

FORT MCMURRAY ICE CONTROL STUDY
SUMMARIES OF REFERENCE MATERIAL

December, 1978

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FORT McMURRAY ICE CONTROL STUDY

SUMMARIES OF REFERENCE MATERIAL

DRAFT

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ICE CONTROL METHODS APPLICABLE TO FORT McMURRAY

A long list, summarizing ice control methods in general, was prepared as Appendix A to the Fort McMurray Ice Control Study proposal. The list was divided into three categories:

- action downstream
- action upstream
- other measures.

When evaluating ice control methods for Fort McMurray, it must be kept in mind that breakup occurs in the headwaters first on north flowing rivers. Severe ice jams form when ice floes moving downstream reach still frozen accumulations of ice in northerly river reaches especially at the marked change in river regime¹¹ near Fort McMurray. Furthermore, at Fort McMurray on the Athabasca River, breakup may be characterised by a sudden wave of water and ice which occurs when an ice jam washes out under the pressure of water building up upstream.

To determine the applicability of these methods to Fort McMurray, a literature search was conducted to examine relevant previous operating experience and site requirements. This review, along with an overview of hydraulic conditions on the Athabasca River, permitted the screening of all available ice control measures to identify those with greatest potential for success in this case.

Action Downstream

The success of downstream ice cover modification depends on the provision of an adequate length of unobstructed river channel to accommodate the ice moving downstream without jamming. The reliability of ice dusting, blasting or ice

breaking with hovercraft to promote early breakup of ice downstream from Fort McMurray is questionable. The thermal reserve of rivers is generally inadequate to successfully operate bubbler systems, and there is no source of thermal waste to modify ice cover conditions. Furthermore, it is difficult to confidently determine the capability of the river channel to pass any ice and water flood wave. Based on these considerations, downstream solutions were eliminated as a primary ice control measure in this instance. ?

Action Upstream

The success of upstream ice retention works to control ice jamming is promising. Various combinations of booms and ice control structures can be examined to determine their effectiveness and economic feasibility. A drawback to ice booms is the yearly installation and maintenance required. A series of opposing groin structures requiring little maintenance would be an attractive method of delaying breakup along the river if it could be shown to be reliable and effective even for moderately rare design conditions. Alternatively, however, if a single upstream location is identified as a chronic jam site that can cause the flood wave phenomenon observed, a permanent ice control structure could be used to eliminate the jam site. Additional hydraulic studies are required to identify the most advantageous types and locations of control measures.

Other Measures

In consideration of other methods of reducing ice jamming and/or combatting flood damages, the expense of river channel modification and the uncertainty related to any design to accommodate a sudden influx of water and ice eliminates

those methods from the list of reliable ice control methods. Diking to control floodwaters has a major drawback since, if the dikes are overtopped, the floodwater cannot escape and damage due to prolonged high flood levels is much more severe. In addition, there are local drainage problems. These alternatives were therefore eliminated from consideration as primary solutions.

Conclusions

Based on a review of available literature and ice conditions at Fort McMurray, the preferred method of ice control involves retention of the ice upstream, eliminating problems at the source. Initially, an attractive solution appears to be installation of one or more ice control elements. These elements would serve to retain ice upstream from Fort McMurray and promote melting in place and strength reduction. Further hydraulic and design computations are required to identify the best alternatives. If a major structure is required to change hydraulic conditions at a jam site, consideration must be given to the possibility of combining this ice control function with hydroelectric power generation.



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

G. D. Ashton
"Use of Air Bubbler Systems to Suppress Ice"
Unofficial memorandum, USA CRRELL
March
1974

No.

AS 74

SUMMARY

Two-dimensional line source bubbler systems used to induce convective melting of the undersurface of an ice cover are analyzed and a procedure developed for predicting the effectiveness of such a system. Various field conditions are considered and limitations to effectiveness pointed out. Example applications of the concepts and the procedures are illustrated in Appendices.

KEYWORDS

bubbler systems

REVIEWED BY

A. B. Cammaert

DATE

January 4, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

G. D. Ashton
"Experimental Evaluation of Bubbler-Induced
Heat Transfer Coefficients"
3rd International Symposium on Ice Problems
Hanover
1975

No.

AS 75

SUMMARY

The results of laboratory experiments to evaluate the heat transfer coefficients associated with flow induced by a line source bubbler system are reported. The heat transfer coefficients, both in the impingement area and laterally outward from the axis of the impingement region, were evaluated by observation of melting rates induced at the underside of an ice cover formed in a large cold room. The experimental results are compared and interpreted in light of an analytical model previously developed. Implications for field applications of bubbler systems are discussed.

KEYWORDS

bubbler systems

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Ashton, G. D.

"Numerical simulation of air bubbler systems"
Third National Hydrotechnical Conference, Canada
Quebec
1977

No.

As 77

SUMMARY

The use of air bubbler systems to suppress ice formation is a technique which has been applied in a variety of situations and with varying degrees of success.

The simulation presented uses a steady state analysis developed earlier (Ashton, 1974) and steps it in time with each new condition determined from the results of the previous time step. In this sense the analysis may be considered quasi-steady.

Results of the simulation are presented for an example case for a winter in Duluth, Minnesota, and illustrate selection of time step size, effect of various strategies of intermittent operation, and variation in width of open water with changing weather conditions.

KEYWORDS

air bubbles
ice control

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

No.

W. D. Baines
"The Principles of Operation of Bubbling Systems"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

BA 61

SUMMARY

The function of the air bubbler is to increase the transport of heat from a body of water to the ice cover or open upper surface. In this paper the rate at which this heat transport takes place will be discussed. Ideally, the air bubbler should be designed for the minimum rate of heat transport so that the heat in the lake or river will be available for the maximum length of time. This is not feasible because of several gaps in the theory which prevent the complete detailed analysis from being made. Nevertheless, sufficient is known of the heat flow so that the general principles of operation can be delineated. It is thus possible to avoid serious mistakes in the design of air bubblers.

KEYWORDS

Air bubblers

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Bauer, A. and Workman, J. L.
"Explosives for ice blasting"
Seminar on Ice Jams in Canada
NRC Technical Memorandum No. 107
1973

No.

Ba 73

SUMMARY

Blasting techniques are described for removing different ice jam types. Successful blasting depends on size and placement of the proper explosive.

KEYWORDS

explosives
ice blasting
ice jams

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Bolsenga, S. J.

"River Ice Jams - A Literature Review"

U.S. Lake Survey Research Report 5-5

Department of the Army Corps of Engineers

1968

No.

Bo 68

SUMMARY

A comprehensive review of literature on ice jamming published before 1968, includes a section on Ice Jam Prevention and Removal. All methods of ice control are summarized with extensive references.

KEYWORDS

ice jams

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

W. D. Bonisteel and A. Bergs
"Investigation of a Compressed Air Bubbler System Used
For Ice Melting"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

BO 61

SUMMARY

Rainy Lake is the main obstacle in the path of a highway between Atikokan and Ft. Frances, Ontario. When completed, the Rainy Lake Causeway will carry the highway across the lake providing a direct route for traffic between the two centres.

Two islands in the lake divide the causeway into three separate bridge sections. The two easterly spans support the highway about 15 ft above the water and are together known as the low-level section. The westerly spans are elevated to accommodate logging and navigational operations on the lake and are referred to as the high-level section.

To limit the effect of ice pressure on the steel piles supporting the superstructure a "bubbler" system will be utilized. The first portion of the bubbler system was installed during December 1960. The remainder of the system will follow construction of the high-level section of the causeway.

The purpose of the investigation was to collect information on the de-icing system as installed on the low-level section of the Rainy Lake Causeway. The data obtained from the experiments with this system are correlated with those of other installations as recorded in the technical literature. It is expected that this information will be useful for the design of the remainder of the bubbler system on the Causeway. It is also intended to provide design information for bubbler systems in general.

KEYWORDS

bubbler systems

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Boulanger, F., Dumalo, E., Le Van, D. and Racicot, L.
"Ice Control Study, Lake St. Francis-Beauharnois Canal"
Third International Symposium on Ice Problems
Hanover, N. H.
1975

No.

Bo 75

SUMMARY

Ice problems associated with the joint usage of the Beauharnois Canal for navigation and hydroelectric power production are discussed. The results of model tests to determine the installation of ice booms to promote the formation of a stable ice cover are discussed.

KEYWORDS

ice booms
ice control

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Bryce, J. B.
"Ice and River Control"
ASCE Journal of the Power Division
November, 1968

No.

Br 68

SUMMARY

Control of ice on the Niagara and St. Lawrence Rivers for hydro-electric power production is discussed. Ice problems encountered and the most effective measures taken to control the rivers are described, specifically, channel enlargements and ice booms.

KEYWORDS

ice booms
ice control
ice jams

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Burgi, P. H.

"Hydraulic Model Studies of Ice Booms to
Control River Ice"

Third International Symposium on Ice Problems
Hanover, N. H.
1975

No.

Bu 75

SUMMARY

Hydraulic model tests were performed to optimize the design of an ice boom structure for ice control on the North Platte River. The effect of parameters, such as cable sag and timber spikes, on ice retention were tested. Also, two artificial constrictions to decrease flow velocity were tested, a submerged weir and a pair of opposing jetties.

KEYWORDS

ice booms
ice control

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Calkins, D. J. and Ashton, G.D.
"Arching of Fragmented Covers"
Second Canadian Hydrotechnical Conference
Burlington
1975

No.

Ca 75

SUMMARY

A laboratory study was conducted to determine factors affecting ice arching at a gap in a boom and ice retention with ship passage through the gap in the boom. The tests led to formulation of an arching criteria.

KEYWORDS

ice booms
ice arching
ice control

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Calkins, D. J.

"Arching of Model Ice Floes at Bridge Piers"
Fourth International Symposium on Ice Problems.
Lulea, Sweden
1978

No.

Ca 78

SUMMARY

A model study of the formation of ice arching at the upstream faces of rounded bridge piers was conducted in a hydraulic flume using polyethylene simulated ice floes. A relationship to determine arching and nonarching conditions was determined.

KEYWORDS

ice arching
ice jams

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Carey, K. L.
"Performance of the Demonstration Bubbler System
Duluth Harbor, Minnesota"
USACRREL, Technical Note
1971

No.

CA 71

SUMMARY

As part of the demonstration bubbler project in Duluth Harbor, USACRREL was invited to perform observations and measurements, and to provide a technical assessment of the operation of the bubbler system. The fundamental variable governing the performance of a bubbler system is water temperature. Thus it was decided that water temperature measurements would be obtained before and during the operation of the system, to monitor the extraction of heat from the harbor waters. USACRREL also provided recommendations for monitoring the width of the thawed openings by local personnel.

KEYWORDS

Bubbler system , Great Lakes

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Carey, K. L.
"Performance of the Demonstration Bubbler System
Lime Island Turn, St. Marys River, Michigan"
USACRREL Technical Memorandum
June 1972

No.

CA 72

SUMMARY

As part of the Great Lakes and St. Lawrence Seaway Navigation Season Extension - Demonstration Program, USACRREL was invited to perform observations and measurements, and to provide a technical assessment of the operation of the bubbler system installed at the Lime Island Turn of the St. Marys River. The fundamental variable governing the performance of a bubbler system is water temperature. Thus water temperature measurements were obtained during the operation of the system, in an effort to monitor the extraction of heat from the river water. USACRREL also provided recommendations for monitoring the width of the thawed openings by local personnel.

KEYWORDS

Bubbler system, Great Lakes

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Clinch, R. C., Millman, R.N. and Erickson, O. M.
"Ice Problems at McCormick Dam: Tests on a Pilot
Bubbler System"
Proceedings, 8th Congress, IAHR, Vol III
Seminar No. 1, Ice Problems in Hydraulic Structures
1959

No.

C1 59

SUMMARY

The paper describes the design and operation of a bubbler system to reduce ice pressures against the gravity dam and spillway. The results of one season of operation and recommended procedure for future operation are reported.

KEYWORDS

ice control
air bubbles

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Cook, R. G. and Wade, M. D.
"Successful Ice Dusting at Fairbanks, Alaska, 1966"
Journal of the Hydraulics Division
Proceedings of the ASCE
Volume 94, No. HY1
January, 1968

No.

CO 68

SUMMARY

The ice and snow cover of the Chena River was dusted with coal dust and fly ash in the spring of 1966 to increase the absorption of solar energy and hasten melting. Because of a near-record snowfall during the winter of 1965-1966, a good deal of concern was felt for the flood damage which would result if an ice jam were to form at the mouth of the Chena River just downstream from Fairbanks. It was hoped that dusting would increase the absorption of the solar radiation to sufficiently weaken and melt the ice to prevent a jam. Theoretically, dusting could increase the radiation absorbed at breakup time in Fairbanks enough to melt an additional 2 cm of ice per day. Measurements of melting rates made in the dusted and clean sections of the river and observations of the river during breakup showed that dusting apparently had a significant beneficial effect. Because of its specific nature and lack of control, this experiment cannot be considered conclusive.

KEYWORDS

Ice dusting, Alaska

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Danys, J. V.

"Ice Movement Control by the Artificial Islands in
Lac St. Pierre"

Third International Symposium on Ice Problems

Hanover, N. H.

1975

No.

Da 75

SUMMARY

Ice breakers maintain an open channel across Lac St. Pierre throughout the winter for flood control and winter navigation purposes. In addition to ice booms and piers, artificial islands constructed to restrict ice movement have proven to be successful in maintaining an open navigation channel and reducing flooding caused by ice jams.

KEYWORDS

artificial islands
ice booms
ice control

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Danys, J. V.

"Ice Management of Lac St. Pierre"

Third National Hydrotechnical Conference, Canada

Quebec

1977

No.

Da 77

SUMMARY

The narrow outlet to Lac St. Pierre on the St. Lawrence River downstream from Montreal restricts movement of ice which resulted in ice jams and flooding prior to 1960. Ice booms, artificial islands and piers, introduced to control ice movement, have successfully eliminated flooding at Montreal and navigation to Montreal is now possible on a year-round basis.

KEYWORDS

artificial islands
ice booms
ice control

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Degtyarev, V. V., Butyagin, I. P. and Morgunov, V. K.
"Investigations of Ice Jams on the Siberian Rivers and
Measures Taken to Prevent Them"
Third International Symposium on Ice Problems
Hanover, N. H.
1975

No.

De 75

SUMMARY

In the USSR, the most severe jams occur on rivers flowing northward and breaking up in the headwaters first.

Blasting to remove jams already formed is expensive and of limited effect. Blasting to destroy the cover at probable ice jam locations is not very effective and overly detrimental to aquatic life.

Preventive measures appear to be the solution to ice jam problems. Ice dusting and cutting of ice have yielded only fair results. Shifting the ice jam location to a safe spot has proved to be effective with the installation of ice booms or some other means for anchoring ice to the banks. The most reliable means of ice control is a series of regulating structures or hydroelectric stations to control the hydrological regime of the river.

KEYWORDS

ice blasting
ice booms
ice control
ice jams

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Dengo, D.

"Ice Control on the Rideau River, Ottawa"
Seminar on Ice Jams in Canada
NRC Technical Memorandum No. 107
1973

No.

De 73

SUMMARY

Each year before the spring freshet, a program of ice cutting and blasting is conducted on the Rideau River between Rideau Falls where it empties into the Ottawa River and Hog's Back where it enters the City of Ottawa. The operation induces early break-up of the river and subsequent break-up of upstream river reaches occurs without jamming.

The ice cutting and blasting procedure is described.

KEYWORDS

ice blasting
ice cutting
ice jams

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Deslauriers, C. E.

"Projects to Alleviate Ice Jams on the Chaudiere River
in Quebec"

Proceedings, Eastern Snow Conference
1965

No.

De 65

SUMMARY

Observations of the ice regime on the Chaudiere River were made to determine characteristics of ice cover formation and break-up. It was concluded that a program to weaken the cover at potential jam sites using ice dusting and explosives was less effective than permanent regularization of the river with ice detention works and river channelization.

KEYWORDS

ice control
ice jams

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R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

T. M. Dick
"Description of Air Bubbling Systems at
Cambridge Bay and Tuktoyaktuk N.W.T."
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

DI 61

SUMMARY

Owing to their remote location, wharves in Arctic waters are costly to repair when damaged by ice. To combat this, the Harbours and Rivers Branch (Department of Public Works) has installed pneumatic de-icing systems at Tuktoyaktuk, at the mouth of the Mackenzie River, and at Cambridge Bay on the southern shore of Victoria Island. It is hoped that the air bubbles will prevent thick ice freezing to the piles and lifting them as the tide rises. Open water is not necessary to prevent uplift. It is sufficient to reduce the thickness of the ice so that it will fail before the pile is lifted.

KEYWORDS

bubbler systems, Arctic

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A. B. Cammaert

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

T. M. Dick
"Limits to Navigation by Ice in Port of Churchill"
Journal of the Waterways and Harbors Division
Proc. of the ASCE, Volume 93, No. WW4, November 1967.

No.

DI67

SUMMARY

Churchill Harbor lies on the western shore of Hudson Bay at the mouth of the Churchill River. Ice conditions in the harbor limit the navigation to the period from July to October. Icing conditions in the Hudson Bay, Hudson Strait, and in the Churchill Harbor are discussed.

Ice concentration at the shipping berth and dock is aggravated by the action of surface currents which force the pancake and frazil ice against the dock face during the ebb tide, forming a band approximately 0.2 to 0.3 miles across. It has been calculated that the harbor becomes unnavigable about 22 days in advance of the average final freezeup.

The only ice management techniques investigated was the diversion of flow for the river, which would inhibit frazil ice production, and reduce the volume of ice.

KEYWORDS

Arctic

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DATE



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Donnelly, P.

"An Outline of the Design and Operation of the Montreal Ice Control Structure"

Conference on Ice Pressures Against Structures

NRC Technical Memorandum No. 92

1968

No.

Do 68

SUMMARY

To minimize the danger of winter floods caused by ice jams, a special ice control structure was built across the St. Lawrence River at the lower end of LaPrairie Basin about 3 miles upstream of the EXPO '67 site at Montreal. The structure consists of 72 reinforced concrete piers and fitted removable floating steel stop logs. The stop logs permit the early formation of an ice cover on LaPrairie Basin without the jamming associated with natural cover formation at that site.

The report describes the ice problem in the Montreal area of the St. Lawrence, summarizes the results of hydraulic model studies testing the effectiveness of the structure, describes briefly the design of the structure and notes experience gained after one season of operation.

KEYWORDS

ice control

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

W. A. Dotson
"Operational Details of Project Polynya"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

DO 61

SUMMARY

In the fall of 1958 COMSTSLANTAREA was confronted with the task of extending the shipping season at Thule, Greenland, into the freezeup season. Using information obtained from published accounts of successful air-bubble de-icing and ice prevention techniques utilized in Scandinavian countries, United States and Canada, it was decided to attempt the installation of a de-icing system at Thule, Greenland.

As a result of experience in air bubble de-icing and ice prevention in both Sweden and Canada, Atlas Copco Eastern Inc., of Toronto, Ontario, was contacted for advice and technical assistance. Several other possible suppliers of desired equipment were contacted but the necessity of immediate delivery of equipment proved to be a problem. Further, owing to lack of experience, no agency could furnish the technical assistance required. Atlas Copco Eastern, Inc., at Paramus, New Jersey, contracted to furnish all technical and material assistance for initial installation.

KEYWORDS

Greenland, bubbler systems

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ALBERTA ENVIRONMENT
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SUMMARY OF REFERENCE MATERIAL

SOURCE

Foulds, D. M.

"Modification of Ice Covers and Subsequent Runoff by Man-Made Structures"

Proceedings of Banff Symposium - The Rate of Ice and Snow in Hydrology
Banff, 1972

No.

Fo 72

SUMMARY

Case histories of 3 rivers are used to illustrate the influence of dams, ice booms and hydroelectric power generation on ice cover formation and control of ice movement.

Long northward flowing rivers have potentially the worst situation where the headwaters may be in spring flood while the outlet is still choked with ice.

Major ice problems have been solved in the Niagara River with the use of ice booms. Even with seiching of as much as 2 m, the massive ice runs of the past have been reduced in magnitude and frequency.

The most successful solution to ice jam problems is concluded to be the formation of a stable ice cover. Man-made structures have accelerated the rate of formation of covers, improved the ability of rivers to transport water under the ice cover, restricted ice movement into critical areas and greatly reduced the severity and frequency of jams.

KEYWORDS

ice control
ice booms
ice cover formation

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DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Foulds, D. M.

"Ice Booms, Diversions and Ice Control Structures"
Seminar on Ice Jams in Canada
NRC Technical Memorandum No. 107
1973

No.

Fo 73

SUMMARY

Ice control to prevent flooding and ensure uninterrupted hydro-electric power production is described with several examples in Ontario cited.

Hydroelectric dams are ice control structures because they control velocities to allow formation of a stable ice cover. Additional ice cover control can be achieved with ice booms. If a stable cover cannot be formed the ice must be kept moving continuously, providing that there is somewhere for it to go.

KEYWORDS

ice booms
ice control
ice jams

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December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

G. E. Frankenstein and N. Smith
"The Use of Explosives in Removing Ice Jams"
I.A.H.R. Symposium - Ice and Its Action
on Hydraulic Structures
Reykjavik, Iceland
1970

No.

FR 70

SUMMARY

A brief history of the use of explosives for ice jam removal is discussed. Amonium nitrate mixed with fuel oil is considered the best explosive because of its cost and safety features. For maximum effect the charge should be placed in the water below the ice. A curve is included which gives maximum crater hole diameter as a function of the cube root of the charge weight.

KEYWORDS

explosives

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ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Frankenstein, G. and Assur, A.

"Israel River Ice Jam"

I.A.H.R. Symposium, Ice and Its Action on
Hydraulic Structures

Leningrad

1972

No.

Fr 72

SUMMARY

Two consecutive jams on the Israel River near Lancaster, N. H. caused flood and ice damage exceeding \$500,000. A mid-winter thaw induced minor jamming and flooding. A subsequent freezing spell froze the ice jam solidly. Foreseeing ice jam problems at normal spring breakup, the following measures were proposed.

- Construct a temporary dike to hold back upper river ice.
- Dust the area below the jammed ice to encourage early breakup.
- Remove the jammed ice with explosives.

No preventative measures were taken and extensive damage was caused by the second occurrence of jamming.

Relationships were developed to guide design of channel improvements to handle the ice discharge.

KEYWORDS

ice jam

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December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

A. Fuglum
"Experiences from Engineering Works in the
Port of Drammen"
1st International Conference, Port and Ocean Engineering
under Arctic Conditions
Norway
1971

No.

FU 71

SUMMARY

The Port of Drammen is situated approximately 25 miles from Oslo, Norway at the bottom end of The Drammensfjord. Every year for about 3 to 4 months the fjord is frozen in for about 12 nautical miles into the heart of the port. Ice thickness normally reaches 3 - 4 feet. The entrance to the port is maintained by ice breakers, establishing "precut" lanes.

The use of a bubbler system for clearing ice from the waterfront is mentioned only in passing.

A study is underway of reducing the costly maintenance programs for snow and ice clearance. Some innovative solutions like total enclosure of the port area, or moving the port into a large heated hall in the mountainside, are being investigated. Thermal discharge and ice dusting are also being studied.

KEYWORDS

bubbler systems, enclosures, thermal discharge,
ice dusting, Norway

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

J. W. Goode, A. E. Teller
"Ice Breakage with Explosives"
1st International Conference, Port and Ocean Engineering
under Arctic Conditions
Norway
1971

No.

GO 71

SUMMARY

Experimentation has shown that ice thickness is the most important consideration. Beyond six feet, an explosive with high gas producing properties is required. Displacement of the ice in total must occur - over a large area and all at the same time. The charge should be lowered into the water beneath the ice at some optimum depth, which is twice the thickness of the ice. Sleeper charges could be placed during open water months, with detonation reserved until necessary.

KEYWORDS

Explosives

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

E. Hulgaard, T. Sorensen
"Ice Cover Prevention by Means of Air Bubbles,
Narssaq, Greenland"
1st International Conference, Port and Ocean Engineering
under Arctic Conditions
Norway
1971

No.

HU 71

SUMMARY

Narssaq is a small village in the southern-most part of Greenland, located at the middle of one of the long narrow fords in this region. Harbour facilities are planned in Colony Bay, where the water depth is 5 - 10 m and the tidal range about 2 metres. The ice in this area is usually landfast, although it is occasionally carried away by offshore gales.

Field measurements indicated a maximum ice thickness of 0.15 m. A salinity gradient was present due to the inflow of fresh water at the head of the bay.

An experimental air bubbler system was set up in 1967, which suggested that a very significant improvement in ice conditions at Narssaq could be achieved by a properly designed system.

KEYWORDS

Bubbler system, Greenland

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Ince, S., A Guide to the Design of Air Bubblers for
Melting Ice
The Ice Seminar
CIM Special, Volume 10
1968

No.

IN 68

SUMMARY

This paper outlines a design procedure for estimating the air and power requirements of air bubbler systems and develops a heat transfer analysis for the case of a bubbler used to melt an ice sheet. The need for an adequate thermal reserve is emphasized.

KEYWORDS

air bubbler systems
melting ice

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

E. Jasinska, W. Robakiewicz
"Methods of Preventing Ice Propagation in Confined Waters"
23rd International Navigation Conference, Section II
Ottawa
1973

No.

JA 73

SUMMARY

Experience is reported on the use of air bubbling systems in Poland. Details are given concerning installations used successfully to keep ice out of ferry berths, and an experiment to investigate keeping ice out of harbour areas.

KEYWORDS

bubbler systems, Poland

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Karnovich, V. N. and Sokolov, I.N.
"Mechanism of Artificial Ice Jamming"
Fourth International Symposium on Ice Problems
Lulea, Sweden
1978

No.

Ka 78

SUMMARY

Catastrophic effects of large jams can be avoided by initiating a series of smaller jams, distributing the ice along the river. Earth dikes constructed on the flood plain above low water level will restrict ice movement at higher discharges and cause smaller, less severe jams.

KEY WORDS

ice control
ice jams

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Korzhavin, K. N., et al
"Influences of Ice Upon Construction and Methods of
Combatting Ice Problems"
CRREL Report
Draft Translation 422
December
1974

No.

KO 74

SUMMARY

This collection of articles deals with the variety of ice related factors which influence the specifications for building in an Arctic environment. Based on the studies done concerning the effect of ice on completed structures, these articles present logical approaches to estimating effective ice loads and how to determine the necessary ice protective measures while building reservoirs, hydraulic structures, harbour ships, etc. Several articles concern the weakening of ice strength or increasing the rate of thawing.

KEYWORDS

terminal design

REVIEWED BY

S. T. Culshaw

DATE

January 17, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Lawrie, C. J. R.

"Ice Control Structures and Floating Ice Booms"
The Ice Seminar
CIM Special, Volume 10
1968

No.

La 68

SUMMARY

The causes and solutions to jamming on the St. Lawrence River in the vicinity of Montreal are discussed. In particular, the ice control structure in LaPrairie Basin upstream of Montreal and ice booms at Lake St. Peter are described.

KEYWORDS

ice control
ice booms

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Lazier, S. S.

"Hydraulic Model Study of Chunk Ice Storage -
Moir River"

Seminar on Ice Jams in Canada

NRC Technical Memorandum No. 107

1973

No.

La 73

SUMMARY

The city of Belleville, located on the Moira River flood plain is subjected to chronic flooding associated with spring ice jams. A hydraulic model was constructed to test the feasibility of creating an ice storage area upstream of the city. By detaining the ice moving downstream with an ice boom, ice jamming would be prevented. The test results showed that the proposed ice storage site was unsuitable because the ice boom could not detain a sufficient quantity of ice at the high surface velocities experienced.

KEYWORDS

ice control
ice jams

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Mariusson, J. M., Freysteinson, S., Eliasson, E. B.
"Ice Jam Control. Experience from Burfell Power
Plant in Iceland"
Third International Symposium on Ice Problems
Hanover, N. H.
1975

No.

Ma 75

SUMMARY

The Burfell hydroelectric project was built as a run-of-river power plant on the Thjorsa River. The river upstream of the project is wide and shallow with a gradient too steep to form an ice cover except by jamming. The tremendous amounts of frazil ice generated in the open river are flushed over the dam.

Occasionally, the ice flushing breaks down and ice bridges the opening to the ice flushing trough and jams upstream. Channelization and the use of explosives kept a channel open to reduce losses of water for hydroelectric power production.

KEYWORDS

ice control
ice jams

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Matousek, V.

"Utilization of a Water Reservoir to Control Winter
Phenomena on a River"

I.A.H.R. Symposium, Ice and Its Action on Hydraulic
Structures

Leningrad, 1972

No.

Ma 72

SUMMARY

The winter regime on the Ohre River, Czechoslovakia was modified by releasing warm water from the bottom layers of Nechanice Reservoir, thereby eliminating ice jams in the river.

KEYWORDS

ice jams
ice regime modification

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Michel, B.

"Thrust Exerted by an Unconsolidated Ice Cover on a Boom"
Conference on Ice Pressures Against Structures
NRC Technical Memorandum No. 92
1968

No.

Mi 68

SUMMARY

A theoretical discussion, based on the theory by Caquot for estimating pressures in grain elevators, is presented on the forces acting on an unconsolidated ice cover held in place by a boom. Equations are developed for calculating the hydrodynamic force on the front edge of the cover and the tangential force due to the weight of the cover, the flow of the water and the wind. The theory shows that the force on the boom will not increase indefinitely with the upstream length of the cover, and that there is a critical discharge which, if exceeded, will cause the ice field to become unstable, and to break up and pass under the boom. The results of model studies are shown to be in agreement with the theory.

KEYWORDS

ice booms

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Michel, B.

"Winter Regime of Rivers and Lakes"
Cold Regions Science and Engineering Monograph 111-Bla
U.S. Army Corps of Engineers
Cold Regions Research and Engineering Laboratory
1971

No.

Mi 71

SUMMARY

The monograph describes the ice regime of rivers and lakes from ice cover formation to breakup. The section on ice control outlines methods for prevention of ice jamming.

KEYWORDS

ice
ice breakup
ice control
ice formation
ice forecasting
ice jams

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Michel, B.

"Ice Management in Hydraulic Design - Recent
Canadian Experience"

I.A.H.R. Symposium, Ice and Its Action on Hydraulic
Structures

Leningrad, 1972

No.

Mi 72

SUMMARY

Three examples of river ice management are discussed; the Lake Erie - Niagara ice boom, the ice control dam on the Chaudiere River and the combined operation of ice breakers and the ice control structure at Montreal.

In each case, solution to the ice jamming problem is achieved by promoting formation of a stable cover and retention of ice at breakup.

KEYWORDS

ice booms
ice control
ice breakers

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Moor, J. H. and Watson, C. H.

"Field Tests of Ice Jam Prevention Techniques"
ASCE Journal of the Hydraulics Division
June 1971

No.

Mo 71

SUMMARY

A field program was conducted to evaluate ice control methods described by many previous researchers. Weakening of river ice on a well designed line or pattern will enable the large floe to break up into smaller floes when subjected to hydraulic pressures of the spring freshet. Dusting will result in increased melting of ice and snow. Similar results were achieved by pumping silt from the riverbed onto the ice cover. Creating rows of holes by blasting was very effective in creating a shear line in the ice sheet. A disadvantage is the death or damage of aquatic life.

KEYWORDS

ice blasting
ice breakup
ice control
ice dusting

REVIEWED BY

R. K. Carson

DATE



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Perham, R. E. and Racicot, L.

"Forces on an Ice Boom in the Beauharnois Canal"

Third International Symposium on Ice Problems

Hanover, N. H.

1975

No.

Pe 75

SUMMARY

The paper describes the development of instrumentation to measure ice forces on the ice booms located in the Beauharnois Canal and the analyses of the measured forces.

KEYWORDS

ice booms

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Perham, R. E.

"Forces Generated in Ice Booms"
Second Canadian Hydrotechnical Conference
Burlington
1975

No.

Pe 75

SUMMARY

Force measurement instrumentation was installed on ice booms in the Galop Channel of the St. Lawrence River between Prescott and Cardinal. Analysis of forces and field measurements indicated that timber boom design can be improved with more study. Steel boom design is better than timber designs with respect to ice retention under heavy ice forces at spring breakup.

KEYWORDS

ice booms
ice control
ice forces

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Perham, R. E.

"Ice and Ship Effects on the St. Mary's River Ice Booms"
Third National Hydrotechnical Conference, Canada
Quebec
1977

No.

Pe 77

SUMMARY

Two ice booms were installed with a 250-ft wide navigation opening at the southerly outlet from the harbor at Sault Ste. Marie, Michigan and Ontario, to control troublesome ice movements associated with winter navigation.

The ice booms contained 6 force measuring devices. Records of these forces and pertinent data on the weather, water levels, ship passages and ice conditions were kept the following winter of 1975-76.

The ice booms reduced harbor losses to an acceptable level and provided much information about the interaction between itself and the ice cover and the ships.

KEYWORDS

ice booms
ice forces
winter navigation

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Perham, R. E.

"Performance of the St. Mary's River Ice Booms,
1976 - 1977"
CRREL Report 78-24
1978

No.

Pe 78

SUMMARY

The report describes operation of the St. Mary's River ice booms installed at the head of Little Rapids Cut in Sault Ste. Marie, Michigan for the winter of 1976-1977, the second year's operation of the booms. The two most important aspects of the operation are

- a substantially diminished sensitivity of boom forces to the passage of ships compared with the first year's operation
- the sequential breaking of the structure on one occasion.

KEYWORDS

ice booms
ice control
ice forces

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Perham, R.

"Righting Moment in a Rectangular Ice Boom Timber
or Pontoon"

Fourth International Symposium on Ice Problems
Lulea, Sweden
1978

No.

Pe 78

SUMMARY

Ice retention in conventional ice boom structures is limited by rolling of the timbers. Ice forces were analyzed to determine the optimum timber dimensions to resist overturning. Increasing difficulty in obtaining timber of suitable dimension and reduced holding capacity due to loss of buoyancy associated with water absorption make timber booms less attractive than hollow, water-tight steel booms fabricated to optimal dimensions.

KEYWORDS

ice booms

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

E. R. Pounder
"Thermodynamic Considerations on the Use of Air
Bubbling Systems in Salt Water"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

PO 61

SUMMARY

Air bubbling systems have been very successful in preventing ice formation in local areas in fresh water lakes and rivers. The principle of the method is to mix warmer water from appreciable depths with surface water to supply the necessary heat. The availability of warmer water depends on the existence of a density inversion temperature of 4 degrees C in pure water, leading to thermocline formation. If salts, in the proportions found in the oceans, are dissolved in water both the temperature decreases more rapidly with increasing concentration, becoming equal to the freezing point of -1.3 degrees C for a salinity of 24.7 /00*. For salinities greater than this figure a density thermocline will not form, and a still body of salt water cooled by the air will develop convective circulation to maintain a uniform temperature right to the bottom.

These considerations suggest that air bubbling should serve no purpose in sea water. Nevertheless a few experimental installations, such as Operation Polynya at Thule, have shown that air bubbling in salt water can retard or prevent ice formation and even melt an ice cover which has formed. In the Thule experiments the water temperature showed no increase with depth, in agreement with the discussion above. An explanation of the success of air bubbling in salt water must be sought in some secondary effects.

KEYWORDS

air bubblers, Arctic

REVIEWED BY

A. B. Cammaert

DATE

January 4, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Rozsnyoi, P., Pados, I.

"Regulation of the Development of Ice Barriers in the Reach
of the Tisza River above the Barrage of Tiszaalok for a
Secure Winter Operation of the Barrage"
Third International Symposium on Ice Problems
Hanover, N. H., 1975

No.

Ro 75

SUMMARY

A floating "ice trap" similar to the Lake Erie - Niagara ice boom was considered which, combined with curvature of the approach channel would hold river ice away from the power plant intakes.

KEYWORDS

ice booms
ice control

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Rumer, R. R., Atkinson, C. H. and Lavender, S. T.
"Effects of Lake Erie - Niagara River Ice Boom on the
Ice Regime of Lake Erie"
Third International Symposium on Ice Problems
Hanover, N. H.
1975

No.

Ru 75

SUMMARY

The paper discusses the effect of the Lake Erie - Niagara River ice boom on the ice regime of Lake Erie. The boom is designed to accelerate the formation of a stable ice cover at the eastern end of Lake Erie and eliminate the release of massive ice runs into the Niagara River.

KEYWORDS

ice booms
ice regime

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Russell, B. E.

"Ice Formation in Lake Erie and the Niagara River, Its
Effects and Control"

Proceedings of Banff Symposium - The Role of Ice and
Snow in Hydrology
Banff, 1972

No.

Ru 72

SUMMARY

The paper discusses the operation of the Lake Erie - Niagara River ice boom, its efficacy in inhibiting ice flows out of Lake Erie, criticisms leveled at its operation by environmentalists and shipping interests, and if outlines ongoing studies of the effects of the boom on ice accumulation and dissipation in Lake Erie.

KEYWORDS

ice control
ice booms
ice cover formation

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

C. W. Senior
"A Model Describing the Physical Processes of
Project Polynya"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

SE 61

SUMMARY

Successful application, during the fall of 1958, of the air bubbling technique for preventing ice formation enabled the Military Sea Transportation Service to extend the shipping season into the port at Thule Air Base, Greenland. Although the technique had originally been developed in fresh water, an ice free area or "polynya" was maintained adjacent to Delong Pier at Thule harbor despite normal ice formation in the surrounding waters of North Star Bay. Safeguarded against becoming iced-in at the pier, the supply convoy remained at Thule until 25 October 1958, the latest date any MSTs ships had ever operated that far north.

KEYWORDS

Air bubblers, Greenland

REVIEWED BY

A. B. Cammaert

DATE

January 4, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Sigurdsson, G.

"The Burfell Project: A Case Study of System Design for
Ice Conditions"

I.A.H.R. Symposium, Ice and Its Action on Hydraulic
Structures

Leningrad, USSR

1972

No.

Si 72

SUMMARY

The design of the Burfell hydroelectric project on the Thjorsa River in Iceland was greatly influenced by great quantities of slush ice carried down the river each year. The approach to the evaluation of the problem is described, as well as the methods used to solve it. The slush ice problem completely overshadows other ice problems, such as drifting sheet ice, anchor ice and ice jams, because of the tremendous volume of material involved.

KEYWORDS

ice control

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Toomey, Capt. P. R. M.
"Icebreakers to Control Ice Jams"
Seminar on Ice Jams in Canada
NRC Technical Memorandum No. 107
1973

No.

To 73

SUMMARY

Removal of ice jams on the St. Lawrence River at Lac St. Pierre and at the Quebec bridges using ice breakers is described. Two or three ice breakers attack the jams from downstream gradually releasing ice from the jam to flow downstream. When the jam finally fails, the ice breakers must continuously attack the ice moving downstream to prevent it from reforming at some obstruction downstream.

KEYWORDS

ice breaking
ice jams

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Wade, R. G., R. Y. Edwards and J. K. Kim
"Improvements in Ice Breaking by the Use of Air Cushion
Vehicles"
The Society of Naval Architecture and Marine Engineering

No.

WA

SUMMARY

Observations of ice breaking operations of air cushion vehicles over the period 1971 to 1974 are described. Limited data from these trials is used to substantiate the hypothesis that ACV's will progress continuously through an ice cover, breaking it up as thoroughly as an icebreaker providing

- (a) the vehicle cushion pressure expressed as a head exceeds the ice cover depth
- (b) the weight of the vehicle exceeds the weight that would create ultimate collapse of the ice cover.

Model tests were conducted to assess the capability of an ice cushion device deployed at the bow of an icebreaking ship to decrease the resistance encountered by the ship as the combination proceeds through a field of uniformly thick ice. The tests show that the resistance of the model of a CCGS "Norman MacLeod Rogers" equipped with an air cushion device was reduced by 22 to 42 percent below the resistance which would be encountered without an ACV.

KEYWORDS

Ice breaking
Air cushion vehicles

REVIEWED BY

S. T. Culshaw

DATE

January 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

W. F. Weeks and S. L. Dingman
"Thermal Modification of River Ice Covers:
Progress and Problems"
Proceedings of Banff Symposium - The Role of Ice and
Snow in Hydrology
Banff
1972

No.

WE 72

SUMMARY

The thermal modification of river ice is a relatively recent problem or opportunity, depending upon one's point of view. Calculations show that in certain locations excess heat could be used to good advantage in removing ice. Current attempts to model winter river temperatures are discussed. It is concluded that for most planning purposes we are able to adequately estimate water temperatures below thermal pollution sites. In many cases the most important factor in controlling the quality of the estimates is the adequacy of the meteorological data. On the other hand our ability to predict the time dependent behaviour of the ice cover below artificially induced ice-free reaches is poor.

KEYWORDS

thermal discharge

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Willey, C. K.

"Some Aspects of the Design of Ice Passage Facilities
for the Burfell Hydroelectric Project"

I.A.H.R. Symposium, Ice and Its Action on Hydraulic
Structures

Leningrad, USSR, 1972

No.

Wi 72

SUMMARY

A fundamentally new concept in the design of the ice and silt passing facilities was used at Iceland's Burfell hydroelectric project. These facilities have operated through one winter season. This operation, while very satisfactory, has, nevertheless, shown the need of some equipment modifications or demonstrated possible improvements thereto for incorporation into similar designs at other locations. Most of these pertain to the regulating gates and are discussed. The design philosophy of the facilities is presented. Means for preventing the slush ice from reaching the facilities are also presented.

KEYWORDS

ice control

REVIEWED BY

R. K. Carson

DATE

December 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

G. P. Williams
"Thermal Regime of Lakes and Rivers
with Reference to Air Bubbling Systems"
Proceedings of the Symposium on Air Bubbling
Ottawa
1961

No.

WI 61

SUMMARY

Air bubbling systems have been used successfully to melt ice or prevent its formation in lakes, rivers and ocean areas, but there are cases where they have been unsuccessful. If the action of a bubbler results in the melting of ice or the prevention of its formation, the bubbler must have brought, to the surface, water containing sufficient heat for this purpose. If the water does not contain the required heat it is unlikely that a bubbler will open a hole in an already established ice cover. These facts indicate that before a bubbler system is installed careful consideration should be given to the heat reserves available at a proposed site, and the heat losses to be expected, particularly in those cases where the temperature of the water is just at or slightly above the freezing point. The purpose of this paper is to discuss these thermal factors.

KEYWORDS

bubbler systems

REVIEWED BY

A. B. Cammaert

DATE

January 4, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Williams, G. P. and L. W. Gold
"The use of dust to advance the breakup of ice on
lakes and rivers"
Proceedings Eastern Snow Conference
Quebec City
1963
p 31-56

No.

WI 63

SUMMARY

This paper summarizes the findings of several researchers on the subject of ice dusting. Initially described are the influencing factors causing the breakup of ice covers. Importance is attached to the effect of the magnitude and duration of radiation on the melting processes of ice covers. The average air temperatures for southern and northern Canada for which dusting should be feasible are estimated.

The density and particle size of dusting material is considered.

KEYWORDS

ice dusting, albedo modification

REVIEWED BY

J. B. FitzPatrick

DATE

February 2, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Williams, G. P.
"Ice Dusting Experiments to increase the rate of
melting of Ice"
Technical Paper No. 239
Division of Building Research, NRC
Ottawa
1967

No.

WI 67

SUMMARY

This report evaluates ice dusting based on past published information. The author emphasizes the "near perfect" conditions that are necessary for successful dusting including the minimum daily temperature which should not fall below 32 degrees F irrespective of latitudes as well as zero snowfall during the melting period. The report describes the deterioration of ice for different dusting materials and initial ice thickness

KEYWORDS

ice dusting, albedo modification

REVIEWED BY

J. B. FitzPatrick

DATE

February 13, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

I. A. Zotikov and G. P. Moiseeva
"A Theoretical Study of Ice Surface Dusting
Influence on Melting Intensity"
Proceedings of Banff Symposium - The Role of Ice and
Snow in Hydrology
Banff
1972

No.

ZO 72

SUMMARY

Dusting of ice surfaces is considered to change the intensity of melting mainly because of the change in albedo, due to the dust within a melting layer. A simple model of heat exchange mechanism within a melting layer simplified as a muddy medium where single particles of the dust exchange heat through their whole surface was constructed to calculate the influence of dusting. It was also supposed that, when the number of the particles is great enough, the particles shadow each other and only some of their surface takes part in radiation exchange. To calculate the effect of the shadowing the probability of the interference is estimated when circles representing the particles are placed independently and randomly on the surface. Formulae were obtained to calculate the change of albedo and intensity of surface melting due to dusting. The comparison of the theory and the experiments showed a sufficient agreement in the results obtained.

KEYWORDS

ice dusting

REVIEWED BY

A. B. Cammaert

DATE

January 3, 1978



ALBERTA ENVIRONMENT
FORT McMURRAY ICE CONTROL STUDY

SUMMARY OF REFERENCE MATERIAL

SOURCE

Williams, G. P.

"Breakup and Control of River Ice"

I.A.H.R. Symposium - Ice and Its Action on Hydraulic
Structures

Reykjavik, Iceland

1970

No.

Wi 70

SUMMARY

The review paper presents background information on the process of river breakup and control of ice during breakup. The limitations and main problems associated with various control methods are summarized. In particular, control by ice dusting, thermal discharge, explosives, ice breakers and ice booms is discussed. The importance of economics and local conditions in selecting a method for a particular site is stressed.

Attempts to control massive ice jams extending over several kilometres using any form of ice modification are often impractical. In these cases, structures must be designed or located to avoid serious ice damage.

Ice modification techniques are sometimes not completely reliable because they cannot be depended on during years with adverse weather and ice conditions. The design of structures depends primarily on the ability to predict the most serious ice conditions that can occur.

KEYWORDS

ice booms
ice breakers
ice control
ice dusting
explosives
thermal discharge

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