Experiences of the Spring Break-up 2000 on the River Kalajoki

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Abstract

The River Kalajoki with its watershed of 4 260 km^2 is a typical river in Ostrobothnia area. There are only few lakes in the watershed of the river and its discharge varies quite strongly during a year. During winter the discharge is below 10 m^3/s, during break-up 130 – 300 m^3/s and the highest observed discharge is 469 m^3/s. The mean slope of the lower Kalajoki river is about 0.93 m/km, but the slope varies a lot along the river which has many short rapids and long pool stretches. The river width is mainly about 70 m.

The spring flood of the year 2000 having a peak of 420 m^3/s was the second largest during the observation period since 1911. The water levels and discharges of the river started to rise slowly in the beginning of April. The measured water equivalent of the snow in the beginning of April was about 1.5 times higher than the average value. An exceptionally warm period made the discharge increase quickly after April 14th. Several ice jams causing flooding and damages were formed along the river between April 17th and April 22nd. Prior to the break-up a special ice saw machine was used to cut the ice cover on certain locations to prevent ice jam damages. Successful watershed regulation together with ice cutting probably prevented more serious damages.

In this paper a general description of the break-up event at the River Kalajoki during the spring 2000 is given and the effects of preventive measures like discharge regulation and ice sawing on the ice break-up are estimated. Also the results of the analyses of some of the occurred ice jams with a numerical model are presented.

1. Introduction

The River Kalajoki with its watershed of 4 260 km^2 is a typical river in Ostrobothnia area. Due to small number of lakes the variations of water levels and discharges are great. At the gauging station Niskakoski located in the lower part of Kalajoki (F=3025 km^2, L=1.8%) observations have been made since1911. The lowest observed flow NQ = 0.0 m^3/s, mean low flow MNQ = 1.5 m^3/s, mean flow MQ = 26 m3/s, mean high flow MHQ = 245 m^3/s and highest observed flow HQ = 469 m3/s. Thanks to the regulation of Kalajoki, low flows have raised 2-3 m^3/s. During winter the discharge is below 10 m^3/s, during break-up 130 – 300 m^3/s and the highest observed discharge is 469 m^3/s. The mean slope of the lower Kalajoki river is about 0.93 m/km, but the slope varies a lot along the river which has many short rapids and long pool stretches. The river width is mainly about 70 m.

In the Figure 1 there are presented a general map of the Kalajoki watershed and the longitudinal profile of the river. Regulated and unregulated lakes and artificial lakes as well as flood areas and areas effected by flood protection works are presented in the figure. The water course is regulated to benefit flood protection, power production, water pollution control, and the recreational use of waters. The regulation permits are owned by the Regional Environment Centre of North Ostrobothnia. The local power companies, Vattenfall and Vieska Energia, take care of the regulation discharges in accordance with the water court decisions and guidelines by the environment centre.

The yearly precipitation in the area is around 550 mm, evaporation around 270 mm and mean discharge 8,6 l/s /km^2. Around 45% or 200 mm of the precipitation falls as snow. The average maximum of water equivalent in snow cover is 105 mm at the turn March April. Dikes and clearings done in the catchment area have accelerated the flow forming especially in high flow situations. Artificial reservoirs and regulation in use have made flows more even and low flow requirements have increased flows during dry seasons.

The greatest flood damages in the Kalajoki water course have been caused by floods originated by ice jams. The worst situation shows up when snow melts rapidly and the melting is accelerated by rainfall so that flows increase suddenly causing ice break-up. In this kind of case, the ice usually has not yet become thinner and weaker and risk for ice jams is therefore high. The situation in spring 2000 developed just in this way.

In a normal situation, as melting of snow is even, the ice break-up can be delayed by storing melting waters in reservoirs. So the ice gets time to weaken and the risk of forming ice jam diminishes. In addition, ice of the middle part is melted by the heat storage of Pidisjärvi by lowering the water level in the lake evenly to the regulation limit about two weeks before the melting season begins. Unfortunately the lake is relatively small and ice can be melted only in a small part of the river.

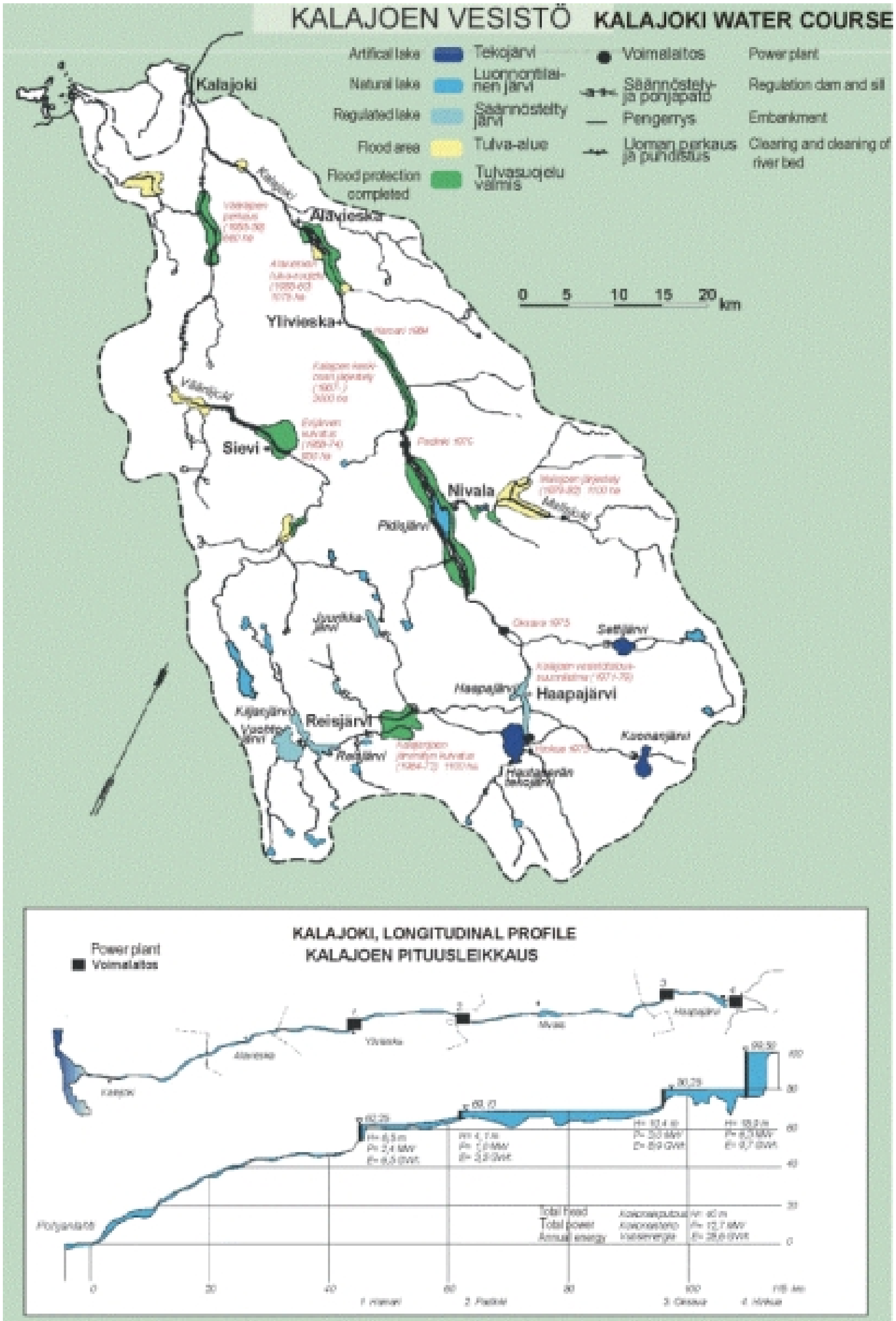

Figure 1. General map of the Kalajoki watershed and the longitudinal profile of the river.

There are runoff and regulation models as well as a river ice model (Huokuna 1990) in use to serve water management of the watershed. The runoff model can be used to estimate inflow time series based on the given precipitation and temperature bservations. Using water level, flow, and weather observations, and weather forecasts the model makes inflow prognosis for different points of the water course. The runoff model includes also reservoir models and simplified river model giving means to create water level and flow hydrographs of reservoirs and certain river sections. The river ice model can be used to study the effect of discharge on ice cover formation and to predict the decay of ice cover during spring. The model has also been used to study the effect of the use of the heat storage of Pidisjärvi lake on ice thickness downstream of the lake.

2. Use of ice saw to prevent flood damages

Two special ice sawing machines have been used to cut ice cover during several springs in Western and Northern Finland. The experience is that cutting should not be done too early, because then cutting slots may freeze again. Normally sawing is done about two weeks or one month before the break-up. The local environment centres are taking care of the sawing. The locations of the river stretches where sawing is done during a normal spring are presented in the figure 2. The sawing machine is used extensively on the Kalajoki river where ice is cut normally on eight river stretches. The length of those stretches varies from 0.1 km to 3 km

The sawing machine (see Fig. 3) is a self moving machine weighting about 8000 kg and it is capable to saw 20 cm wide cutting to a 1,2 m thick ice cover in a speed of about 1 km/h. If the ice cover is thinner the sawing speed may be as high as 2 km/h. (Personal communication, Erkki Mykkänen, Finnish Environment Institute) For safety reasons the machine is designed to be floating. It can move independently on the working area and also short distances to the truck which is used for transportation. The main body of the sawing machine is made of aluminium and because of that it’s weight is relatively low. The main information of the machine is presented in the Table 1. There are two existing machines and the values are lightly different for those machines. The first sawing machine was build by the local Environment Centre in Kokkola and designed by Erkki Mykkänen from Finnish Environment institute. The other one was build by a private firm Mobimar Ltd. First time the sawing machine was used extensively during spring 1993.

There is hydraulic power transmission in the machine. In the back of the machine there is a circular saw which diameter is 1.8 m and which can be lowered and raised hydraulically. In the front of the machine there is a winch which can be used to help the machine move if ice cover is broken under it. The minimum ice thickness needed for sawing with the machine is about 0.5 m.

The main reason for the development of the sawing machine was the expenses of the other preventive methods like dusting or using of explosives. An ice jam prevention method was needed which can be used before break up, which is economical, which do not need a lot of man work and which is environmentally acceptable.

Robert B. Haehnel reports several nonstructural methods for ice control (Haehnel 1998). He also compares costs and performance of various methods of ice control and according to that data the Finnish ice saw is very economical and effective method.

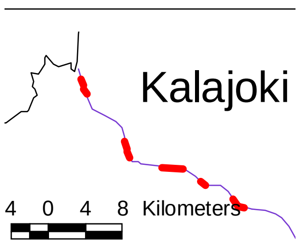

Figure 2. River stretches were ice sawing is normally done in Finland.

Table 1. Main properties of the ice sawing machine.

Property	**Value**
Sawing speed	1 – 2 km/h
Maximum speed	16 km/h
Width of the sawing slot	18 cm / 20 cm
Maximum sawing thickness of the ice cover	120 cm
Length/width/height	7.3 m / 3.2 m / 3.4 m
Weight	8000 – 9000 kg
Power of the engine	168 kW
Generator	5 kVA 3*380V / 50 Hz

Figure 3. The ice sawing machine. (Photo by Pekka Leiviskä)

3. The spring flood 2000 on Kalajoki River

3.1 Hydrological conditions in the watershed during the spring 2000

The second half of the year 1999 gave more than average precipitation. In December the precipitation was twice the normal. Also the beginning of the year 2000 continued to be more rainy than the average. Though a great share of the precipitation in January came as water, the water equivalent of snow was 25% higher than the average at the end of March. The beginning of April continued rainy and the maximum water equivalent of snow was measured on April 4th being almost two weeks later than the average date of maximum water equivalent. The measured water equivalent 140 mm was approximately 1.5 times the average equivalent at this time (Figure 4) . As there was much rain fall during the latter part of April and the temperatures were exceptionally high (Figure 5) and no night frost existed the snow melted in a record short time causing both ice jam and water floods in the region.

The water levels and discharges of Kalajoki river started to rise slowly in the beginning of April. The warm period and rain made the discharge rise roughly since April 14th, and the maximum flood was achieved overall in the watershed between April 23rd and 27th. The maximum discharge at Niskakoski observation station was observed on April 24th. The observed discharge, 414 m^3/s, was the second greatest discharge ever recorded during the observation period since 1911.

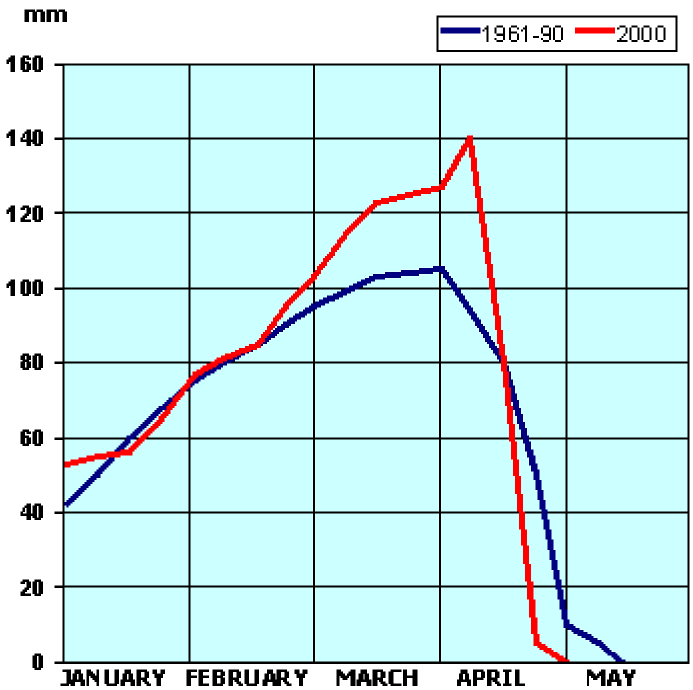

Figure 4. The average water equivalent of snow for the years1960-1990 and the observed water equivalent of snow in 2000 in the Kalajoki watershed.

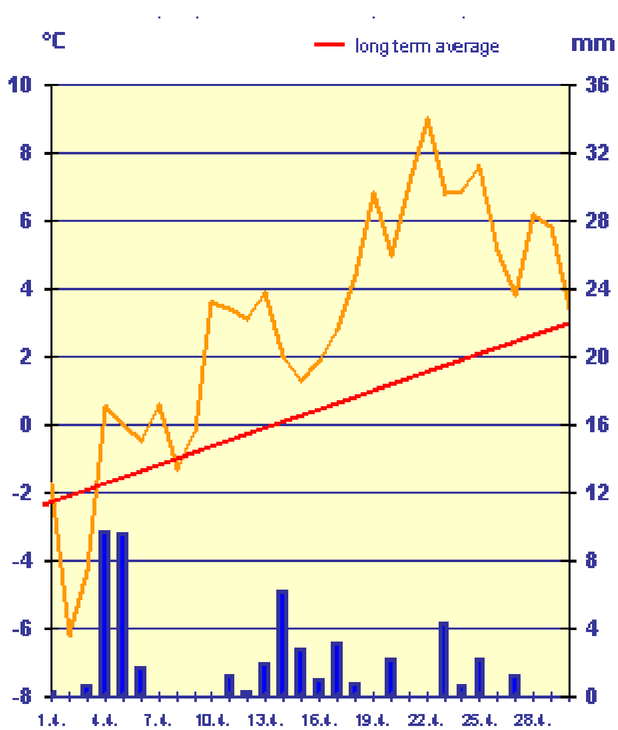

Figure 5. Observed temperature and precipitation at Nivala observation station in April 2000.

The melt waters were stored to the reservoirs since April 14th. During the flood the total maximum flow stored in the reservoirs was about 130 m^3/s, which means that without regulation the flood maximum in the river Kalajoki would have been the greatest ever recorded at Niskakoski. Figure 6 shows discharge values in the upper part (Oksava), the middle part (Padinki) and the lower part (Niskakoski) of the River Kalajoki as well as the combined actual storage in the reservoirs.

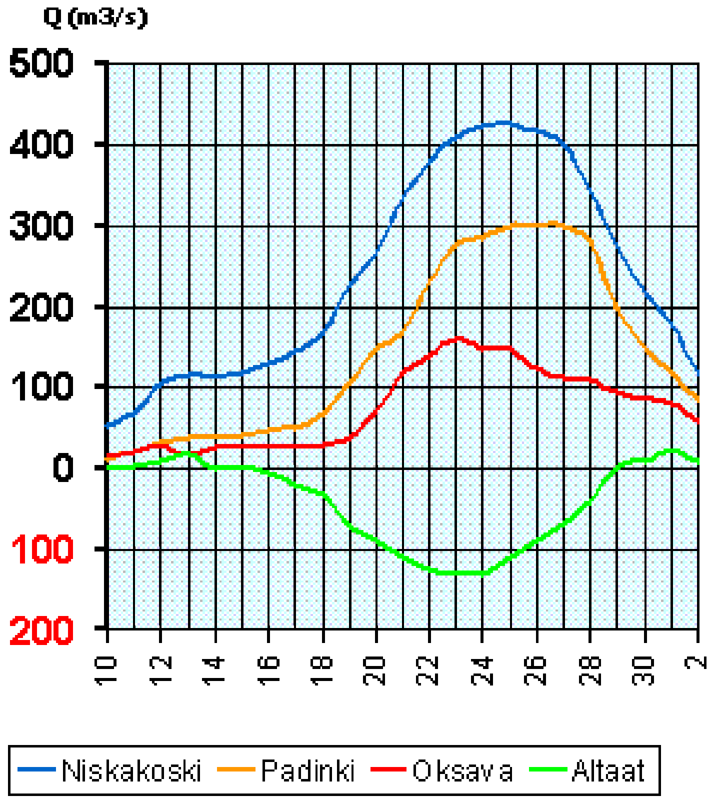

Figure 6. Discharge in the upper part (Oksava), the middle part (Padinki) and the lower part (Niskakoski) of the River Kalajoki as well as the combined actual flow stored in the reservoirs (Altaat).

3.2 General description of the Ice break-up 2000 on Kalajoki river

During the spring 2000 the break-up started at the lower part of the Kalajoki River at the main village of Kalajoki in the afternoon of April 17th (Figure 7). On April 19th a small ice jam was formed in Raudaskylä, 60 km from the mouth of the river. During the afternoon on the following day ice moved in Alavieska, 26 km from the mouth of the river. Ice from the Alavieska ice jam moved downstream and new jams were formed during that afternoon and evening in Kääntä and Tilvis (Figure 7). During the following day, April 21st, the Tilvis ice jam moved downstream and a new jam was formed in Tynkä. When the jam in Tynkä on April 21st was released, the river downstream of Alavieska was free of ice. Some of the ice jams are described more in detail in the following chapters.

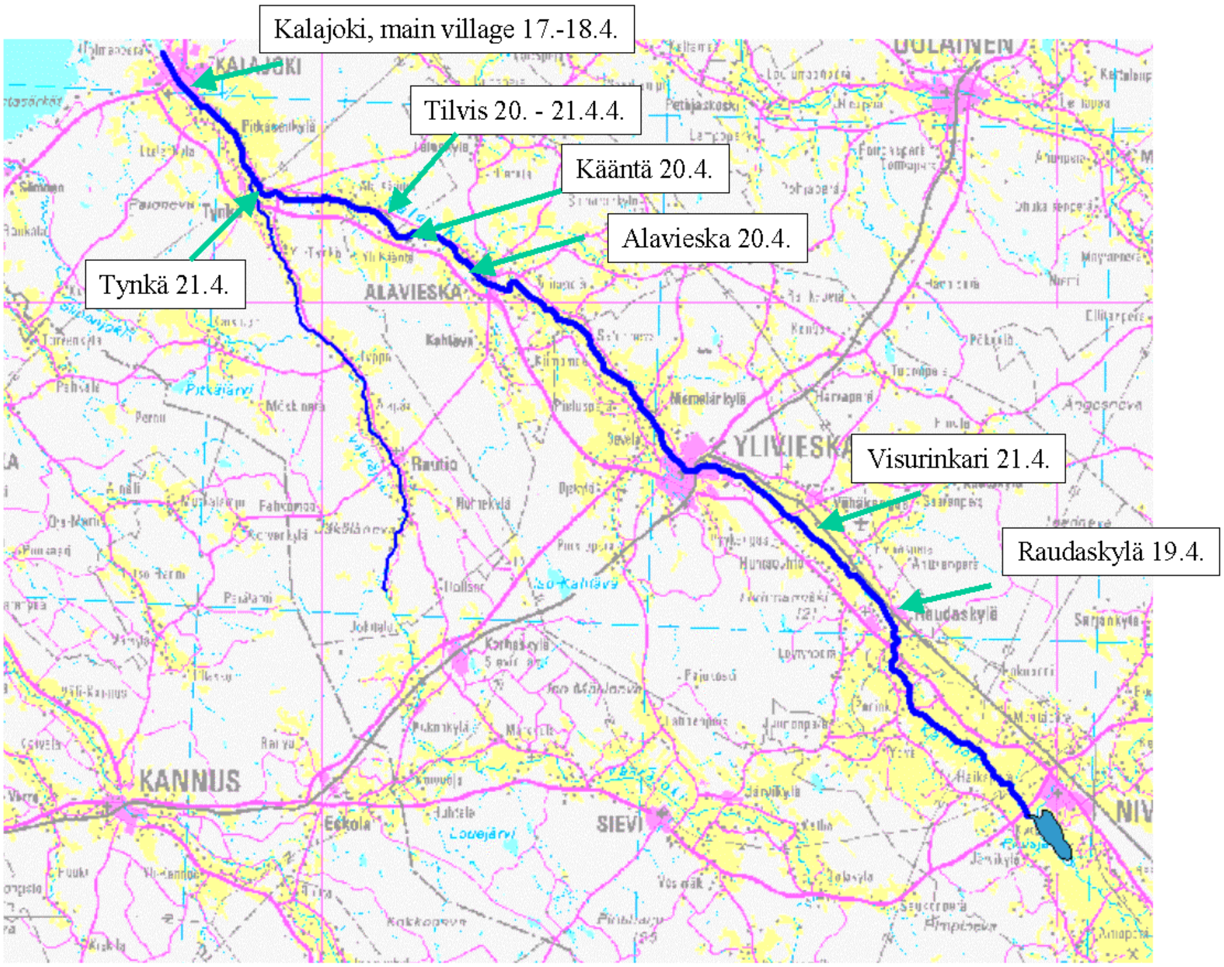

Figure 7. The main ice jams during the 2000 break-up at Kalajoki River.

3.3 Ice jam at the main village of Kalajoki

There has been several bad ice jam floods at the main village of 9000 inhabitants Kalajoki municipality. For example 1977 and 1983 ice jams caused damages to buildings. During spring 2000 the ice cover was cut by the sawing machine prior to the break-up below the lower bridge. (Figure 8 a). Ice cover between the bridges could not be cut because there is a lot of big stones in the river. Before the noon on April 17th there was about 300 m long open water area below the upper bridge. During the afternoon of April 17th the ice cover from the distance of about 1 km upstream of the upper bridge was moved downstream (Figure 8 b). The ice formed a jam between the bridges and some houses were surrounded by water. However no bad damages were caused. The discharge was estimated to be slightly above 100 m^3/s when the first jam was formed. During the next night more ice from the distance of about 500 m were moved to the jam (Figure 8 c). Water level rose rapidly and several houses were damaged by water. During the night and the following morning the ice cover at the shore downstream of the jam was broken by digging machines. At that time the estimated discharge was about 150 m^3/s. The jam was released at 9:01 (Figure 8 d) and it moved downstream and stopped for some time downstream of the lower bridge. After that it moved relatively easily downstream through the section were cutting was done.

The longitudinal profile of the river at the main village of Kalajoki is presented in the figure 9 . The river slope changes from steep to flat on the location were jam was formed. There is also several big stones in the river at that location. In the same figure there is also presented the calculated water level profiles for open water condition and ice jam condition for discharge 150 m^3/s. The profiles have been calculated with HEC-RAS-program and the values of the parameters used in the calculation are presented in the table 2. The observed maximum stages are also presented in the Figure 9 .

Table 2

Parameter	**Value**
Roughness of the bottom of the river (Manning –n)	0.04
Roughness of the ice jam (Manning –n, fixed)	0.06
Friction angle of the jam	45 °
Porosity of the jam	0.4
Stress K1 ratio of the jam	0.33

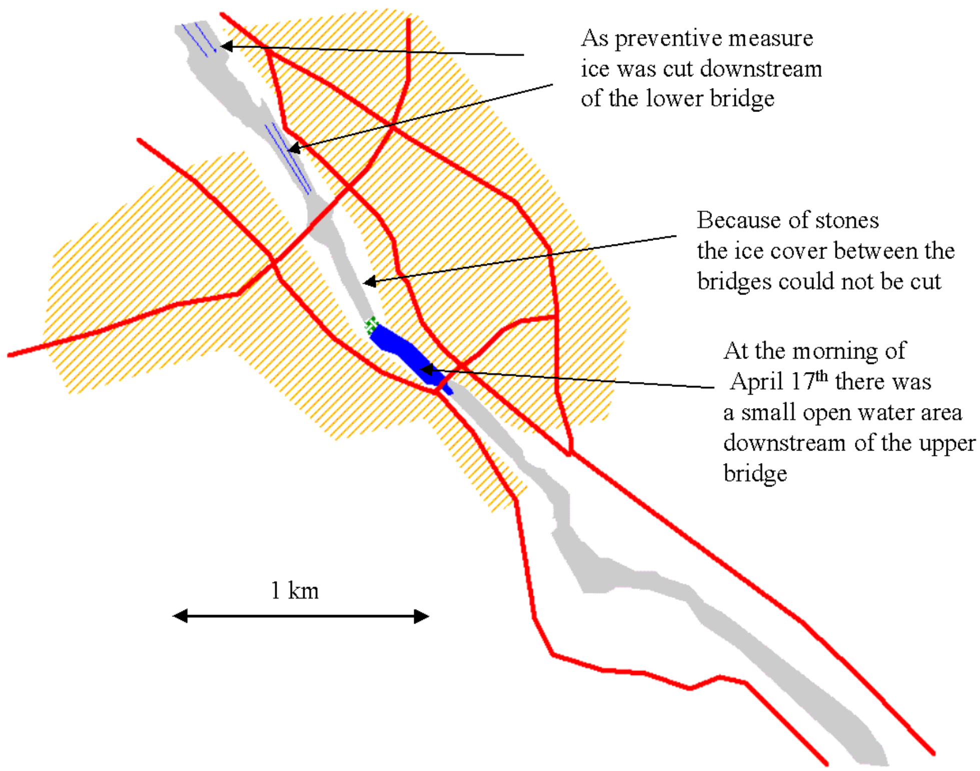

Figure 8 a. The ice condition at the main village of Kalajoki at the morning of April 17th.

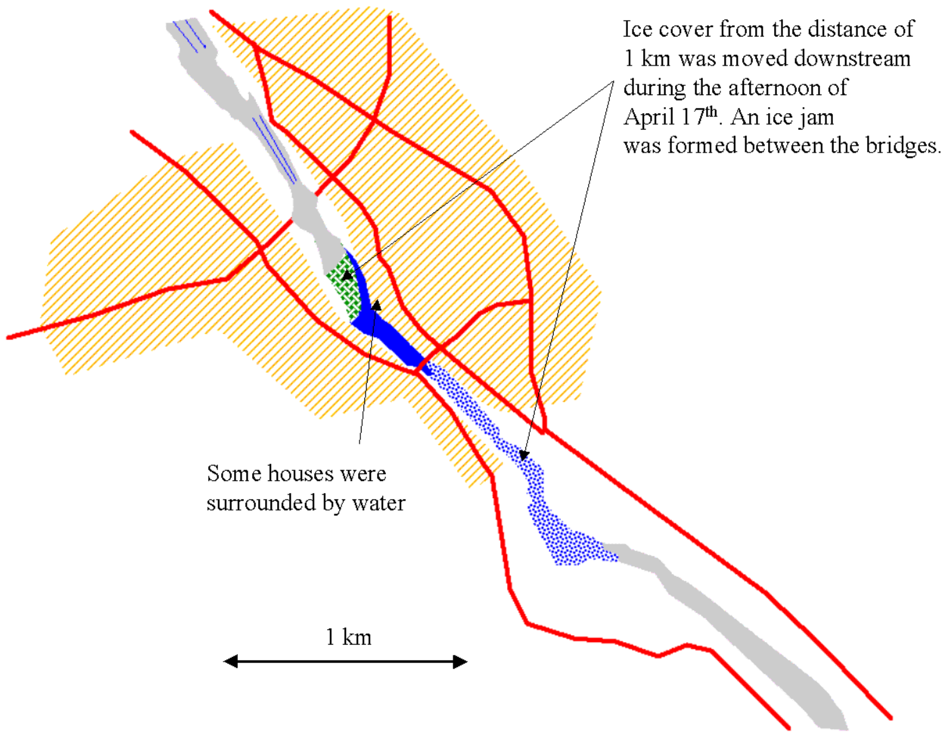

Figure 8 b. Formation of the first ice jam in the afternoon of April 17th.

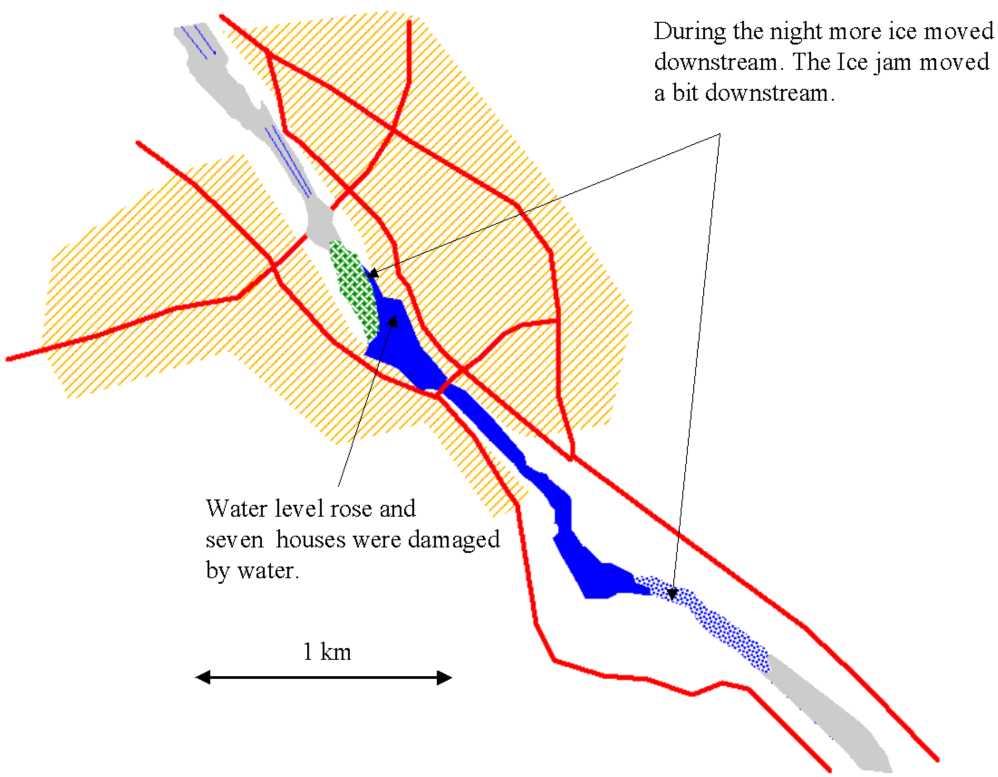

Figure 8 c. During the night between April 17th and 18th more ice moved to the jam and some houses were damaged by water.

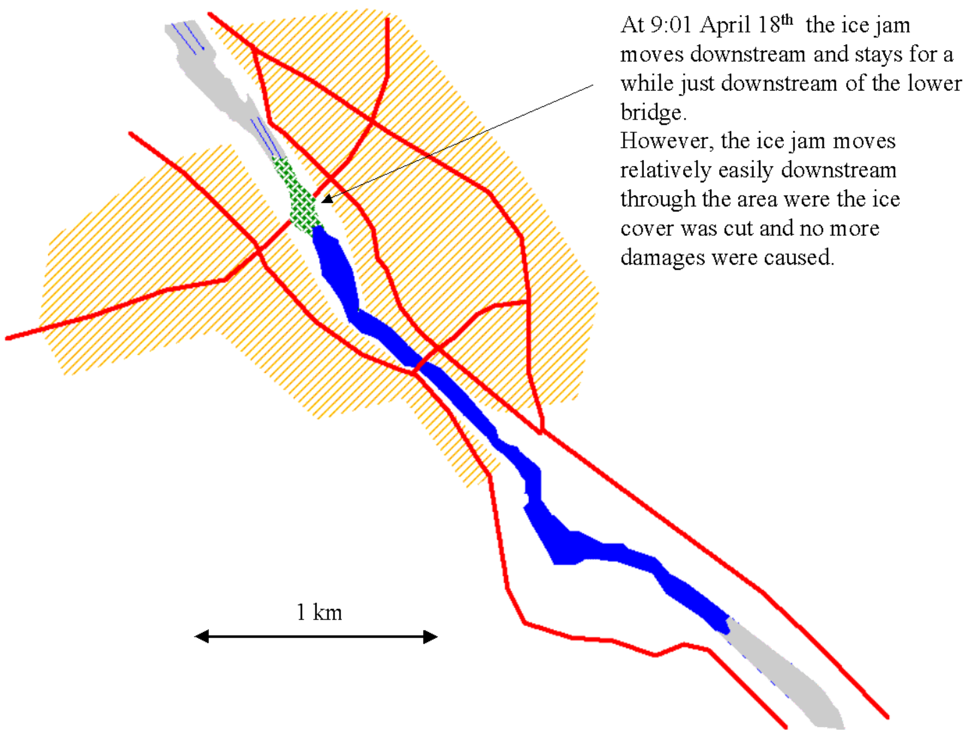

Figure 8 d. In the morning April 18th the jam was released.

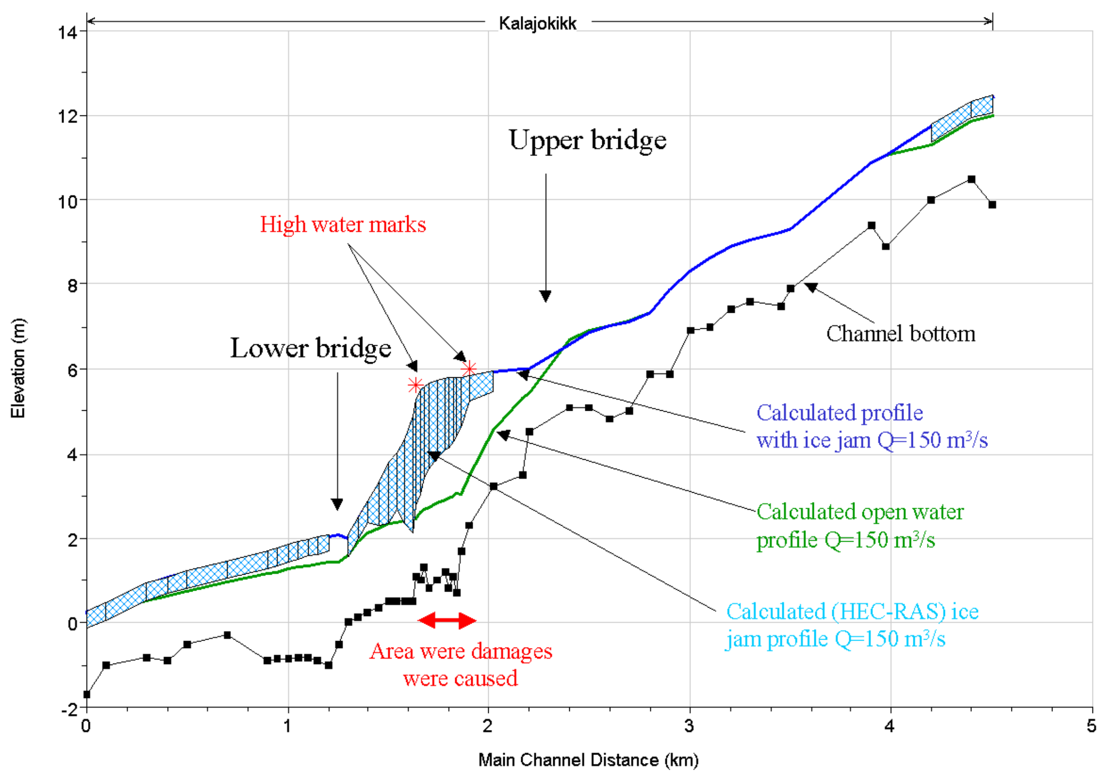

Figure 9. The longitudinal profile of the river at the main village of Kalajoki. The ice jam calculated with HEC-RAS as well as water level profiles and high water marks are presented in the figure.

3.4 Ice jam in Alavieska

Alavieska is a small municipality of 3000 inhabitants located 26 km from the mouth of the River Kalajoki. There has been several ice jams during previous years and bad damages has been caused by ice jams for example in 1977 and 1979 . As a preventive measure ice cover was cut with the sawing machine 2.5 km downstream from the bridge (Figure 10 a).

In the afternoon on 20th of April ice moved downstream from a distance of about 1 km upstream of the bridge (Figure 10 b). An ice jam was formed downstream of the bridge. Between the cuttings downstream of the jam the ice cover was broken by floating and rolling ice sheets which came under the ice jam. At 16:35 the jam was released and it moved downstream and stopped at the end of the cuttings. The discharge was estimated to be about 240 m^3/s when the jam was released. There is a low overflow weir at 3.5 km downstream of the bridge. There was about 300 m reach upstream of the overflow weir were cutting was not done. At that 300 m reach the jam stopped for a while but at 16:50 it moved downstream.

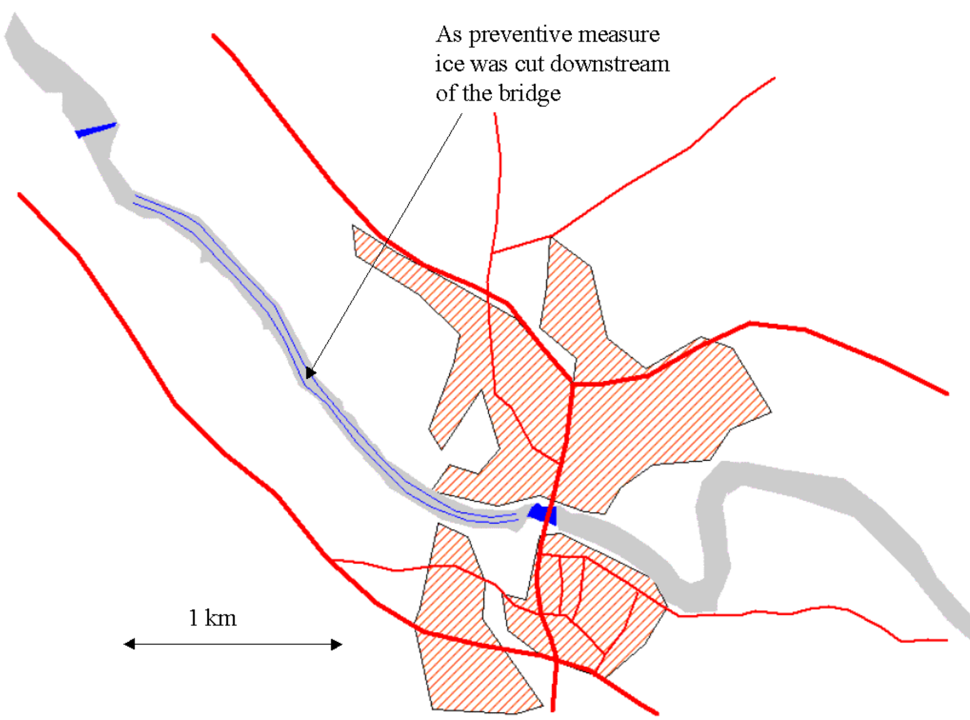

Figure 10 a. Use of ice sawing as preventive measure in Alavieska.

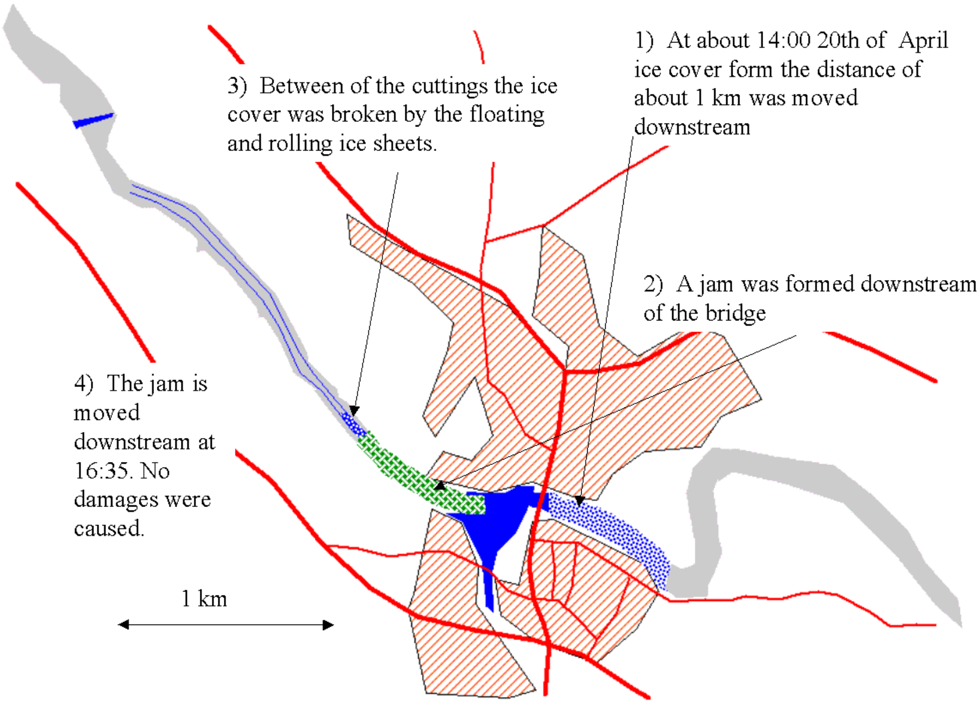

Figure 10 b. Formation of ice jam in Alavieska on April 20th.

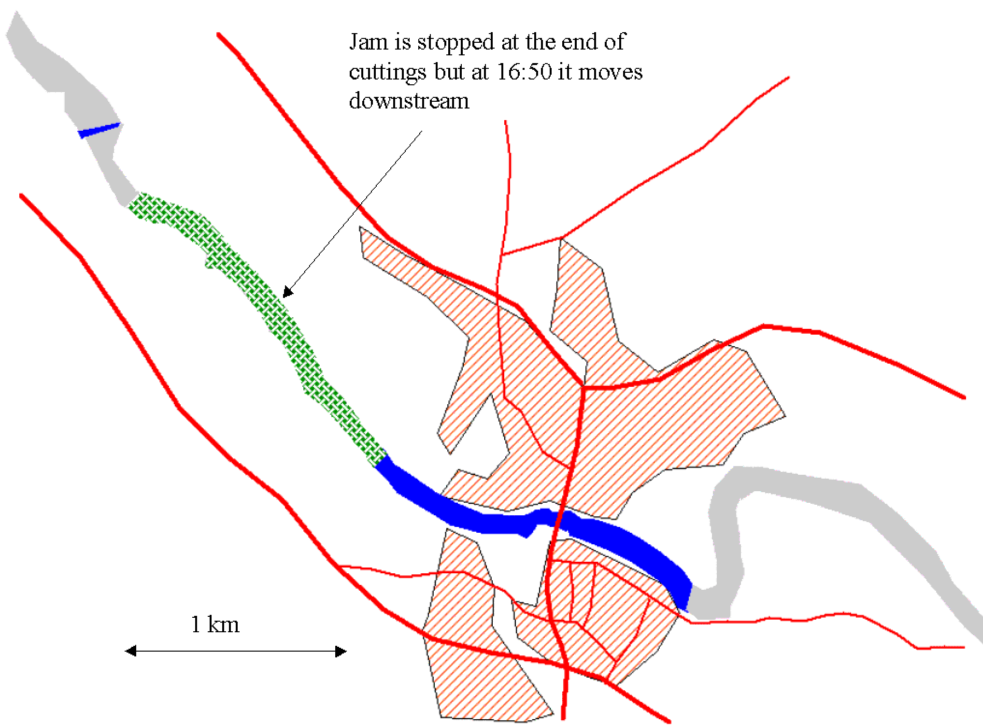

Figure 10 c. Release of the ice jam and the formation of a new jam in Alavieska on April 20th.

In Alavieska there were several houses very near to be wetted when the first ice jam was formed downstream of the bridge. Sawing of the ice cover probably prevented a lot of damages on that site.

The longitudinal profile of the river at Alavieska is presented in the figure 11. Also here the river slope changes from steep to flat on the location were jam was formed. In the same figure there is also presented the calculated water level profiles for open water condition and ice jam condition when the discharge is 240 m^3/s. The profiles are calculated with HEC-RAS-program and the values of the parameters used in the calculation are the same than presented in the table 2. The water level calculated with the model is a bit higher than the observed high water mark.

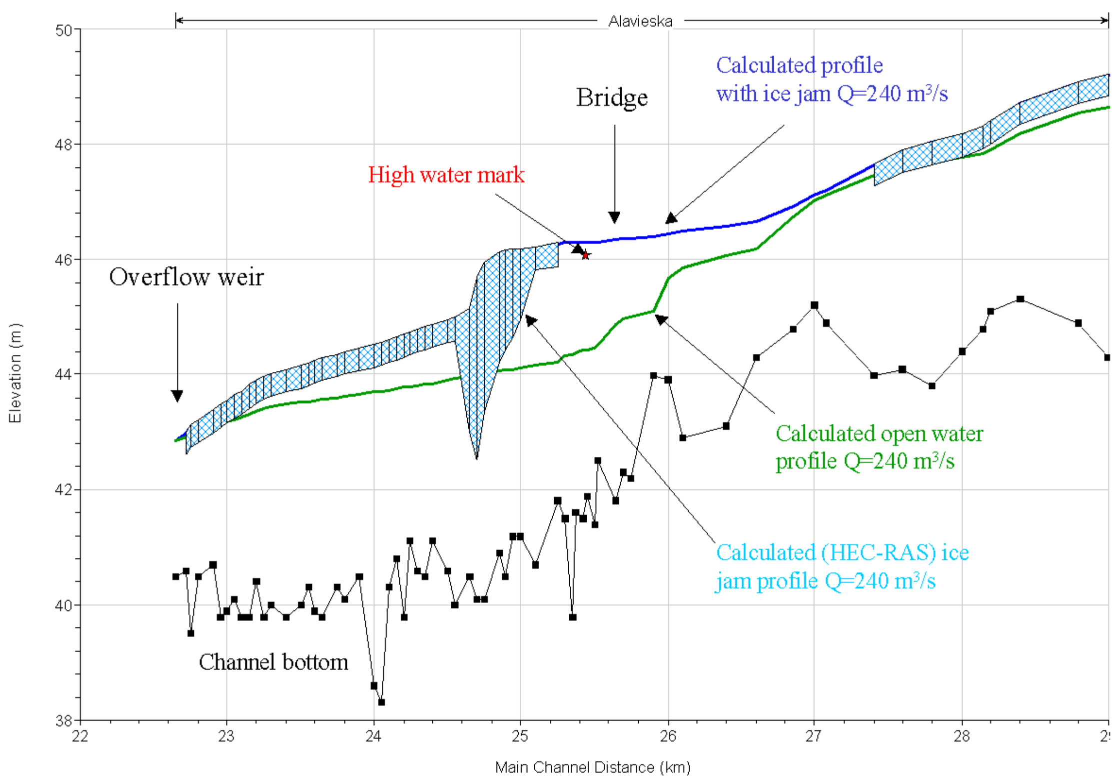

Figure 11. The longitudinal profile of the river in Alavieska. The ice jam calculated with HEC-RAS as well as water level profiles and the high water mark are presented in the figure.

4. Conclusions

The lower parts of the River Kalajoki have always been under thread of ice jams. Even thought the ice cover was thinner than in average before the break-up time in spring 2000 bad ice jams were formed. The ice cover had only little time to became thinner and weaker before the discharge started to increase. The strength of the ice was diminished only a little before the ice started to move because there was snow cover on the ice and the weather was cloudy. Worst ice jam situation developed in the main village of Kalajoki where seven one-family-houses were damaged. In the whole watershed of Kalajoki river the damages were caused to real estates, roads, bridges etc, costs were estimated to be several million marks.

In spite of the fact that damages were considerable, the combating operations done must be seen successful and remunerative. Without combating works, instead of ten some fifty homes had been damaged by water and many cow stables and piggeries had needed to be evacuated. The entire field team of the regional environment centre was ordered on duty and they worked the whole flood week over Easter having practically only 4 hours sleep per night.

Specially ice sawing with the special ice saw machine seems to be useful method for preventing ice jam damages.

References

Haehnel, R.B., 1998. Nonstructural Ice Control. CRREL Report 98-14, U:S Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hannover, N.H.,U.S.A., 44p.

Huokuna, M., 1990. The Finnish River Ice Research Project - the Numerical Model in Use. *Proceedings, IAHR, International Symposium on Ice*, Espoo, Finland, Vol. 3, 215-230

Enbuske, R. , Nikkarikoski, H., and Savolainen H., 2000. Spring 2000 Large Flood in North Ostrobothnia. Article in the Journal MAANSIIRTO 5/2000 (in Finnish)