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Inventory of ice problem sites and remedial ice control structures

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RIM
RIVER ICE MANAGEMENT

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OFFICE OF THE CHIEF OF ENGINEERS

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As part of the River Ice Management (RIM) program, several ice-affected, navigable rivers were studied to find locations where ice problems occur on a regular basis. The rivers studied were the Illinois River and the Ohio River and its tributaries, especially the Allegheny and the Monongahela. Several problem areas were found at river bends, islands, and locks and dams and were generally caused by having too much broken ice in the ship track. One site had a serious frazil ice problem. Ice control structures such as ice booms and deflector booms were investigated for use at certain locations. The report includes a list of 64 ice problem sites, 5 locks and dams that could benefit from ice control structures, and 3 proven structures that are technically applicable.

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PREFACE

This report was prepared by Roscoe E. Perham, Mechanical Engineer, Ice Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H. The study was funded under the River Ice Management Program work unit Civil Works No. 32296, *Ice Control Structures*. He was assisted in gathering data by Edward Foltyn, whose efforts are appreciated. He also thanks Robert Schmitt, Pittsburgh District; Samuel French, Huntington District; David Kreutzer, Consolidated Coal Company, and Donald Byczynski, Starved Rock L&D, for their assistance. The report was technically reviewed by Mr. Foltyn and Jon Zufelt of CRREL, whose suggestions and comments were helpful and much appreciated.

CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM *Metric Practice Guide* (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

Multiply	*By*	*To obtain*
foot	0.3048*	meter
mile	1.609344*	kilometer

*Exact

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ROSCOE E. PERHAM

INTRODUCTION

This report is a summary of efforts to determine where winter navigation can be improved on inland waterways by using ice control structures. The work was done under the River Ice Management program of the Corps of Enginneers. The object of this study was to identify ice problem locations and determine if ice control structures could be used to alleviate these problems. The data were obtained by a literature search, on-site visits, discussions with waterway operators and users, and questionnaires by Zufelt and Calkins (1985).

Many locations where ice problems have developed are listed here; the magnitude and extent of the problems are not characterized nor is it known how frequently they occur. I learned of the sites from operations personnel and users, and I visited the sites during the study. The ice problems at most sites develop during the normal ice break-up periods, and though they may be serious, they usually last only two or three days. Other sites experience frequent, fairly intense ice problems and may be suitable for ice control structures. In general, though, potential structures or other required changes are too expensive to be worthwhile.

The Missouri River and the upper Mississippi River above the confluence with the Illinois are usually closed to navigation during winter. Therefore, I concentrated my efforts on other

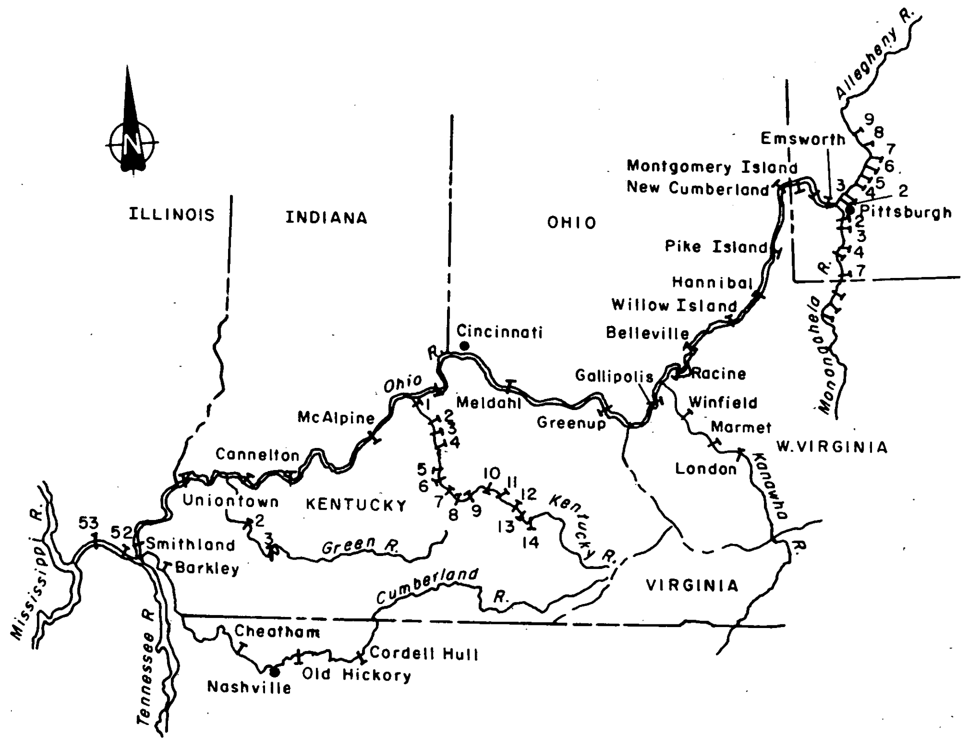

Figure 1. Ohio River and tributaries navigation system.

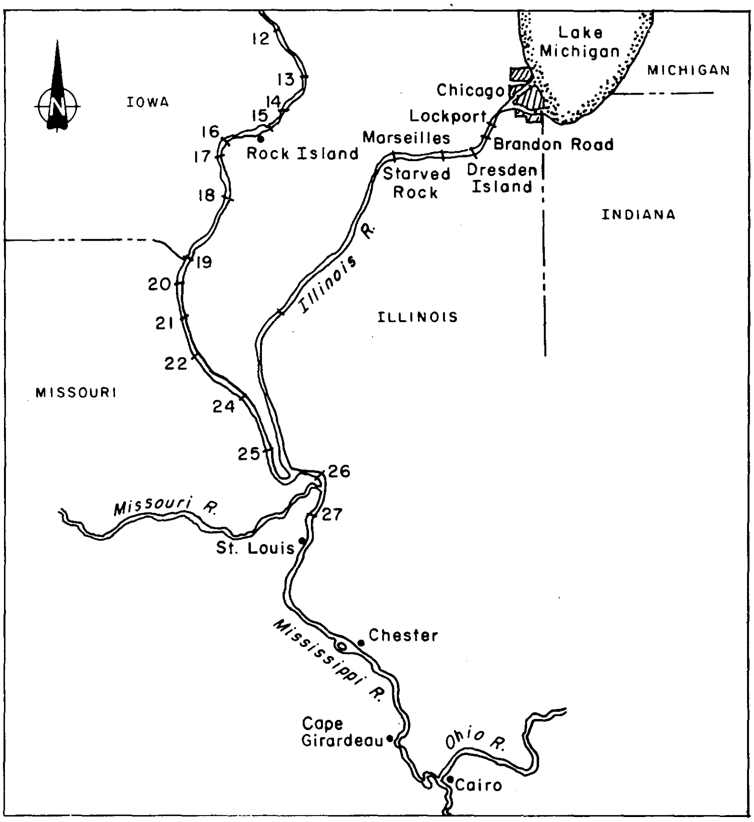

Figure 2. Upper Mississippi River and Illinois Waterway navigation systems.

areas, mainly the Corps of Engineer Districts of Pittsburgh, Huntington and Rock Island, which I visited several times. I also held some discussions with the St. Louis, Chicago and Louisville Districts and with the Consolidated Coal Company in Elizabeth, Pennsylvania. An invaluable view of the effects of ice on river navigation was provided by a ride through heavy ice on the Illinois River on the M/V Sally Polk owned by the Canal Barge Company of New Orleans.

Considerable information about the design of the waterways and how they are used is available in *Layout and Design of Shallow-Draft Waterways* (U.S. Army Corps of Engineers 1980). The manual *Ice Engineering* (U.S. Army Corps of Engineers 1982) also gives an inventory of ice control structures and methods.

The present report describes potential ice control structure sites and gives locations of navigation-related ice problems on the Ohio, Allegheny, Monongahela, Illinois and upper Mississippi river systems (Fig. 1 and 2). I believe that most problem sites are included, but I welcome identification of other locations by readers.

TYPES OF PROBLEM AREAS

In general the major winter navigation problem between locks and dams is moving through large quantities of broken ice, including moving ice (Tronin and Pusharev 1979). The source of the ice is usually the navigation channel itself and adjacent parts of the main stream. The tows often break ice in transit, and light boats (towboats without attached barges) break out additional areas of ice to improve maneuverability in trouble spots, such as sharp bends.

Tributaries

The confluences of tributaries and mainstem rivers identified as problem sites are in the backwater pools of navigation structures, and the ice covers in these locations are quite stable. An ice boom could give the ice covers more resistance to dislodgement by mid-winter thaw, but they do little to hold ice back during the usual spring ice break-up.

An important example is the Muskingum River, a tributary of the Ohio River (Mile 172), which has a sizable ice discharge. On occasion its ice cover will break up before that on the Ohio, and the ice will jam at the confluence, in Marietta, Ohio, and back up into the mooring facilities of an old river boat and other private structures. When the Ohio River ice breaks up first, a boom could decrease the rate at which the Muskingum ice discharges into the Ohio River and in so doing may cause ice to back up into the same facilities. The Muskingum also discharges sizable quantities of floating woody debris that could become entangled in the boom. The debris would have to be removed periodically.

Bends

Some ice piers and fleeting areas are located at bends, which are poor locations for them. Ice piers are typically rectangular concrete piers 15 ft wide by 25 ft long protruding 10 ft out of the water. Even in a straight reach, ice floes and brash ice moving in the ship track will tend to arch across the ship track and stop. Acceleration forces around a bend are not high, but they can accentuate the tendency for the ice to stop on the outside of the bends. Also the water velocities are generally lower on the inside of the bend.

Barges and tows have difficulty moving around a bend through ice. They tend to compress the broken ice and break out more ice, which aggravates the situation (Kray 1974, U.S. Army Corps of Engineers 1969). It seems best to try to reduce the amount of ice coming to the bend and to improve the movement of ice out of the bend. There seem to be no structures, however, that will help in the latter effect.

Islands and sand bars

The ice problems at islands and sand bars are similar. The narrowing of the river restricts movement of the large, wide ice floes, which often ride up on beaches and shallow banks. Subsequent floes ride up on them, creating multilayered ice. Passing barge tows can concentrate the ice further, and low temperatures may freeze the ice floes together, making subsequent passages more difficult.

Locks and dams

The most persistent problems for winter navigation seem to develop at the locks and dams (U.S. Army Corps of Engineers 1978). Midstream ice accumulations can be broken up by light boats, and the barge tows can then make it through. But at lock entrances the ice must be moved out of the way so that the barges can enter the locks. Often the only way to do this is to make one or more ice lockages prior to tow entry. At L&D #17 and at the Chain of Rocks Canal, both on the Mississippi River, floating ice deflection techniques have done a good job of keeping ice out of an upstream lock entrance when there is sufficient water flow. The more difficult task of getting ice over to the control dam and passing it through is done by the excess water.

Reservoirs

Another possible problem is reservoir regulation. It is known that discharging water too rapidly into a tributary can break up its ice cover and cause the ice to move downstream. I have no examples of where this has caused navigation problems in winter, but the potential exists.

PROBLEM SITES

Table 1 lists the areas having ice problems fairly often. The list relates to navigation on the main stem rivers and not necessarily on the tributaries. Most of the tributaries listed are not navigable, but they contribute substantial quantities of ice to the main stems, the islands and bars, the bends, and especially the locks and dams, possibly causing or intensifying the ice problems.

The ice problems are most severe at the locks and dams. On the Ohio River the worst problems occur at Meldahl and Emsworth. Tainter gates were damaged by an ice run at Dresden Island on the Illinois River, and ice occasionally breaks the debris boom at Winfield on the Kanawha River.

Winter navigation in the Illinois River above Peoria Lake has been difficult for a long time. The reason is that broken ice moves downstream with the swift river currents until it reaches the slack waters of Peoria Lake. There it accumulates against the stationary ice on the lake. A stationary front of broken ice backs up into the river, where the ice tends to pile downward in response to current drag and flow pressures. The action of barge tows causes this mass to deepen, and light boats redistribute the ice. In time an ice jam develops, usually at Chillicothe Island, halting navigation, sometimes for the remainder of the winter.

Table 1. Ice problem sites.

River	*Locks and dams*	*River mile*	*Tributary rivers*	*River mile*	*Islands and bars*	*River mile*	*Bends*	*River mile*
					Islands			
Ohio	Emsworth	6	Beaver	25	Marietta	170	Marietta	171
	Montgomery	31	Little Beaver	40	Mustapha	19	Parkersburg	194
	New Cumberland	54	Yellow Creek	50	Letart	235	Long Bottom	210
	Willow Island	162	Wheeling Creek	91	Manchester 1	396	Ravenswood	222
	Belleville	204	Capatina Creek	109	Manchester 2	396	Letart	236
	Racine	237	Fish Creek	111			Long Bottom	210
	Gallipolis	279	Muskingum	172	*Bars*			
	Greenup	341	Little Kanawha	185	Sandy Creek	221		
	Meldahl	436	Hocking	199	Little Scioto	349		
			Kanawha	266				
			Big Sandy	317				
			Scioto	357				
			Little Scioto	349				
Monongahela	No. 2	11	Turtle Creek	11				
	No. 3	24	Youghiogheny	15				
	No. 4	41	Tenmile Creek	65				
	Maxwell	61	Dunkard Creek	87				
			Cheat River	89				
Allegheny	No. 4	24	Kiskiminetas	29				
	No. 5	30						
Kanawha	Winfield	32						
Muskingum	No. 2	6						
Illinois	Peoria	158	Blue Creek (Pt.)	173	Henry	196		
Waterway	Starved Rock	231	Vermilion	226	Chillicothe	215		
	Marseilles	244	Fox	239				
	Dresden Island	271	Kankakee	273				
	T.J. O'Brien	326						
Upper	No. 27	190	Kaskaskia	118				
Mississippi	No. 17	437	Missouri	195				

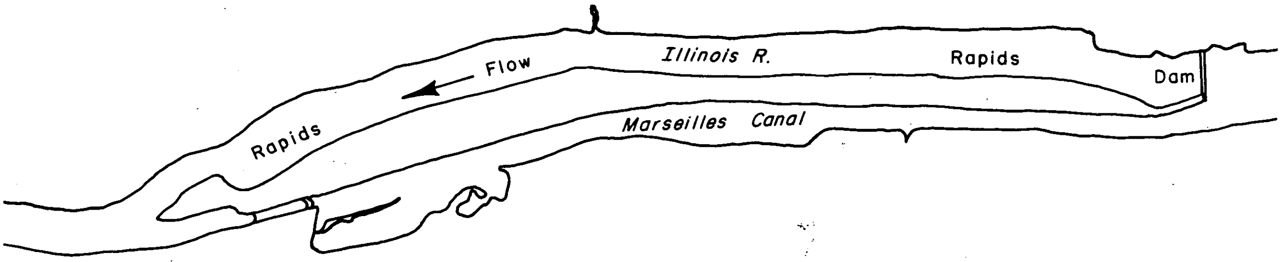

Figure 3. Open river reach where the frazil ice generated in winter is enough to severely restrict navigation below the Marseilles Lock.

The frazil ice problem at Marseilles in the Illinois River is similar to ice jam development in a large number of rivers and streams. At Marseilles the river is split by an island about 3 miles long. The navigation course follows the south side of the island, and Marseilles Lock is at its downstream end (Fig. 3). The main dam is at the upstream end of the island, allowing most of the river discharge to flow down a rather steep gradient to the lower end of the island. Because of its high velocities, the main part of the river remains open in winter and continually generates frazil ice. The frazil ice collects downstream of the lower lock entrance, eventually in large quantities. In 1948 all navigation below Marseilles was stopped for about 13 days by a frazil ice blockage (U.S. Army Corps of Engineers 1968). This problem returns to varying degrees nearly every winter. Some research has been directed towards structural solutions for this type of problem (Perham 1983), but considerably more research must be done before a solution can be chosen (Foltyn 1985).

METHODS OF ICE CONTROL

Ice booms

An ice boom is a line of floating timbers or pontoons across a body of water for the purpose of stopping or deflecting moving ice. There are two general types of booms: retention booms collect and hold ice floes (Fig. 4), and deflector booms cause the ice to change its course towards a pass or spillway. The boom acts only on the surface and allows the water to flow beneath with little added restriction. Ice booms are commonly used by hydroelectric plants to stabilize the ice cover upstream of their dams. They usually reach from shore to shore and, of course, block winter navigation. A few booms, however, are designed to accommodate winter navigation, one of which was

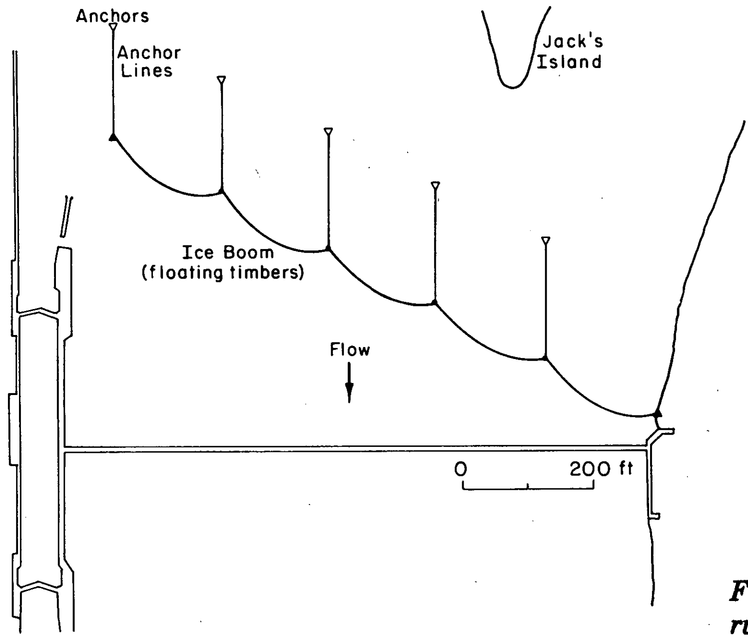

Figure 4. Ice boom to prevent continual ice runs at a fixed-crest concrete dam.

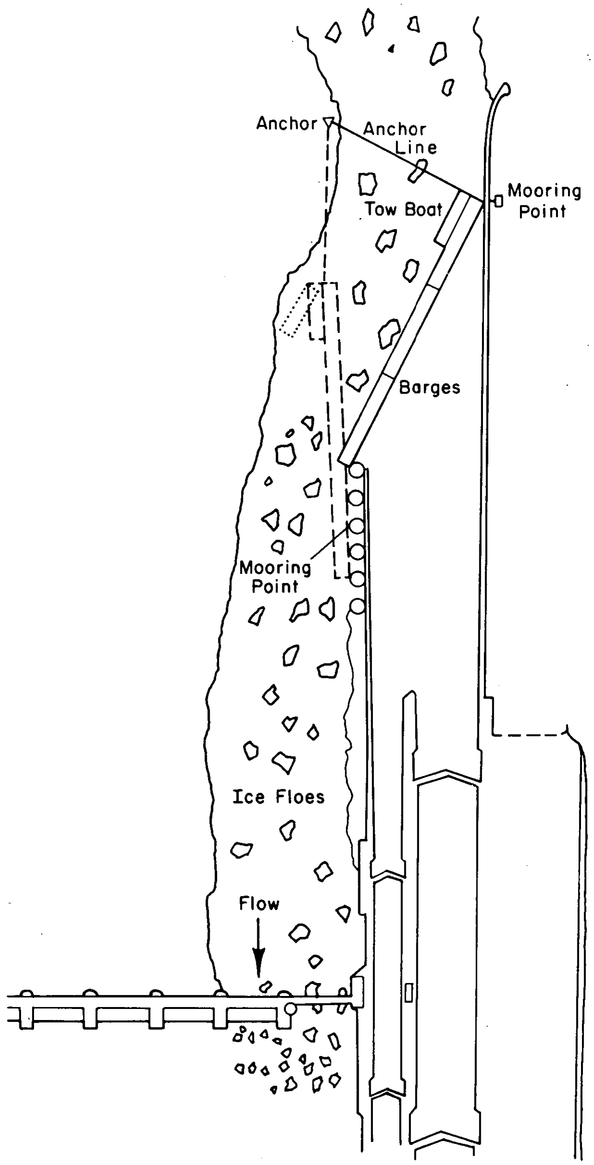

Figure 5. Proposed, prototype-scale test of lock entrance ice deflector.

built by the Corps of Engineers at Saulte Ste. Marie, Michigan (Perham 1977). The St. Marys River ice boom has a 250-ft opening for ships to pass through. As ships transit the navigation course, the boom moves up and down with the ice cover, which it holds in place quite well. Generally ice covers beside the ship track can be anchored in place by short booms extending out from shore but not into the ship track; these are called spur booms.

An ice boom should be removed soon after the ice leaves the river and be put back in place just before ice reappears the following winter. If this is not done, the boom will receive unnecessary wear from wind and wave activity. In addition to the cost of building and installing an ice boom, one is faced with the cost of this seasonal handling, a maintenance crew and equipment, and a place to store the boom safely (Perham 1976).

A deflector or shear boom is a continuous line of floats for changing the direction of movement of ice pieces and the debris that often accompanies ice. The boom is set at an acute angle to the stream flow so that the ice floes will slide along its upstream face. A long floating guidewall and a series of barges connected end to end have made excellent diversion structures (Fig. 5). When the boom is built of timber segments, part of each timber face should overlap the face of the adjacent, downstream timber to avoid gaps.

Air bubblers

Air bubblers can restrain and divert broken ice (Hanamoto 1981) but not to the same level of force as a boom. The rising bubbles raise the water level locally and cause an outward flow of water. Both of these effects retard or stop moving ice. The bubbler lines are installed on the bottom of the lock, either square with the longitudinal axis of the lock or at an acute angle to it. The water should not be flowing through the bubbler curtain, or the bubbler intensity will be dispersed.

Anchors

Several methods for anchoring ice covers have been used. Examples are ice booms, anchored rafts, timber cribs, man-made islands and cell structures (Perham 1983).

Structures such as man-made islands remain fixed when water level fluctuations make the ice cover move up and down. This may be a disadvantage in some locations, because this movement may cause fracturing of the ice cover and the subsequent loss of part of it. Devices such as anchored rafts can move up and down with the ice cover, leaving the restrained ice intact until a major event such as spring breakup occurs. These structures, however, are generally more susceptible to damage than well-designed islands and may require more maintenance.

I found no sites where anchoring would reduce the amount of ice entering the navigation channel by any substantial amount. A careful review of aerial video coverage of the river systems may point out dominant ice-source reaches. Before ice sheet anchoring is applied, one has to consider whether it will aid or hinder navigation. Anchors could prevent barges and tows from easily passing each other, they could reduce the effectiveness of icebreaking, and they could inhibit the brash ice concentration technique (forcing brash ice into smaller areas) used by private industry.

CONCLUSIONS AND RECOMMENDATIONS

The locations of ice problems that could be remedied by the application of structures are listed in Table 2. At each location an ice boom of some type is needed—either an ice-holding boom as in Figure 4 or a shear or deflector boom as in Figure 5. For each site Table 2 lists a preliminary conclusion and a major reason for reaching that conclusion.

The proposed solution at Lock and Dam No. 4 in the Allegheny River is a typical ice boom. It would provide greater stability for the upstream ice cover and would prevent continual ice loss over the dam. The estimated cost of the anchors is quite high, however, and there is little traffic in winter. The application does not seem to be economically sound.

No. 4 and Maxwell on the Monongahela River and Montgomery on the Ohio River are good locations for shear booms that deflect ice away from the upstream lock entrance (Fig. 5). However, getting ice over to the dam and then passing it through the dam are not easy tasks. The shear boom application here calls for the Corps to establish a structure that is similar to the barge tows used to deflect ice at No. 17 Lock and Dam and at the Chain of Rocks Canal on the Mississippi River. A channel would need to be broken through ice in the forebay fairly often, and ice passage at the dams would need to be improved. If these things are done, then the shear boom is feasible; otherwise it is not.

The ice problem at Marseilles is serious and recurring, and it is doubtful that the problem will be cured or reduced by private industry. The solution, however, would also have application in non-navigation areas where the Corps has an interest. Problems of this type generally require that the water velocities be decreased so that an ice cover can form over most of the open water. The ice cover has an insulating effect and prevents the formation of frazil ice. Raising the water levels by constructing an overflow weir or dam is the usual approach to reducing stream velocities (Fig. 6). An ice boom on the pool will help an ice cover to form and resist early break-up from wind and wave action. The main difficulties, however, often lie with trying to satisfy the many interests, such as hydropower and fishing, that also use the river reach. It seems worthwhile to work out a solution for Marseilles because of its direct bene-

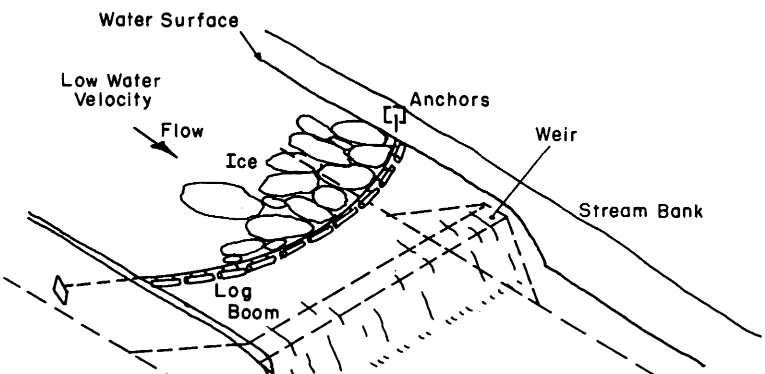

Figure 6. Combination of submerged weir and ice boom to reduce water velocity and allow a stable ice cover to develop upstream.

Table 2. Locks and dams that could use ice control structures.

River	*River mile*	*Site name*	*Main problem*	*Proposed control structure*	*Chance of success*	*Preliminary conclusion*	*Major reasons for conclusion*
Allegheny	24	No. 4 Lock and dam	Ice flows over dam, collects in d/s bend, causes passage problems to barges incl. drag on lock sill	Ice boom (Fig. 4)	Excellent	Defer	Expensive anchor; little winter traffic
Monongehela	41	No. 4 Lock and dam	Ice enters u/s lock entrance increasing lockage time substantially	Shear ice boom	Good but depends on ice passage at dam	Defer	Another site is better to try
Ohio	31	Montgomery Lock and dam	Ice enters u/s lock entrance increasing lockage time substantially	Shear ice boom (Fig. 5)	Excellent but depends on ice passage at dam	Defer	Similar to towing industry effort in other areas
Illinois	244	Marseilles Lock and dam	Frazil ice in great quantity enters channel d/s of lock, mixes with brash ice to form a deep, dense ice mass	Frazil ice/slush ice control weir/ dam (Fig. 6)	Fair	Study means; build prototype	Problem is serious and perennial; solution has wide application
Monongahela	61	Maxwell Lock and dam	Ice accumulates in the upper lock approach often causing every other lockage to be ice only	Shear ice boom w/work-boat velocity inducer bubbler	Excellent if ice passage is improved	Ice passage at dams needs to be improved	Shear boom excludes most ice from lock but deflected ice must be given passage or stored in dam forebay

fits and its technology transfer possibilities in the area of ice jam control.

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