AN ICE ENGINEERING OVERVIEW

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ABSTRACT

The impact of river and lake ice on the private, economic and working lives of North Americans tends to be discounted, poorly documented and poorly understood. The purpose of this paper is to stimulate thought about the broader aspects of the field of Ice Science and Engineering that are normally not covered in technical papers. This is an "Ice is big, ice is important, let's give it due consideration" kind of discussion.

BACKGROUND

Most of Canada is ice covered at least six months of the year (Figure 1). This ice reduces winter flow capacity for hydro-electricity production, creates pressure on hydraulic structures, obstructs water intakes, contributes to shoreline erosion, causes scour under ice jams and hanging dams, isolates communities during freeze-up and break-up, impacts on fish movement and survival, blocks winter ship navigation, creates or worsens floods and generally increases the cost of design, maintenance and operation of engineering works.

Number of Months of Water Body Ice Cover in Canada

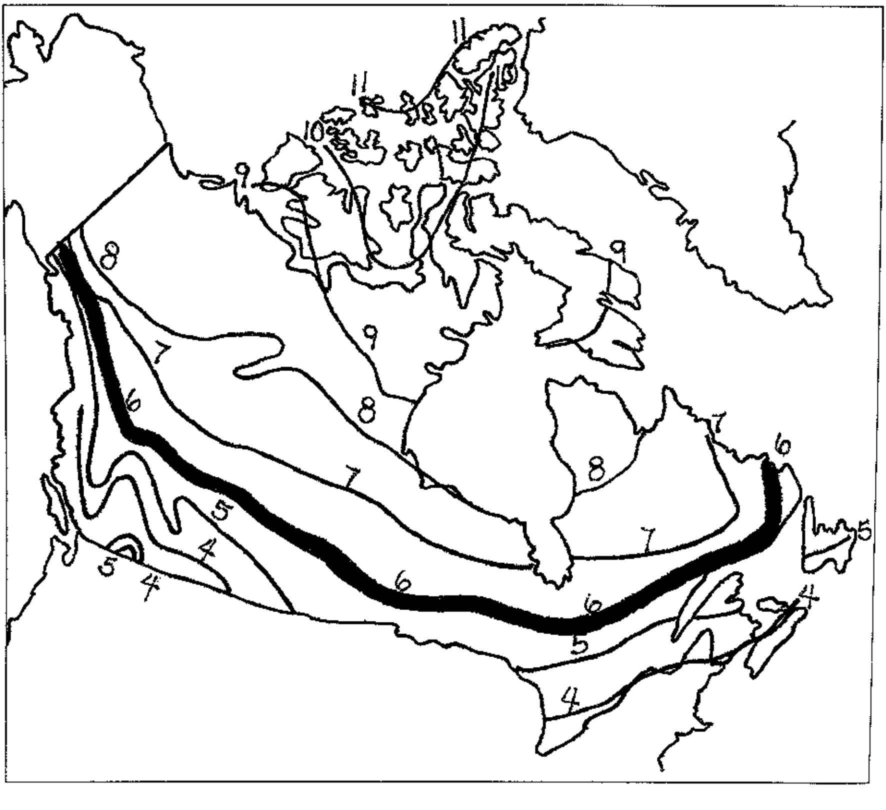

Figure 1

On the other hand, ice can be a valuable resource. It makes a good floating work platform for exploration and construction, enables ground transportation to remote communities, offers recreational opportunities, replenishes the habitat for many aquatic/terrestrial/avian animals by temporarily flooding deltas and it reduces evaporation.

ECONOMIC IMPACTS

Manitoba Hydro has spent $10's to $100's of millions of dollars to accommodate the impact of ice in the planning, design and construction of major capital works. The Corporation loses $10's of millions each year in hydro-electricity production because of the resistance to flow caused by ice, loss of head and because of the need to modify operations to accommodate ice. Manitoba Hydro spends $500 000 annually to monitor ice covered waterways and $50 000 annually to manage specific ice problems.

If ice costs one industry in one province of Canada $100's of millions, the cost to all the industries and citizens of North America and the other cold climate areas of the world must be many billions annually. Consider what fraction of this could be saved if we knew all there is to know about ice processes. At present, we may be spending too little on ice research.

We do have a limited number of ice specialists scattered around the northern hemisphere. However, each specialist tends to have detailed knowledge in only a few of the many ice processes.

Ice scientists must be concerned with a broad range of thermal, mechanical and dynamic ice processes, forms and properties. These include blue/white ice growth, cracking, jacking, break-up, freeze-up, thickness, strength, border ice, hanging dams, hinging, candling, juxtaposition, floes, jams, shoves, pressure, pressure ridges, hummocking, stability, friction, cohesion, agglomeration, impact, scour, inclusions, frazil, runs, pans, flocks, flooding, slush over, slush under, sheets, booms, bridging, roughness, anchor ice and aufeis. Ice scientists must develop the relationships and understanding required by engineers to deal with these manifestations.

OPTIMIZING RESEARCH RESOURCES

The science and application of ice engineering are quite juvenile compared to the more mature disciplines of open water hydraulics, hydrology and meteorology. Research can be classed as fundamental, practical and innovative. We must optimize the use of our limited resources among these unique research areas.

Excellent fundamental research has been done by scientists and engineers in North America and throughout the northern countries of the globe. This work was summarized in books by Michel in 1978, Ashton in 1986, Beltaos in 1995, Shen (book in progress - due 1996) and perhaps others. The researchers however, will probably be the first to admit that we have a long way to go in the development of basic relationships and understandings in ice science. The development of centres of excellence at institutes of learning has been touted as a good way to address fundamental research.

The development of the RIVICE model (see for example, Martinson et all, 1993) is an excellent attempt to assemble the results of fundamental research from all corners of the world into a practical package for use by engineers. I hope that this model becomes the tool of preference for ice engineers. If it does not, the development will at least have helped us identify areas of required research.

Most of us have yet to explore the application of expert systems, artificial neural networks, fuzzy logic and other modern and innovative techniques to solve practical ice engineering problems.

EXAMPLES OF RESEARCH NEEDS

The "Committee on River Ice Processes and the Environment" is affiliated with the Canadian Geophysical Union, Hydrology Section. This group has done some canvassing and has identified several areas of research that could be worth pursuing. The following list is fleshed out in a paper in progress by Beltaos et al (1995/96) which is contained in these proceedings:

- Academic requirements in ice engineering.
- Evaluation of stability and breakup of solid ice covers. Interactions between ice runs and intact ice covers.
- Use of Radarsat SAR images to evaluate river ice conditions.
- Two dimensional modeling of ice jams upstream of a constriction.
- Development of a frazil, anchor ice and border ice model with the help of Project Archipel data.
- Methods of accelerating the formation of stable and smooth ice covers.
- Cohesion effects on the stability of ice jams subject to freezing.
- Evaluation of maximum ice impact loads on control structure gates.

THE FUTURE

We have entered an era where industry and government are both exercising fiscal restraint. Given this change, we must ensure that the importance of our discipline is recognized and appreciated, not only by the public and government agencies but by decision makers within our own organizations. We must ensure that appropriate resources are allocated to ice research and problem solving. The $100's of millions lost to ice by individual organizations warrants a significant investment in support of basic research and development.

It has never been more important than right now to ensure that there is a sound succession plan for experts in our discipline. The ice science and engineering community has, in the past few years, lost most of the experienced ice academics.

Action must be taken while there are still enough experienced people available to kindle the interest of the next generation and to pass on the science.

OUR ROLE

Nations - Canadians, Americans, Europeans and Asians face many common ice problems. Cold climate nations have to find ways to work together to solve these problems. The current cooperative effort between Dr. H. T. Shen at Clarkson University in New York and L. Hammar of Lulea University of Technology in Sweden is a good example of international cooperation. The Canada/USA utility consortium that supported frazil and anchor ice research at the National Water Research Institute is a good example from the recent past. All participants benefit from these international contacts. We must foster and encourage this type of activity.

Government - Research areas seem to be hardest hit by cutbacks as governments at all levels reduce spending. We must promote Ice Engineering research more vigorously to secure an appropriate share of the limited research funding.

Industry - Often industry is not aware of the extent and cost of ice problems to their operations. They are also prone to accepting ice problems as unmanageable. The Committee on River Ice Processes and the Environment (CRIPE) intends to quantify the costs of ice to hydro-power utilities. The hope is that this information will prompt these utilities to support ice research. Similar efforts may be appropriate for other ice affected industries.

Academia - There is room to establish and support at least three centers of excellence in ice engineering at universities in North America. The University of Manitoba is a willing host for one of these. In Canada, government support for such centres is more and more contingent on industry support than it has been in the past. Manitoba Hydro could be a "flagship" industry supporter of this activity at the University of Manitoba if there is adequate support from other areas. Clarkson University is well on its way and the University of Alberta has indicated an interest in pursuing a complementary program.

The scientific and engineering community has to collaborate and coordinate its efforts with the recognition that resources are scarce. The Committee on River Ice Processes and the Environment provides a good forum for this activity.

REFERENCES

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