RESEARCH NEEDS - RESULTS OF PANEL DISCUSSION

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ABSTRACT

The overall objective of the panel was to identify specific top priority research topics for better evaluation of river ice conditions and associated environmental impacts.

These published notes and discussions from the Workshop should help to improve the quality of proposals and future research results produced by universities, research institutes, and other organizations. The reader is also encouraged to refer to other references on research needs given by Gerard (1984), Prowse and Gridley (1993) and Wuebben *et al.* (1994).

Presented below is a number of specific research needs which have been identified by each of the panel members. This is followed by published discussions from the workshop participants. (Individuals mentioned in this report may be contacted from the addresses given in the "List of Participants" published in these Workshop Proceedings.)

Proceedings of the Workshop on Environmental Aspects of River Ice, T.D. Prowse (Editor), National Hydrology Research Institute, Saskatoon, Saskatchewan, 1993, NHRI Symposium Series No. 12, p. 177-195.

1.0 TWO-DIMENSIONAL MODELLING OF ICE JAMS UPSTREAM OF RIVER CONSTRICTIONS

1.1 Scope of Research Need

The current theory on ice jams is limited to one-dimensional analysis. That is, the changes in river cross-sections should be relatively gradual with distance (particularly with respect to the variation in the river width).

At relatively sharp natural or man-made river constrictions, such as at bridge approaches, one-dimensional ice jam theory is inadequate and very difficult to apply. The main objective of this research need is to develop a two-dimensional ice jam model which could be applied at river constrictions.

1.2 Application and Significance of Expected Results

The results are expected to greatly improve the accuracy of ice jam evaluation at natural and man-made constrictions. This includes bridge approach and bridge pier spacing evaluation, designing of excavation (or fill) profiles in a natural river to reduce ice jamming effects; docks, marinas and other constricting structures in a river; and evaluation of ice jams at the entrance to channels around islands in a river.

1.3 Research Approaches

Figure 1 illustrates the river bank shape effects on ice jam stability. The finite-element method can be used to solve the evolution of ice jams as a function of the bathymetry of the river, water discharge, ice discharge, hydraulic, and meteorologic conditions (particularly wind) as a function of time. Existing two-dimensional hydraulic models could be used to evaluate the hydraulic conditions under the ice cover.

The theory from the following two related fields should be helpful in developing the two dimensional ice accumulation model.

1) Two-dimensional finite-element models from soil mechanics;

2) Two-dimension models developed for modelling sea ice (Pritchard and Colony (1976)).

Figure 2 schematically illustrates the nature of expected ice forces of an ice jam on the South Nations River. The application of the one-dimensional SIMGLACE model did not yield satisfactory results without adjustment of the ice stability factor to field conditions (Rousseau *et al.* (1983)).

Description by: Sylvester Petryk

2.0 COHESION EFFECTS ON THE STABILITY OF ICE JAMS SUBJECT TO FREEZING

2.1 Scope of Research Need

Currently the stability and evolution of ice jams is determined under one of the following two hypotheses:

1) The ice accumulation is cohesionless, or;

2) The ice accumulation has cohesion where the shear term is considered in the following form:

$$F_c = 2ctL$$

Where

F_c = Force of cohesion of ice to two river banks

c = Cohesion per unit area of ice/bank interface

t = Average thickness of ice cover between cross sections

L = Distance between cross sections

The main problem is that there are no guidelines to evaluate "c". Also it is recognized that "c" is also variable as a function of solid ice cover freezing from the surface, and a function of compaction and inter-particle freezing in ice accumulations. Guidelines are required to evaluate "c" for difference field conditions associated with release of ice jams and hanging ice dams.

2.2 Application and Significance of Expected Results

The results would be applied for the evaluation of the release of ice jams and hanging ice dams under the following difficult conditions:

1) Release of an ice jam in the spring after its formation during a winter freshet. In this case freezing from the top has occurred after the ice jam formation as well as inter-particle freezing from the cold ice blocs which may take a number of hours to attain 0°C.

2) Release of hanging dams which were subject to ice processes which are described in Section 2.3.

The release of the ice jams/hanging dams is required for flood level calculations with numerical models. Currently only "good judgement" is used in estimating "c". Underestimating cohesion can result in premature calculated release of ice jams/hanging dams and significant under estimation of design flood levels.

Also, if unacceptable flood levels can occur due to important winter accumulations of ice, then mitigation measures can be considered, such as clearing of ice cover along the shore. This will lower the discharge at which the ice jam/hanging ice dam will release. After release, the ice accumulation is expected to loose its cohesion effects between ice blocks/ice particles. This hypothesis should be verified by research.

2.3 Possible Research Approach

1) Evaluate ice processes contributing to cohesion. These include :

   a) Inter-particle freezing of ice fragments which are submerged with an average internal temperature of less than 0°C.

   b) Freezing from the water surface down through the ice accumulation.

   c) Inter-particle freezing from super-cooled water. (This is believed to be major factor in forming "compact frazil" ice accumulation in hanging dams downstream of rapids).

   d) Compaction of ice accumulations.

2) Identify river sites where potential winter ice jams occur from winter freshets such as on the Chaudière River, and sites where frazil hanging dams occur downstream of rapids such as on the Smoky River upstream of the town of Peace River.

3) Monitor the above identified ice processes with field measurement of water temperature, ice accumulation thickness, surface freezing, which may be complimented by laboratory measurements of the rigidity of the ice accumulations until breakup.

4.0 IMPACTS OF RIVER ICE ON RIVERINE FISHES

The following list of research needs are aimed at understanding the impacts of river ice on the aquatic biota, specifically riverine fishes.

4.1 Measurement of Sub-Ice Habitat Space and Characteristics

The dynamics of ice in rivers can markedly affect habitat availability and suitability for aquatic biota. For example, hanging dams of frazil ice in pools can limit the amount of space available for fish to occupy for overwintering and flow patterns around such ice accumulations may preclude the use of the available space.

At present, no useful information exists for adequately quantifying aquatic habitats in ice-covered rivers. Further, the dynamics of ice is such that any evaluation needs to incorporate a spatial and a temporal component. Spatial evaluations could involve measurements among habitat-types (e.g. size and location). Temporal evaluations need to contrast the habitat changes during freeze-up, throughout the winter, and during break-up.

4.2 Validation and Modification of Predictive Models

Models for predicting the amount of aquatic habitat available to stream fishes (e.g. Instream Flow Incremental Methodology (IFIM)/(PHABSIM)) following discharge changes stemming from in-basin development are becoming increasingly popular in North America. Unfortunately, these models were not intended for use in ice-covered rivers as the hydraulic simulations and the species-specific habitat suitability curves do not account for the significant effects of ice and winter conditions. If such models are going to continue to be used, they will require modification and field testing to validate the predictions.

4.3 Behaviour of Fishes in Relation to River Ice Dynamics

Our understanding of the behaviour of fishes in winter is rudimentary although there has been considerable progress in the past 10 years. However, quantification of the effect of ice conditions on fish behaviour remains a mystery despite the acknowledgment of its probable importance to winter survival. This needs to be addressed to ensure sound species management in our rivers. The main problem for carrying out such research is the logistical complications of working under ice. Direct observations (snorkelling, SCUBA, u/w camera) could be employed in certain rivers. In other river systems, indirect methods of monitoring fish behaviour may be employed. For example, radio-tagging and subsequent tracking of individuals has proven to be an important tool for quantifying the sub-ice movements of sturgeon, salmon, trout and pike in many rivers and lakes. More likely, the development of innovative methodologies will be needed to monitor fish behaviour especially in the demanding circumstances surrounding ice formation and break-up events.

4.4 Do Man-Man Activities Affect River Ice-Biota Relations?

Although our basic understanding of the effects of ice on the aquatic biota is minimal, the situation becomes more complicated when anthropogenic effects are factored into the equation. Development within river basins will continue despite the need to determine "pre-impact" conditions. This inevitability underlines the need to address ice impact issues as soon as possible. Recent examples of such activities and their likely ice-related impacts include stream water withdrawal for ski-hill operations (snow-making), hydroelectric development, and downstream extent of pollution (mine spills, sewage disposal).

Description by: Rick Cunjak

5.0 DISPERSION AND MIXING OF EFFLUENTS UNDER ICE COVERS OF VARIOUS TYPES

5.1 Objectives

1) To determine near-field effluent distribution as affected by various arrangements and types of outfalls.

2) To delineate effluent plume geometry and concentration distribution of entities within it.

3) To investigate the effects of varying channel geometry on mixing of effluent.

4) To investigate the effects of river bends on mixing of effluents.

5) To compare these results with those for open water conditions.

5.2 Scope (see figure 3)

Initial investigations should aim at river channel reaches. Later investigations should consider estuarine zones; these are greatly complicated by tidal and saline intrusion effects.

5.3 Applications and Significance

1) Determining downstream concentrations of effluents from industrial plants (pulp and paper mills, food processing plants, municipal disposals, etc.).

2) Environmental and ecologic impacts of industrial effluent necessitate such research for the winter ice covered regime (3 or more months); government regulations now require monitoring and reporting to meet specifications.

Description by: Kersi Davar

6.0 EFFECTS OF DAMS/RESERVOIRS ON WINTER REGIME OF RIVERS

6.1 Objectives

1) To investigate the effects of constructing dams/reservoirs on ice cover formation, breakup and jamming, upstream and downstream of the site. The changes need to be compared to previous natural conditions.

2) To investigate the effects of operating reservoirs on ice cover breakup and ice jam development (changes in location, flooding levels, frequency of occurrence, etc.).

3) To investigate environmental and ecologic changes resulting from the reservoir developments.

6.2 Scope (see figure 4)

1) The resulting changes can extend long distances upstream and downstream, depending on type of reservoir and its pattern of operation.

2) Field data need to be collected systematically for long periods, covering many varieties of conditions. Such data collection is sometimes difficult due to reluctance of controlling agencies.

6.3 Applications and Significance

1) Planning for construction of new dams/reservoirs in cold regions makes such information invaluable.

2) Evaluation of the effects of operating dams/reservoirs during the winter regime makes necessary the availability of such information.

3) Court cases involving such problems, and amounting to millions of dollars, are floundering in the absence of definitive procedures for evaluation of changes.

Description by: Kersi Davar

7.0 DISSOLVED OXYGEN

Many human activities have the potential to modify natural dissolved oxygen concentrations. Fisheries and water managers want to maintain high D.O. levels while permitting water abstractions and waste discharges. Developers are required to quantify impacts during environmental assessment.

7.1 Scope of Research Need

Improved methods of describing and predicting D.O. in rivers are needed.

7.2 Application and Significance of Work

Rational methods of predicting D.O. concentrations resulting from new projects and changes to existing projects have the potential of reducing project costs and uncertainty with large cost benefits. Work by Environment Alberta and others on the Athabasca River demonstrates the value and importance of the subject.

Description by: Gerry Whitely

8.0 MEASUREMENTS AND ANALYSIS OF WATER CHEMISTRY DATA IN RIVERS

Instrument improvements have created the opportunity to collect some water chemistry data at high temporal resolution and in real time. Studies which previously were impossible due to sampling method and lab costs are becoming possible with "off the shelf" instruments.

8.1 Scope of Research

Measure changes in water chemistry simultaneously with ice breakup and formation events, variation of selected variables with solar inputs through ice and change through the ice thickening process.

Basic experience of deploying and retrieving instruments in rivers is needed.

8.2 Application and Significance of Work

This research would give us an opportunity to observe events in new and different ways. The results are expected to improve our understanding of the parameters affecting water quality and how to quantitatively evaluate their influence in ice covered rivers.

Description by: G. Whitely

9.0 FRAZIL ICE - ITS FORMATION AND EFFECT ON RIVER FLOWS

9.1 Scope of Research Need

The accuracy of river flow measurements and their translation into winter flow records is largely dependent on the consistency of the cross-sectional area at which the flow is measured. Depositions of frazil ice can rapidly change cross-sectional areas and hence adversely affect uncertainties of winter flow records. This problem can be minimized through avoidance i.e., measurement sites could be selected in river reaches where frazil ice production, transport and deposition are known to be minimal. This approach however, assumes a knowledge of frazil ice characteristics, knowledge which at present is unavailable for operational use.

9.2 Application and Significance of Expected Results

Accurate winter flow records are required for input to environmental impact assessments, etc.

9.3 Field Data Requirements

Comprehensive data sets are available at specific sites. For a more general or generic approach to this problem, data can be acquired to research project specifications.

Description by: Klaus Wiebe, Water Survey of Canada
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10.0 DISCUSSIONS BY WORKSHOP PARTICIPANTS

1) Fay Hicks: We have analyzed the hydraulic component of the "IFIM" model mentioned by Rick Cunjak, and have found it to be extremely inadequate because it is one-dimensional. A two-dimensional model is required to represent the variation of hydraulic conditions across the channel cross-section, as well as to have a more accurate description of flow conditions from section to section along the channel. Work is currently in progress to help satisfy this research need.

2) Norman C. Gridley: The variability of flow conditions on a small stream as a function of time and as a function of position along the stream may make it very difficult to model. For small streams new approaches should be considered. The uncertainties associated with habitat assessment in streams should be evaluated, and research priorities established to help improve our environmental assessment procedures and results.

3) Maurice Sydor: In general, there is more theory available, than can be applied to through well-documented numerical models. We need to work more on the application side through numerical modelling development work, documentation of case studies, and comparing field and laboratory measurements with new and previously developed theory. In relation to Gerry Whitley's presentation on water quality, it is very important to note that on major rivers the pollutants tend to hug the banks (the lateral dispersion can be very slow). We have observations to that effect on the St.-Lawrence River and have evaluated lateral mixing with 2-d models. For certain applications we need 3-d models (or at least the so-called "2.5-d" models) to model flow conditions - such as modelling the salinity of stratified flow in estuaries.

4) Geoff Power: When you ask a physical habitat modeller to give you a detailed description of the kinds and quantities of habitats that exist in a given river, you are assuming you know why the habitats are there and why the

habitats are important to your ecosystem. In fact very often you do not, and we can not identify the critical periods in the lives of the organisms that we are trying to protect. In other words we have trouble identifying and evaluating some of the most critical parameters in our ecosystem.

5) Mike Ferrick: Numerical models are only as strong as the weakest link. Research in improvement of numerical models should be directed at defining which are the weakest links and directing our efforts at solving them.

6) Terry Prouse: There is a great deal of interest in oxygen modelling. One of the biggest concerns is the effect of the pulp mills on the water quality of the Athabasca river. This is a hot topic; there is a great deal of interest from an industrial as well as the researchers' point of view.

7) Hanson Chang: Winter measurements are typically required to calibrate numerical models. However, measurements in rivers under the various possible ice conditions are difficult. Therefore there is a research need to develop better instrumentation and procedures measurement of water discharge, ice discharge, flow velocity, precise water temperature and many other types of measurements.

8) Kersi Davar: For multi-disciplinary projects such as suggested by Darryl Calkins, the project management structure may be a major factor for its success. One option is to call all the required specialists to one office to work on the project together. Another approach is to define the problems, the disciplines required, and to call all the specialists together for project progress meetings after completing each project phase. In addition, there are a number of other options besides these two.

11.0 REFERENCES

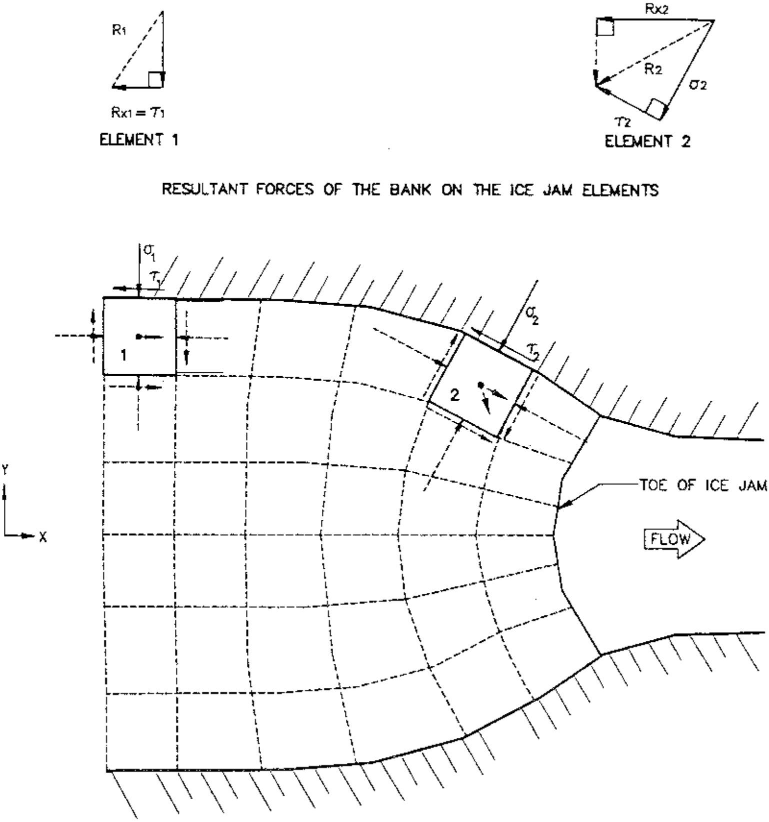
1) Gerard, R. (1984). "Ice Jam Research Needs". 4th Workshop on the Hydraulics of River Ice, Fredericton, N.B.

2) Pritchard, R.S. and R. Colony (1976), "A Difference Scheme for the AIDJEX Sea Ice Model" published in "Numerical Methods in Geomechanics by C.S. Desai (editor), ASCE, pages 1194-1209.

3) Prouse, T. and Gridley, N. (1993) - editors. "Environmental Aspects of River Ice". Report of the Task Force, Published by the National Hydrology Institute, Saskatoon, Sask.

4) Rousseau, Sauvé, Warren, Inc. et Hydro-Québec (1983), "SIMGLACE - Documentation du programme".

5) Wuebben, J. (editor). (1994). "Research Needs in River Ice Hydraulics". Report to be published by the IAHR Working Group on River Ice Hydraulics.



— FORCE OF THE RIVER BANK ON THE ICE JAM

— OTHER INTERNAL FORCES (SHEAR AND COMPRESSIVE STRESSES AND WEIGHT COMPONENT) AND EXTERNAL FORCES (DRAG FORCES OF WIND AND WATER)

τ_1, τ_2 — BANK SHEAR FORCES ON ELEMENTS 1 AND 2 RESPECTIVELY

σ_1, σ_2 — BANK COMPRESSIVE FORCES ON ELEMENTS 1 AND 2 RESPECTIVELY

R_1, R_2 — RESULTANT FORCES OF THE BANK ON THE ICE JAM ELEMENT 1 AND 2 RESPECTIVELY

R_{x1}, R_{x2} — RESULTANT LONGITUDINAL FORCES OF THE BANK ON ELEMENTS 1 AND 2 RESPECTIVELY

FIGURE 1 — ILLUSTRATION OF RIVER BANK SHAPE EFFECTS ON ICE JAM STABILITY

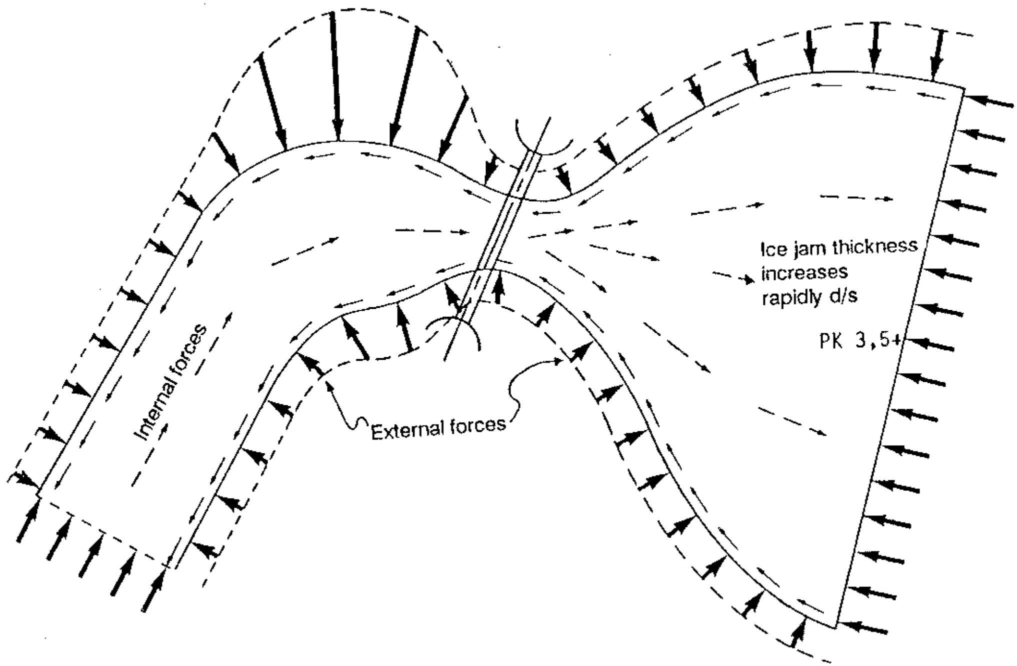


Figure 2 : South Nation River - Sketch of Expected Internal and External Forces on the Ice Jam Around the Bridge

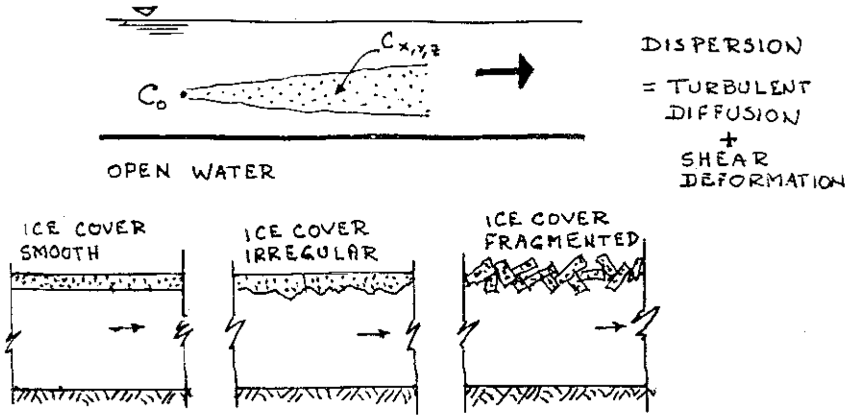


Figure 3: Dispersion and mixing of effluents under ice covers of various types

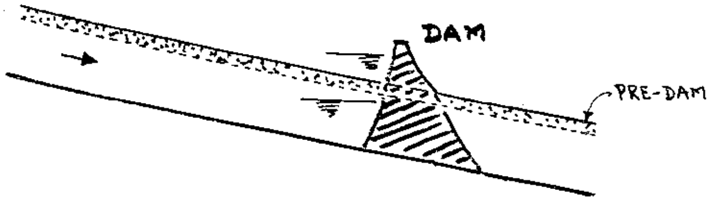


Figure 4: Effects of dams/reservoirs on winter regime of rivers