# APPENDIX VIII

## SAUGUS RIVER FLOODGATE PROJECT
## POTENTIAL ICE PROBLEMS REPORT

DEPARTMENT OF THE ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, CORPS OF ENGINEERS
HANOVER, NEW HAMPSHIRE 03755-1290

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MEMORANDUM FOR RECORD

SUBJECT: Saugus River Floodgate Project

## Introduction

The Saugus River Floodgate structure is under design by the New England Division, Army Corps of Engineers (NED), as part of a larger project to minimize coastal flooding in the cities of Lynn, Malden, and Revere, and town of Saugus, MA. The structure is located at the mouth of the Saugus River, just upstream from its confluence with Lynn Harbor, and consists of a gravity portion containing eight 50-foot-wide tainter gates and one 100-foot-wide miter gate. The floodgate structure, along with a series of dikes and flood walls, will prevent high water associated with tidal surges from reaching interior areas and causing flooding. Under normal operating conditions, the tainter gates will be in a raised position. The miter gate will be open to allow for passage of commercial and recreational boats. When flooding due to tidal surge is expected, the tainter gates and miter gate will be closed. The gates are expected to be closed two to three times annually, with the gates remaining closed for one to two hours at the peak of each tide. A high percentage of these tidal flood events are expected to take place during the winter months.

A 1:50 scale physical model which includes the area about 2000 feet to seaward and 3000 feet to landward of the proposed floodgate structure has been constructed at the Waterways Experiment Station (WES). This model has been used to obtain information on the impact of the structure on navigation and currents in open water conditions. The model will also be used to determine the impacts of different phases of the project construction. As part of the project review, NED arranged for several residents of Revere and Saugus, including commercial fishermen who are based in the Saugus River, to visit WES. The model was described and several flow conditions were presented. During the presentation, the visitors expressed their concern about the potential for ice accumulations at the structure that might restrict access to the river.

## Potential Ice Effects

As a result of the concerns expressed at this meeting, NED contacted the Ice Engineering Research Branch of the Cold Regions Research and Engineering Laboratory (IERB) to obtain advice on potential ice impacts associated with the Saugus River Floodgate Project. IERB personnel first visited the project site and

met with local representatives to discuss ice problems, and then traveled to WES to observe the model and discuss the performance of the test structure.

*Site Visit.* On 24 March, 1992 Jon Zufelt and Kate White traveled to Revere, MA, with Bob Hunt, Don Wood, and Greg Buteau (all of NED) to meet with local fishermen and yacht club members to discuss existing ice accumulation problems in the area of the proposed Saugus River Floodgate Project. Also discussed were the potential effects of the project on ice accumulations. Several people brought photographs of past ice events, which were made available for copies.

From these conversations with the local residents, it appears that a solid ice sheet grows on the Saugus River and Pines River estuaries most winters by February. When the river ice is more than an inch thick, the fishermen are not able to travel in the channel without damaging their boats. The commercial fisherman are moored on the Saugus River and do not need access to the Pines River during the winter.

The floating ice which causes the most trouble grows in the interior marshes of the Pines and Saugus River. At high tide, the ice can be lifted up, sometimes breaking loose. Repetitive wetting and snowfall can thicken the ice substantially. Most of the broken ice is probably 6 inches to eighteen inches thick, but ice pieces up to three feet thick are not uncommon. Very thick blocks (up to 8 to 10 feet thick) have been reported but are quite rare. The pieces can be "three times the size of a car" in plan. Most of the floating ice will have a freeboard of less than one foot, with occasional ice blocks that have up to eighteen inches of freeboard. Broken ice originating in the Saugus and Pines River goes out with the tide, but often becomes grounded in shallow Lynn Bay, and returns with the next tide. The incoming tide generally pushes the ice up into the Saugus River rather than the Pines River.

Broken ice accumulates between the General Edwards Bridge and the lift bridge upstream from the railroad bridge. In the past, ice accumulations have blocked the navigation channel at the General Edwards Bridge, and the fishermen are worried that the same thing will happen at the navigation gate at the new structure. They are concerned that the new structure will exacerbate the ice accumulation problem. (They are also concerned about debris blockages at other times of the year; apparently there is a lot of debris in the river). Ice also collects on the pilings in the vicinity of the General Edwards Bridge, and in a NW wind (which reportedly is the prevailing wind in cold weather), the ice is blown up onto the Point of Pines beach.

A strong NW wind can also clear the channel of ice. In many winters (but not the past two), the fishermen have to call the Coast Guard ice breaker to come

break up the ice accumulation. The breaker makes one or two passes on an outgoing tide (to flush the ice out), and the fishermen then keep the channel open with their own boats. It has been about 12 years since the last severe ice event.

Information gained during the site visit indicated two areas of concern. First, ice could potentially bridge across the gate openings of the structure, which could impact gate operations as well as navigation. Second, icing of the gates could restrict operation during the cold months, which is when most of the tidal surges are expected.

*Physical Model Observations.* Jon Zufelt and Kate White met at WES with Larry Daggett (Chief, Navigation Branch, Hydraulics Laboratory, WES) and Chuck Wener (Chief, Hydraulics & Water Quality Branch, NED) on 30 March, 1992, to review the physical model of the Saugus River Floodgate Project area. The primary reasons for the visit were to observe the performance of the physical model and discuss the potential ice interactions with the Saugus River flood control project. Since the model structure will soon be removed for other tests, we were also to determine whether any additional testing to model ice passage and/or accumulation would be required while the model flood control structure was still in place.

The operation of the model during spring flood tide with the top of the gate opening set at +6 feet NGVD was observed. At this tide, the water stage is about 6.2 feet NGVD, so the gates, or rather the roadway which serves as the gate seal, were slightly submerged. Videotapes of earlier tests with spring ebb flow conditions and different gate openings were shown.

Howard Park was able to locate some polyethylene blocks, which could be used to illustrate ice movement and accumulation. These blocks would be roughly 8 ft by 8 ft by 3 ft thick in prototype, with a few one foot thick pieces thrown in, so they are fairly close in size to the expected ice pieces. A neap ebb flow condition was set up in the model, and the model ice blocks were added. As expected, the blocks accumulated at the gate openings when the gates were slightly submerged. There was not enough model ice blocks available to model the expected ice discharge conditions, so bridging at the gate openings could not be modeled. However, based on our conversations with the local fishermen and yacht club members, we expect that ice may bridge the gate openings, which are 50 feet wide (ice has bridged at the General Edwards Bridge openings, which are 100 feet wide).

## Assessment of Potential Ice Impacts

Ice impacts on the Saugus River Floodgate structure can be broken into two categories: impacts to navigation as a result of blockage of the gate openings, and ice impacts on the gate operations. Ice accumulations may be caused by partial gate submergence or by ice bridging due to a combination of low velocities or eddies, high ice discharge, or lodgment of several large blocks of ice. The ice accumulations may in some cases block the miter gate opening, preventing boat passage. Impacts on gates include the effects of icing and ice adhesion on the gates and gate walls, and the effects of ice accumulations on gate operation. While the potential for gate blockage is of most concern to the commercial fishermen, impacts on gate operation are more critical to the project.

*Gate Operation.* Gate operations can be affected in a number of ways at the Saugus River Floodgate structure (COE 1982, 1990). Wind-blown spray and splashing can result in icing of the tainter gate arms. This may prevent the complete closing of the arms. Tainter gate icing can also appreciably increase the weight of the gate, adding to the stresses on the gate, and even cause the gates to be inoperable. If the tainter gates are left in the closed position for a length of time in cold conditions, they may freeze shut, particularly if there is leakage around the gate seals. Spray icing can coat the miter gate arms when the gate is in the closed position, preventing the gate from opening completely.

Ice adhesion to the gates and gate walls as a result of water level fluctuations can encourage the growth of "ice collars", which may hinder tainter gate closure. Ice adhesion to the miter gate will add to the weight of the gate, stressing the miter gate arms. Ice growth between the miter gate and the miter gate recesses may freeze the gate in the open position.

Ice accumulation in the miter gate opening during gate closure may cause difficulties in opening the gate. Ice caught in the miter gate recesses will prevent the gate from opening completely. Similarly, ice accumulated in and on a tainter gate while in the closed position may cause problems in raising the gate.

*Ice Accumulation.* Broken ice pieces moving upstream and downstream with the tide may be stopped by a partially submerged gate. The ice pieces will accumulate at the gate and, in cold conditions, will freeze into an ice cover. Based on the surface water velocities given in the preliminary data from the model study, the ice pieces will likely form a single layer on the upstream side of the gate. Wave action may result in shoved and thickened ice on the seaward side of the gate. Whether or not the ice breaks up and passes through the gate when the water level drops will depend on the length of time that the ice is held in place by the closed gate and the forces on the ice. Blockage of gate openings in

this manner can hinder gate operations and change the hydraulic performance of the structure.

There is some evidence that ice pieces originating in the Saugus and Pines Rivers can reach sizes large enough to allow for lodgment and subsequent blockage of the floodgate structure gate openings. However, many of these large pieces will be captured upstream by the General Edwards Bridge, the General Electric pier and timber pier upstream from the General Edwards Bridge, and the B&M Railroad Bridge, and the Route 107 Bridge on the Saugus River.

Ice can also accumulate as a result of "bridging" or "arching" at a gate opening. Bridging and arching are terms used to describe the stoppage of ice resulting in the blockage of a channel. This most frequently occurs in low velocity areas where the channel is narrow and the ratio between the average ice piece size and the width of the opening is greater than 0.1 (Calkins and Ashton 1976). Ice pieces with an average plan dimension of 5 feet or greater would be likely to bridge the tainter gate openings. If the gate opening were decreased by ice collar growth, smaller pieces could form an ice bridge. Once the ice bridges at an opening, additional ice can accumulate and form an ice cover in the same manner as if they had been stopped against a partially submerged gate. Surface velocities greater than about 2 feet per second inhibit ice accumulation, since the ice blocks are likely to submerge and pass beneath the obstacle.

Based on the reports by local fishermen and Point of Pines Yacht Club members, it appears that broken ice pieces will tend to be driven onto the shore by the wind in the vicinity of the upstream right side of the structure. Over the course of the winter, ice may accumulate in this area and could possibly block the tainter gate openings near the shore. The model results indicate that large eddies may be present near the shore upstream and downstream of the structure. These are likely spots for shore ice growth and broken ice piece accumulation into an ice cover. Again, these ice accumulations can affect the hydraulic performance of the structure and increase velocities through the gate openings. The increased velocities may discourage bridging at the gate openings by smaller pieces of ice.

*Tainter Gate Setting.* Predicted tidal levels at the Saugus River floodgate structure site are given in figure 2-3A of the Roughan's Point Project Design Memorandum (NED 1991). The gate setting at 0 ft NGVD (top of gate opening) is clearly unsuitable as the gate will be submerged part of every high tide. A gate setting of +3 ft NGVD will also result in frequent gate submergence. If the bottom of the gate is set at +6 ft NGVD, it will be submerged during about 15% of the high water events (or about 1.7% of the total annual hours). Assuming an average ice block freeboard of less than 0.2 feet (based on 92% submergence of an

average thickness ice block), ice would be expected to accumulate at the gate due to gate submergence about 2% of the total hours.

However, the structure must also be designed to take into account a one-foot rise in sea level over the life of the project. A gate setting of elevation +6 at the present time will effectively model a gate setting of elevation +5 if the water level were to rise one foot. In this case, the gates would be partially submerged during about 46% of the high water periods (7% of the total annual hours).

*Design Considerations.* Based on the available information, it is not possible to determine whether the presence of the Saugus River Floodgate structure will increase the frequency of blockage of the navigation channel by ice. Because of the difficulties inherent in extrapolating unsteady flow conditions from a steady flow model, particularly when ice is involved, it is unlikely that additional tests of the physical model using model ice will provide an answer to this question. There is no evidence to support the theory that increasing the width of the tainter gate openings will significantly decrease the frequency of potential channel blockage due to ice.

Considering the preliminary data from the physical model, we recommend that the Saugus River Floodgate Structure be designed with a tainter gate setting of elevation 7 ft NGVD (top of opening) in order to minimize ice accumulations at the structure due to partial gate submergence under present flow conditions. Astronomic tides exceed elevation 7 ft NGVD less than 0.2% of the time, causing a significantly reduced risk of ice blockage due to gate submergence. This gate setting will also provide some protection against the anticipated one-foot rise in sea level, in addition to decreasing spray and splash icing. With a one foot rise in sea level, the gate would be submerged about 2% of the time at this gate setting. Top of gate openings above elevation 7 ft NGVD provide only minimal additional protection against submergence.

Operation under ice loading should be considered in the design of the tainter gates. Atmospheric ice loading may be minimized if some sort of housing is constructed over the gate to protect it while in the open position. Consideration should be given to providing skins on both sides of the tainter gates to decrease icing.

If a flat plate with seal combination is used in the tainter gates, side seal gate heaters could be installed to keep the plates free of ice. Hollow J-seals should be considered so that heating cables can be inserted in the J-seals and replaced when necessary (COE 1989a). If a housing is used, the J-seal heaters may be activated only when the gate is to be closed. Otherwise, heaters should be operated December through February. If the tainter gates are designed with

side wall recesses, a permanent submerged bubbler system could be used to keep the recess area ice free. Submersible tainter gates could be considered in this application, since many icing problems could be avoided by storing the gates in the submerged position. However, there may be other constraints against using submersible gates in a marine environment.

The miter gates might also be skinned both sides to avoid ice accumulation within the gates. Permanent, submerged air bubbler lines could be placed at the bottom of the miter gate recesses to insure that they can be fully opened and closed. A high flow, low pressure bubbler system might be applicable in this situation. Alternatively, the use of floating infrared radiant heaters in the miter gate recesses might be considered. Ice control at miter gates is discussed in Engineer Manuals and Engineering Technical Letters (COE 1982, 1985, 1989b, 1990) which were forwarded to NED.

**Summary**

The Saugus River Floodgate Structure is designed to protect inland area against flooding associated with tidal surges. The project consists of a concrete gravity structure with eight fifty-foot-wide tainter gates and one one-hundred-foot-wide miter gate used for navigation. The gates will be closed during expected tidal surges for a period of one to two hours. It is expected that gate closure will occur two to three times annually, primarily during the winter months.

Local sources indicate that broken ice pieces up to three feet thick and 10 to 15 feet in length have been observed in the river. The ice usually originates in the Saugus and Pines Rivers, although some may be carried into the estuaries from Lynn Harbor with the tide. The General Edwards Bridge, which has pier spacings of 100 feet, has been blocked with ice in the past, preventing navigation. Local commercial and recreational boaters have expressed concern about a potential increase in the frequency of navigation channel closure due to ice blockage at the structure.

Observations at the site of the proposed structure, discussions with local residents, and review of the preliminary data from the physical model study, are the sources of information presently available regarding potential ice impacts to the structure and caused by the structure. Based on this information, potential ice impacts to the tainter and miter gate operations include spray and splash icing of gates and gate arms, ice adhesion to gates and gate walls, and ice accumulations in the tainter gate openings and miter gate recesses. Ice accumulations will occur as a result of both partial submergence of the gates and ice bridging across the gate openings.

Because the floodgate structure will be operated largely during the winter months, we recommend that gate design take ice effects into account. Further, we recommend that the minimum tainter gate setting be set at elevation +7 ft NGVD (top of opening) to avoid ice accumulation by partial gate submergence at present tidal conditions, and to minimize submergence at the tidal levels anticipated with a one-foot water level rise. Prior to being finalized, design of the project should be reviewed by CRREL Ice Engineering Research Branch personnel to identify potential ice problems. We also recommend that a monitoring program be designed so that ice conditions in the Saugus River may be closely watched at least for the next winter season, and preferably for the next several seasons.

If you have any questions or would like further information, please contact Kathleen D. White at 603-646-4187.

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May 21, 1992

Mr. Charles Wener
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Dear Chuck:

I have finally gotten some information on Coast Guard ice breaking in the Saugus River. Apparently, each year a report on domestic ice breaking operations is preapred by the officer in charge of the USCGC Pendant and sent to the First Coast Guard District Search and Rescue Office. Chief Mauck is in charge of the Pendant at the present time, and Mr. Robert Patton is the officer I spoke with at the District SAR Office. The SAR Office only keeps the reports received for the past 5 years.

The records indicate that there were no ice breaking operations in the Saugus River during the winters of 1986-87, 88-89, 90-91, and 91-92. This means that the ice was less than two inches thick according to Mr. Patton. In 1989-90, there was one-ice-breaking trip to the Saugus River (December 29). The lower Saugus River between Point of Pines to the General Edwards Bridge was reportedly blocked with "6" ± of solid/broken ice." Ten commercial fishing vessels were aided.

During the winter of 1987-88, two trips were made to the Saugus River (January 8 and 16). On January 8, one to two inches of ice were broken between the mouth of the river and a point about one quarter of a nautical mile upstream from the Fox Hill Bridge. The Pendant was unable to continue farther upstream because of high wind conditions. Ten commercial fishing vessels were freed to go fishing. On January 16, the ice was reported as 2 inches thick and 100% of the

approach channel was frozen. But only 10% of the channel was frozen above the General Edwards Bridge. I assume this means that the lower river, from Point of Pines to the General Edwards Bridge, was frozen, but the river was open upstream from the bridge. One tug and two barges were aided.

Chief Mauck will forward the ice operations report for this past season when it is done in early June. Meanwhile, I am trying to locate records earlier than 1986. If any are available, I will let you know.

Sincerely,

Kate

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