in the area to help evaluate this clearance.

Keywords: Ice jams; Bridge clearance; RIVJAM Applications.

Introduction

The Miramichi River, located in northern New Brunswick, is one of the largest river systems in the province. The Miramichi River has a history of flooding in the Newcastle-Chatham area which is documented back to 1874. There has been a total of 42 recorded flood events in the area. A recent study under the Canada-New Brunswick Flood Damage Reduction Program (WMS 1990) investigated the historical flooding in this area and concluded that the areas was highly prone to ice jam flooding and that any new construction which impinges on the River should carefully consider the implication of changes to the river flows, the ice regime and possibility of ice jamming.

The New Brunswick Department of Transportation (NBDOT) has recently proposed to construct a new bridge across the Miramichi River in the vicinity of Newcastle. WMS Associates Ltd. (WMS) conducted the environmental overview for the proposed bridge. The proposed bridge was located at a narrow stretch of the River, approximately 2000 m upstream from the location of a major jam in 1970 (Figure 1).

At the request of the New Brunswick Department of the Environment, an assessment was made to determine wether the proposed clearance of the bridge was sufficient to avoid high levels of ice and water behind an ice jam from impinging on the bridge superstructure. This task was initially undertaken through the application of simplified methods for the estimation of maximum ice jam height (Beltaos 1983; Pariset and Hausser 1961). These simplified methods indicated that the maximum level of an equilibrium jam could exceed the level experienced during the 1970 ice jam; which was the largest ice jam flood on record in this area. However, these methods were not strictly applicable to the bridge site because of the tidal nature of the river.

An alternative, more detailed method for assessing the maximum water levels due to an ice jam was employed through the use of the computer program RIVJAM (Beltaos and Wong 1990). This program takes into account variation in cross-sections and friction under the jam; it generates the profile of an equilibrium ice jam and related water levels (Figure 2). The model used the data from the 1970 ice jam as input and was used to determine whether that jam could have reached a higher level if a sufficient quantity of ice had been available in the river.

This paper presents the methodology used with a limited number of trials, for the assessment of the clearance for the proposed bridge across the Miramichi River at Newcastle. It describes the application of the RIVJAM model based on the limited amount of data from previous ice jam events in the vicinity of the proposed bridge to help determine this clearance. The results of the RIVJAM analysis are compared to other methods of analysis and the conclusions from the study are presented.

Background Information

Frequent flooding in the Newcastle-Chatham area has been mainly due to ice jams and ice related events. WMS (1990) identified 42 flood events in the area which have occurred in the past 115 years. A total of 10 of these events occurred in the vicinity of Newcastle and were a result of heavy ice runs and ice jamming. Ice jams were responsible for the largest flood in the area, which occurred in 1970. In that year, there were heavy ice runs and ice jamming at many points within the Miramichi River system. These conditions resulted in the destruction of 12 bridges (Kindervater, 1985).

Figure 2 indicates the location of ice jams which have been identified in the Newcastle area and in the upstream reaches of the Miramichi River system over the past 115 years. In the past, ice jams were often prevalent in the upstream river reaches without significant jamming at Newcastle. The river widens at this point as it enters the Miramichi Estuary and it is only under heavy ice run conditions, usually as a result of mid-season breakup, that the ice from the upper river reaches will encounter intact ice on the estuary and jamming may occur.

Heavy ice jamming caused by the scenario described above, occurred in 1934, 1936, and 1970. Newspaper reports for these periods describe the ice in the river as piling high and restricting shipping for considerable periods. Mention is also made of concern for the safety of the Morrissey Bridge which spans the River at Newcastle. However, these reports provide little usable information for determining the exact jam locations and thickness for each event.

Although the 1970 ice jam at Newcastle produced the highest water levels on record and resulted in extensive flooding of the town, which is relatively well documented, there is only limited data available on the jam itself. Local residents were able to identify the approximate location of the toe (downstream end) of the jam. Newspaper reports and photos provided information on the maximum level of ice behind the jam and the flood study (WMS 1990) provided the information on water levels upstream of the jam. The information was used in assessing the validity of the water levels produced by various ice jam models applied to the area. The available information from this jam was used to provide a limited calibration of the models. Table 1 summarizes this information.

River flow information was readily available for the Miramichi River system, however the flow at Newcastle had to be estimated from upstream gauges, which represented approximately 74% of the total drainage area at Newcastle. The estimated flow at Newcastle for the 1970 event was estimated to be 5100 m^3/s. The 1970 event was a mid-winter breakup event caused by warm temperatures and heavy rain. It was estimated that the return period of the River flow was approximately 50 years for open water conditions. For the purpose of the study five events were analyzed. They were the 20 and 100 year ice break up flows, the 1970 event, the 100 year open water flow and an extreme flow calculated at the 100 year open water flow plus 25%. The ice break up flow was determined from an analysis of the ice season on the Miramichi River based on the indications of ice presence in the historical daily stream flow summaries (Beltaos 1984). It was found that the 1970 event exceeded the estimated 100 year return period breakup flow, as indicated in Table 2. Although, the accuracy of breakup flows determined this way is estimated to be only within 10-15%, no methods other than close monitoring provide more reliable results.

The tidal variation in the Miramichi River at this point is approximately 1.3 m, with the tidal influence extending a further 20 km upstream from this site. High tides, driven by storm surges, have also been known to cause extreme highwater levels in the area, reaching to within 0.5 m of the 1970 ice jam flooding levels recorded in the Newcastle area. Although, it was considered possible that an extreme tide with storm surge could occur in conjunction with the ice jam event, this joint occurrence was not considered in the study due to the low probability of simultaneous occurrence of these events.

Methodology

In determining the clearance for bridges that are to be constructed in ice infested waters, the recommendations contained in the referenced RTAC report (1981) are commonly used; a clearance of 1 to 3 m above the maximum known ice level is recommended. The provision is made that more detailed study may be required if the ice regime is unknown or if ice jamming is known to cause problems at the proposed site. One of the objectives of the Miramichi River bridge study was to determine whether the clearance proposed for the bridge was adequate in light of these recommendations and to determine whether an additional evaluation of the ice levels was required. The proposed elevation of the bridge centre span was 7.5 m which is 5.5 m above the maximum high tide level at the proposed bridge site. All elevations in this reports are referenced to Geodetic Datum. No specific studies had been done on the ice regime of the river during the preliminary design.

The historical information indicated that the water level behind the 1970 ice jam rose to an approximate elevation of 4.2 m at the Morrissey Bridge, while the intact ice sheet downstream of the jam had an approximate elevation of 1.7 m. It was assumed that the ice extended approximately 0.3 m above the water level and therefore a recommended bottom chord elevation for the bridge would be 5.5 m to 7.5 m using the RTAC (1981) criteria. The proposed bridge had a centre span bottom chord elevation of 7.5 m, but this tapered to 5.5 m at the abutments.

Therefore, although the centre of the bridge would provide adequate clearance for the known ice level, the clearance at the abutments would be insufficient. In view of the known history of jamming, and the importance of determining a proper level for the ice before making a recommendation for changing the bridge bottom elevation, more detailed studies were undertaken.

Two simplified methods were initially considered for the computation of the ice jam levels. The method developed by Pariset and Hauser (1961) and the method developed by Beltaos (1983) were used. These methods allow for the computation of the maximum water level upstream of a fully developed equilibrium jam. The computed water levels would be the maximum water level attained upstream of the jam. The two methods were applied assuming the approximate downstream ice cover elevation of the 1970 event, and the range of flows described in Table 2. Using the flows from the 1970 event, the maximum attainable upstream water level was estimated at 6.2 m at the Morrissey Bridge, or approximately 2 m higher than the observed level.

While these methods have been shown to provide a reasonable indication of the water levels upstream of ice jams, they were not developed for use in tidal water. The cross section of the river in an estuary is wider than a non-tidal river and the change in water level due to a large increase in flow can be relatively small in the tidal reach of a river.

However, the application of these methods did indicate that the 1970 ice jam at Newcastle did not reach equilibrium conditions, and the maximum ice jam level could have been higher than was observed. The fact that the 1970 ice jam did not reach equilibrium conditions could have been due to a shortage in the supply of ice to the jam or due to the tidal influence of the river.

Based on these initial findings, it was decided to use a more detailed method to determine the water levels behind the ice jam. The RIVJAM computer software package (Beltaos and Wong 1990) was initially developed as a research tool and has been applied and calibrated against ice jams on the Thames River in Ontario and the Restigouche River in New Brunswick. The model uses detailed cross-sectional information of the river to determine the flow characteristics, and allows for changes in the channel cross-sections. Because the river cross section is fully defined, the tidal variation and wider esturial river section can be accommodated. The model provides a longitudinal profile of the estimated top and bottom surface of the ice in the jam as output. Using the profile, the known 1970 ice jam data could be used to obtain an approximate calibration of the model. The Morrissey Bridge is located too close to the toe of the 1970 ice jam (approximately 500 m) to be located over the fully developed, equilibrium section of the jam.

Although the study identified five flows (Table 2) for use in the analysis, the main emphasis was placed on the flows associated with the 1970 event. This event was viewed as rare and the only event which has seriously threatened the safety of the existing Morrissey Bridge. Although a return period could not be assigned to the event, it has not been exceeded in the 115 years of record on the River. Therefore, this event was selected as the key event on which to focus the ice related design of the proposed bridge.

Application of the RIVJAM Model

The computer program RIVJAM was used to estimate the maximum height of the ice jam along the channel in the study area. The model takes into account the hydraulic resistance and porosity of the jam, as well as the actual cross sectional geometry and slope variation of the river channel. Detailed cross sections of the river were made available by the New Brunswick Department of Transportation.

The lodgement point and estimated flow associated with the 1970 ice jam were used as input to the RIVJAM model. It was also assumed that a sufficient quantity of ice was available in the River to establish an equilibrium jam, and that the ice jam grounded, i.e. that the toe of the jam blocked the entire river channel at the lodgement point, as the worst scenario. These assumed conditions were consistent with the recommendations for the application of the model to the tidal conditions of the area.

The model output for an equilibrium ice jam indicated a maximum water level of 6.7 m at the Morrissey Bridge. This is 0.5 m higher than the equilibrium jam levels found using the simplified methods, described earlier. This difference may be explained by the fact that this reach of the river is located in an estuary, and the fact that the river slope is not well defined. This result provides an indication of the water level which could have been reached if there had been a sufficient volume of ice available in the River at the time of the jam, and the toe of the jam had been grounded. The toe conditions of the jam were then varied to simulate a jam which was not fully grounded. This would occur if a reduced amount of ice was available to the jam. It was found that with a jam thickness of 3.5 m at the toe of the jam and a clearance of 5 m between the underside of the toe of the jam and the river bed, the water levels would approximate those observed during the 1970 event (Figure 3).

The 1970 ice jam had an observed upstream maximum water level of 4.2 m. Approximations of the ice jam geometry using the RIVJAM program indicated that had there been a sufficient volume of ice available in the River, the maximum height of the jam could have been substantially higher. The water level at the proposed bridge location was estimated at 7.1 m for an equilibrium jam which would have a grounded toe at the same location of the 1970 jam. This is indicated in Figure 3 which shows the calculated ice jam levels from these analyses for a range of assumed toe conditions for the jam. The ice jam thickness at the proposed bridge was estimated at 3.5 m, the top of the floating ice would be 0.35 m above the water surface at an elevation of 7.45 m.

It was therefore recommended that the clearance of the bridge be increased so that the centre span elevation of 7.5 m be maintained throughout the length of the bridge. This level would provide a 3 m clearance above the known historic jam and would be sufficient to just clear the estimated maximum ice level calculated.

Examinations of higher tide level, such as storm surge conditions were not considered in the study. The 1970 flow, as an open water flow, had a return period of approximately 50 years. The timing of the highest flows on record indicate that the highest open water flows could occur during the ice breakup period and therefore a 1 in 100 years open water flow would be possible during the ice breakup period. The extreme flow used for the study was 7,200 m^3/s, 25% above the 1 in 100 year open water flow. The maximum water levels behind the ice jam were determined using the RIVJAM program based on a flow of 7,200 m^3/s and assuming sufficient ice is available in the river to form an equilibrium jam. Using these assumptions an equilibrium jam water level of 7.9 m at the proposed bridge location was estimated. These factors indicate that although the recommended level for the bridge appears high, it is not an overly conservative value. The recommended level could be refined based on more detailed studies to determine the maximum possible ice volume which would be available to an ice jam.

Conclusions

The use of the RIVJAM model provided a general confirmation of the initial estimates for maximum ice jam levels derived with the simplified models which use average cross-section and slope. It has provided a general confirmation of these levels even though the variable channel bathymetry occurring in the estuarial reach was included. It has also shown that the upper limit of the ice clearance recommended in RTAC (1981) would be applicable to the bridge site. The various water and ice levels determined in this study are summarized in Table 3. Although the ice jam which occurred in 1970 can be seen as a rare event it can not be ascertained, with present technology, that such an event could not re-occur. If a similar event were to occur, the ice levels reached during 1970 may be exceeded, and threaten the superstructure of the proposed bridge. It was recommended that more detailed studies be conducted to determine whether there is a physical limit to the volume of ice available to the ice jam. If it could be determined that such a limit exists, it would be possible to lower the maximum ice level determined in the original analyses.

The attempt to determine the safe clearance for a bridge in ice infested water often entails difficulties in collecting sufficient information to allow a proper estimate of past and future ice jam levels. The application of a number of models and estimating techniques, as was done in this study, allows a reasonable and safe estimate to be made. The RIVJAM model proved useful in this procedure, and allowed the investigation of the variation in possible ice levels along the length of the jam. Also, the model could be approximately calibrated using the siting information and the observed 1970 ice jam levels.

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Table 1 Data from 1970 Ice Jam

Toe Location	200 m downstream of proposed bridge
	500 m downstream of existing bridge
River Flow	5100 m^3/s
Return Period of River Flow	50 years (approx)
Maximum Water Level Behind Jam	4.2 m
Maximum Ice Level at Existing Bridge	4.5 m

Table 2 Flows Used in Study

1 in 20 year breakup flow	2,420 m^3/s
1 in 100 year breakup flow	3,550 m^3/s
1970 flow	5,100 m^3/s
1 in 100 year open water flow	6,030 m^3/s
Extreme Flow (100 yr + 25%)	7,200 m^3/s

Table 3: Comparison of Bridge Clearance for Various Design Conditions

Design Event	Flow	Max Water Level (m)	Max Ice Level (m)	Present Clearance[3]	Clearance for Recommended Design [4] (m)
Maximum Equilibrium Ice Jam	5000	7.05	7.4	-1.9	0.00
Historic Ice Jam Level	5000	4.5[1]	4.85[2]	0.65	2.55
100 Year Open Water Flood Flow (at extreme high tide)	5960	2.43	--	3.07	4.97
Extreme Open Water Flood Flow (100 yr. + 25% + extreme high tide)	7200	2.65	--	2.85	4.75
Extreme Flor + Ice Jam	7200	7.90	8.07	-2.57	-0.67
Historic Extreme Tide Level (Storm Surge)	--	3.8	--	1.7	3.60

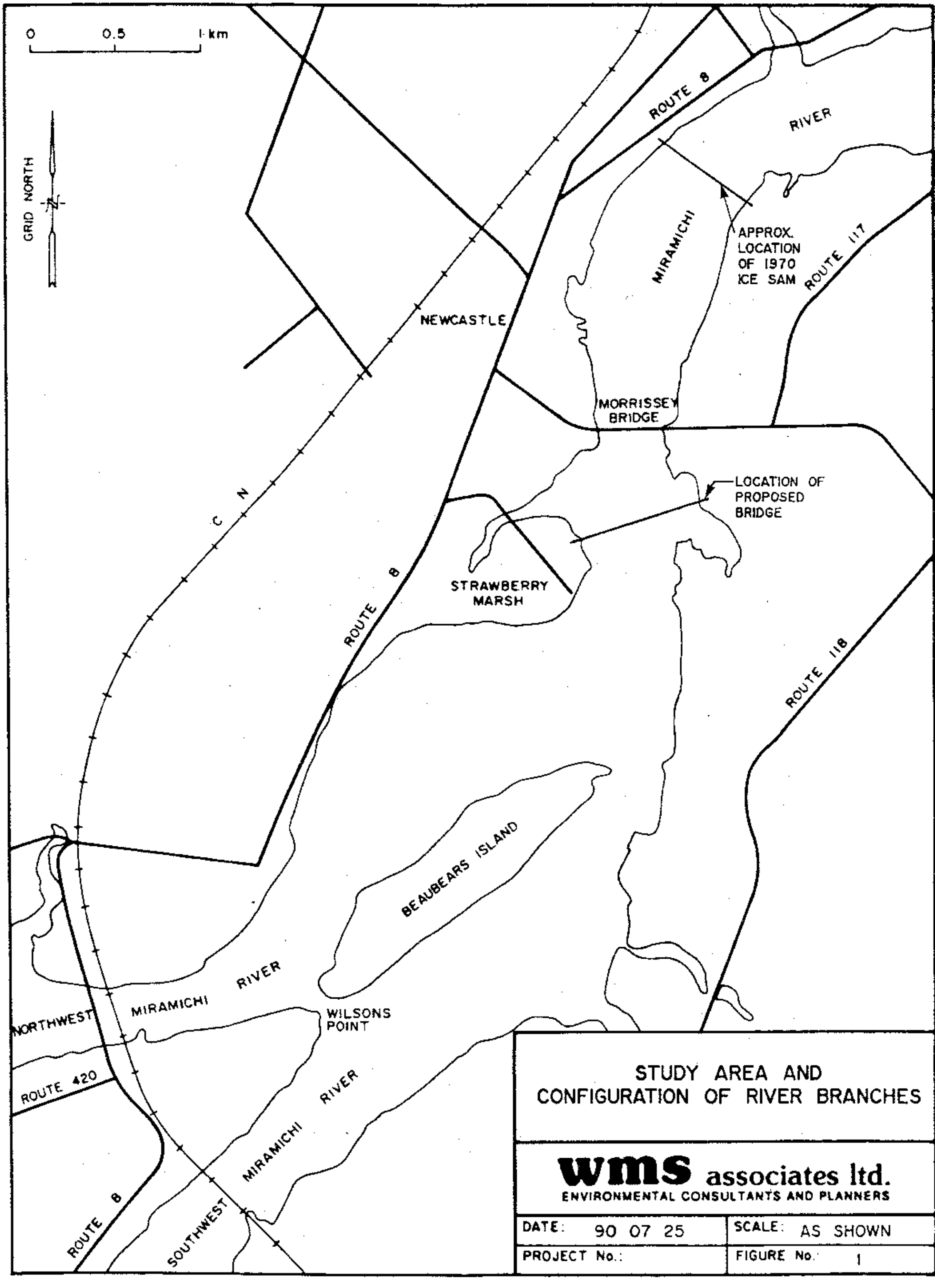
Notes:

1. Assuming 0.3 m higher than level at Morrissey Bridge, based on RIVJAM estimates for level between the two sites.

2. Assuming 3.5 m ice thickness with 10% above water.

3. Present design with minimum lower chord level of 5.5 m at abutments.

4. Recommended design clearance with minimum lower chord level of 7.4 m.



STUDY AREA AND CONFIGURATION OF RIVER BRANCHES

wms associates ltd.
ENVIRONMENTAL CONSULTANTS AND PLANNERS

DATE: 90 07 25	SCALE: AS SHOWN
PROJECT No.:	FIGURE No. 1

Figure 2
RIVJAM Analysis Results

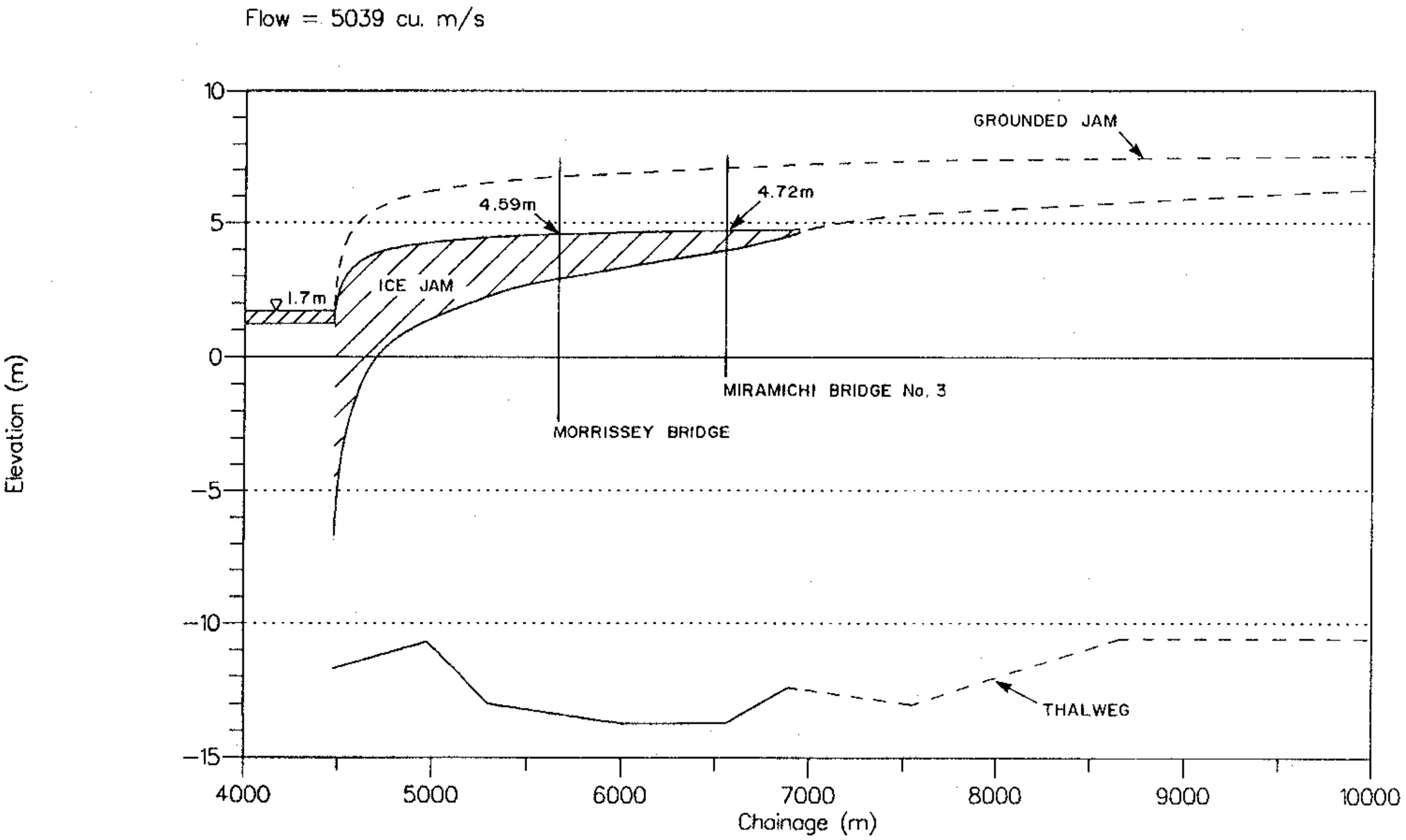


Figure 3

Ice Jam Levels

Comparison of estimated ice jam water levels for variation in toe conditions