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Cold Regions Research & Engineering Laboratory

Ice Engineering

U.S. Army Engineer Research and Development Center, Hanover, New Hampshire

Early Warning Flood Stage Monitoring Equipment

Communities built along both large and small rivers can be threatened by flooding and the associated potential for loss of life and personal property. Whether resulting from heavy rains, snowmelt, ice jams, or combinations of these, flooding can occur unpredictably and without warning. An advanced early flood warning system could prevent fatalities and loss of personal property. The Engineering Resources Branch of the Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (CRREL) has long been involved in the development of environmental monitoring systems for remote sites. Several systems have been modified for use in early flood warning. This report describes a simple early flood warning system along with an example of its use on the Israel River in Lancaster, New Hampshire.

System description

A typical simple low-cost early warning flood stage system (Fig. 1) will consist of commercially available off-the-shelf-components (COTS). The major components of an early warning flood stage system are a stage sensor connected to a data acquisition device with built-in power supply or backup, some type of notification or warning equipment, and a means of communication. Stage is generally monitored using a pressure transducer. The data acquisition system performs two functions: it collects and stores real-time flood stage data from the pressure transducer and initiates the notification process once predetermined flood stage conditions are met. The system can be powered from an AC source via landline or by batteries that are recharged by solar panels. The notification process can incorporate standard telephone or cellular telephone. Transfer of data from the early warning flood stage system can be achieved using standard telephone, cellular telephone, RF telemetry, wireless Ethernet, or satellite transceivers. System configuration options for power and communications are summarized in Table 1.

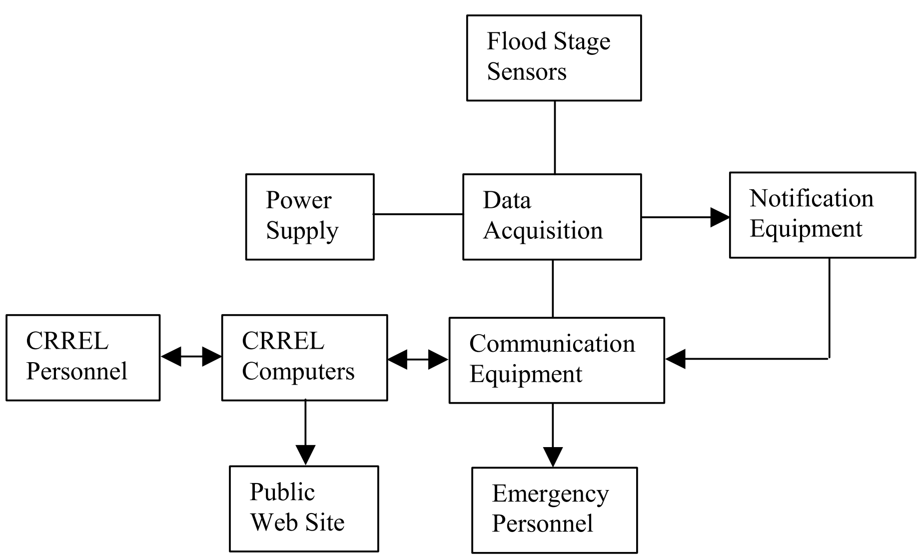

Figure 1. Simple early warning flood stage system tested at CRREL.

Table 1. System configurations.						
Land-line power and standard phone service	**No land-line power, standard phone service**	**Land-line power, no standard phone service**	**No land-line power or standard phone service**			
			Cellular telephone	**RF**	**Wireless Ethernet**	**Satellite transceiver**
Pressure transducer	Pressure transducer	Pressure transducer	Pressure transducer	Pressure transducer	Pressure transducer	Pressure transducer
Data acquisition device	Data acquisition device	Data acquisition device	Data acquisition device	Data acquisition device	Data acquisition device	Data acquisition device
Notification device	Notification device	Notification device	Notification device	Radio telemetry	Wireless Ethernet	Satellite transceiver
Data transfer modem	Data transfer modem	Data transfer modem	Data transfer modem			
Battery backup	Battery	Cellular telephone	Battery	Battery	Battery	Battery
	Charge controller	Battery backup	Charge controller	Charge controller	Charge controller	Charge controller
	Solar panel		Solar panel	Solar panel	Solar panel	Solar panel

Demonstration

Lancaster, New Hampshire, located on the Israel River, is prone to flooding caused by unpredictable ice jams (Fig. 2). The Israel River is appproximately 21 miles long and has a drainage area of about 136 square miles at its confluence with the Connecticut River in Lancaster. The river is generally shallow and relatively steep, with a rough bed, until it reaches the mildly sloping reach about 1.5 miles long that results from the backwater of the Connecticut River. The Israel River produces a tremendous amount of frazil ice during early winter, forming substantial deposits in the backwater reach of the Connecticut River.

Figure 2. Ice jam, 6 February 1996. This jam resulted in flooding, property damage, and street closings in Lancaster, New Hampshire.

As with many New England towns, settlement along the river was accompanied by the construction of dams to supply mechanical power. A New Hampshire Water Resources Board dam inventory in 1936 reported four dams within Lancaster. These included a 20-ft-tall timber crib dam located just downstream from the Main Street Bridge and a second 20-ft-high dam upstream from the bridge. The locations of the third 20-ft-high × 220-ft-long dam, and the fourth dam, 25 feet high, can be seen in Figure 3. Each dam created a small impoundment that captured frazil ice during the winter and slowed the movement of ice downstream during breakup. The delays in ice movement caused by the dams decreased the volume of ice available to jam in and near the center of town.

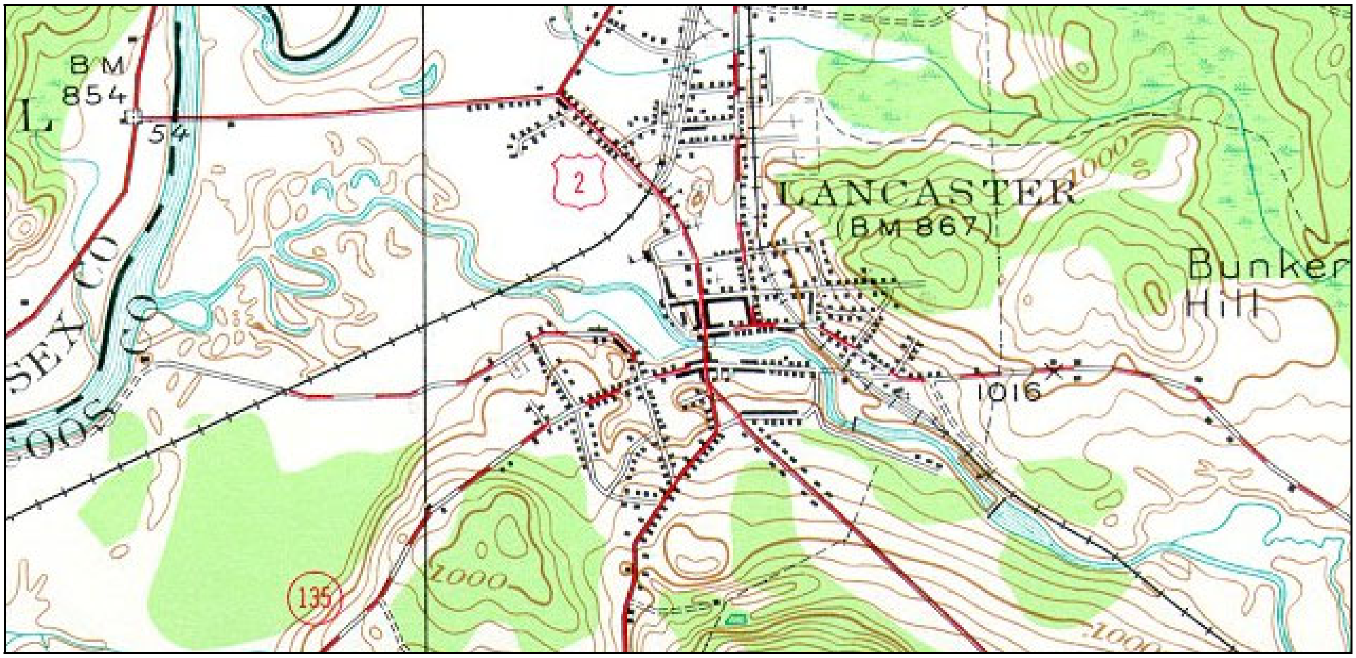

Figure 3. Contour map of Lancaster, New Hampshire (USGS 1935.) Two former dams and their impoundments are shown. The other two former dams were located just upstream and downstream of the Main Street (Route 2) Bridge. Damaging ice jams now form at the upstream end of the backwater from the Connecticut River, near the railroad crossing.

Between 1936 and 1950, these dams were damaged during large flood events, eventually leaving only ruins after 1950. Ice jam flooding has increased in frequency and severity since the failure and removal of the dams. Of the seven large floods reported in Lancaster between 1870 and 1940, only two (1886 and 1895) were reported as being caused by an ice jam, but 15 of the 18 floods between 1940 and 1970 were due to ice jams (USACE 1973). An additional 14 ice jams events since 1970 are listed in the CRREL Ice Jam Database (http://www.crrel.usace.army.mil/ierd/ijdb/).

Following the disappearance of the dams, frazil ice that formerly accumulated in the dam impoundments was able to move downstream and accumulate in the reach of river affected by backwater from the Connecticut River, beginning in the area near the railroad bridge abutments (Fig. 3). Frazil ice deposits seven to ten feet thick have been measured at this location. This thick ice cover, combined with a reduction in energy gradient associated with backwater from the Connecticut River, provides a jam initiation point during ice cover breakup. With the dams no longer in place to delay movement of broken ice, ice transport is unimpeded and a relatively large volume of ice is able to move downstream. When this moving ice reaches the thicker ice in the backwater area, jams can initiate and progress upstream, often causing flooding of the town.

These breakup ice jam flood problems have recently been compounded by the formation of freezeup jams, beginning in 1997. These jams tend to form early in the season and result in higher-than-normal water levels throughout the winter. The high water levels cause infiltration to the sewer lines, thereby increasing operation and maintenance costs. Bank erosion near the toe of the freezeup jam threatens a drop structure that carries sewage under the river to the pump station.

The freezeup jams also have the potential to cause increased flooding during ice cover breakup later in the season. This breakup flooding occurs much more suddenly than a typical breakup jam, leaving virtually no time for emergency response. Over the last decade, Lancaster has flooded as a result of ice jams (Fig. 2) approximately five times without warning.

Following a devastating ice jam flood in 1968 ($3M in damages in 1968 dollars), the Corps of Engineers' New England Division (now District, NAE) and CRREL performed a detailed Section 205 study that resulted in the construction of an ice control structure (completed in 1981) at the approximate location of the third dam. The structure was originally designed to halt the movement of upstream ice, thus limiting the ice volume available to jam in town. However, economic and environmental constraints limited the size and scope of the project, which was constructed as a 160-ft-long, 9-ft-high, concrete-capped gabion weir with four sluiceways intended to assist fish passage.

Detailed studies would be required to determine whether the frequency of jamming has been altered by this ice control structure. However, even though it is much smaller than desired, the structure has reduced the severity of ice jam floods by capturing some frazil ice and delaying somewhat the downstream movement of ice during breakup.

In 2000, CRREL was asked by NAE Emergency Operations to provide technical support for a number of New England communities affected by ice jams. CRREL determined that an early warning flood notification system would provide the most economical and effective advance measure for reduction of flood damage caused by ice jam flooding in Lancaster.

Two conditions of flood stage on the Israel River were selected for monitoring: rate of rise in a 24-hour period and overbank flood stage. Both events can signify the potential for flooding that occurs as the result of an ice jam. If the Israel River rises 18 inches in a 24-hour period, or if the river reaches overbank conditions, the notification process is activated.

The Lancaster system also includes water temperature measurements, which can be used to signal potential frazil ice production and the start of freezeup jamming. The system uses landline power and standard telephone because cellular phone service in Lancaster is limited. The notification system via landline telephone notifies the 24-hour Fire Department dispatch, the Town Hall telephone, and the home telephone of the Public Works Director using a prerecorded message.

A public Web page interface has been incorporated into the early warning flood stage system to allow emergency response personnel in Lancaster to visually inspect the status of the Israel River from any computer that has access to the World Wide Web. The Web page interface is updated every two hours via a computer located at CRREL that retrieves data from the remote site and automatically updates the Web page.

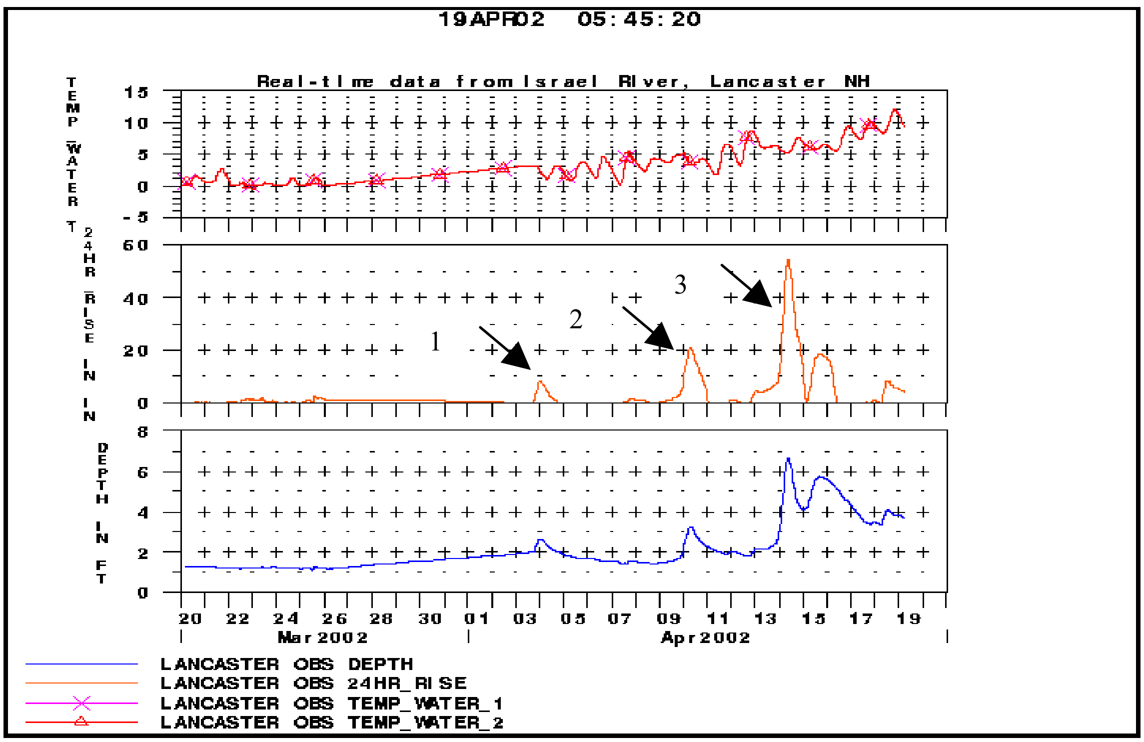

Figure 4. Lancaster Web page interface, showing three events. The first event did not exceed alarm thresholds and did not result in flooding. The second and third events did trigger alarms.

Figure 4 shows a sample plot of data from the CRREL Web page. The first event, on 3 March 2002 (marked 1), was the formation of a breakup jam just downstream of the pressure transducer that did not meet either criterion for notification. The second event, on 10 March 2002 at 0230 hours (marked 2), represents the increase in stage caused by a rain event that caused the Israel River to exceed the rate-of-rise threshold of the data acquisition system. The system did alert response personnel of a potential flooding event. Fortunately, the ice jam released, clearing the river without causing a flooding event, but the emergency personnel were grateful for the early warning. The third event (marked 3) portrays the river rising again as a result of a combined snowmelt and rain event several days after the ice had cleared. Again, emergency personnel were notified and were able to respond quickly to reduce flood damages from this open-water flood event.

In 2003, remote imaging equipment was added to the early warning notification system. This feature gave CRREL personnel and Lancaster's emergency response personnel the ability to remotely inspect the condition of the Israel River. On a predetermined schedule, images from the Lancaster site were retrieved via standard telephone and posted to CRREL's Web page. Three cameras were used: one standard camera and two cameras capable of operating in low-light conditions. Nearby streetlights provided sufficient light for the low-light cameras to successfully obtain images during the night.

Figure 5 depicts the condition of the Israel River prior to ice cover breakup. The water flowing over the ice cover is an indication of increased discharge. Figure 6 shows the breakup's aftermath. The remote imaging equipment proved to be a useful tool when used with the stage equipment to determine a river's condition.

Figure 5. Retrieved remote image of Israel River prior to ice breakup.

Figure 6. Retrieved remote image of Israel River after ice breakup.

Conclusion

Flooding that occurs in communities along rivers can result in loss of life and personal property. Early notification provided by monitoring systems constructed from COTS components could alert personnel of such communities, allowing them to put emergency response plans in motion. A simple early warning system demonstrated in Lancaster, New Hampshire, monitored river stage and notified response personnel of potential flooding associated with ice jams and open water flooding. The system successfully provided the response personnel of Lancaster time to confirm the pending flooding event and allowed the option to put response plans in effect. The Web interface provides an opportunity for remote monitoring of conditions.

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