

Extreme ice-jam flood at the junction of the Sukhona – Yug – Malaya Northern Dvina Rivers near the town of Velikiy Ustyug in spring 2016

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Based on materials :

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Northern Territorial Administration for Hydrometeorological and Environmental Monitoring, Arkhangelsk



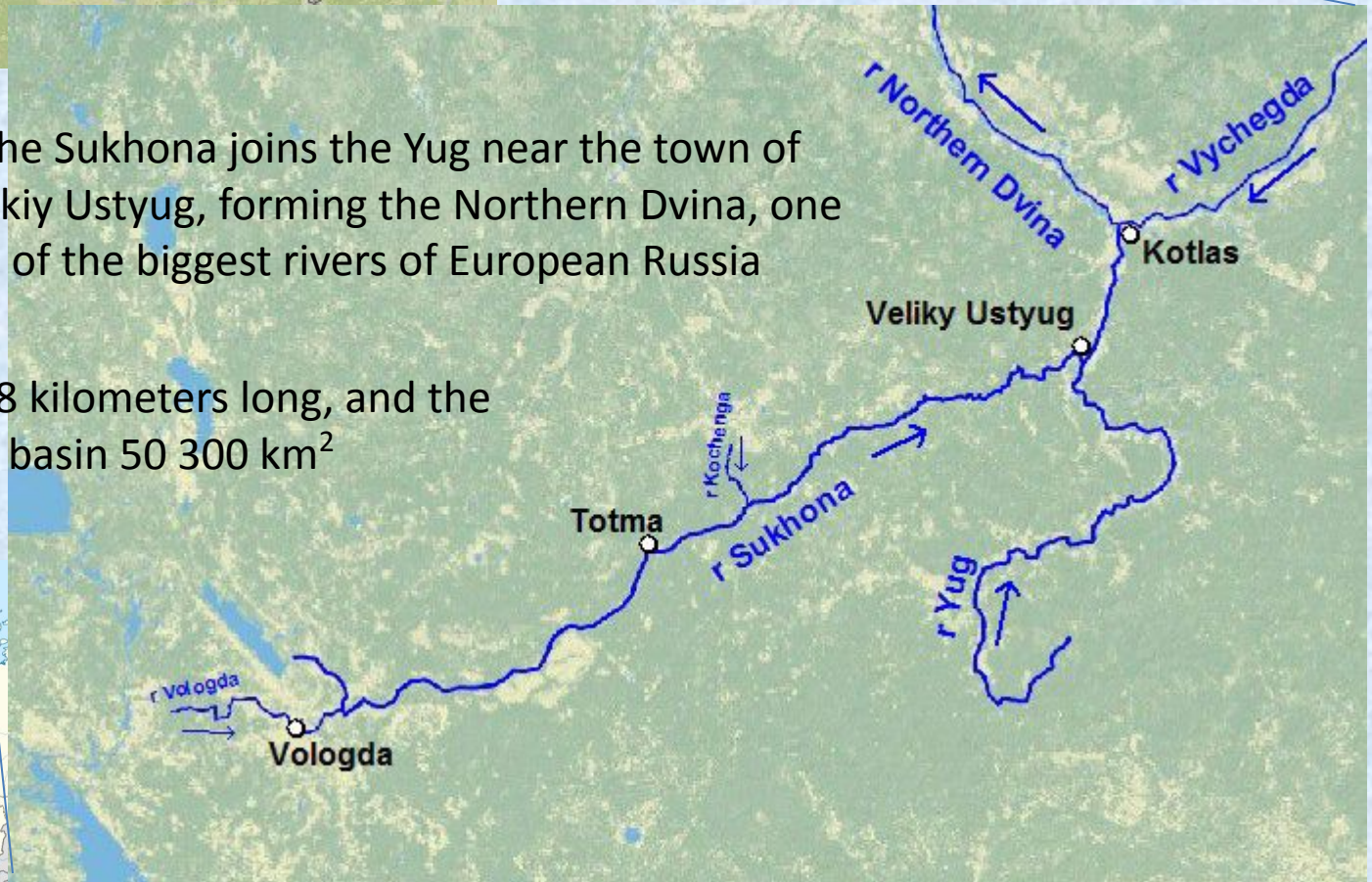
Presentation Outline

1. Features of formation of ice jams and ice-jam floods at the junction of Sukhona – Yug – Malaya Northern Dvina Rivers near Velikiy Ustyug
2. Formation of a giant ice jam on the Sukhona river near Velikiy Ustyug in winter 2015-2016
3. Field research of the giant ice jam in spring 2016
4. A catastrophic ice-jam flood in Velikiy Ustyug and its environs during the spring of 2016 and its consequences

The junction of the Sukhona – Yug – Malaya Northern Dvina Rivers near Velikiy Ustyug

The Sukhona joins the Yug near the town of Velikiy Ustyug, forming the Northern Dvina, one of the biggest rivers of European Russia

The Sukhona is 558 kilometers long, and the area of its basin 50 300 km²



Velikiy Ustyug

Velikiy Ustyug is a town in Vologda region, Russia, located in the northeast of the region at the confluence of the Sukhona and Yug Rivers.

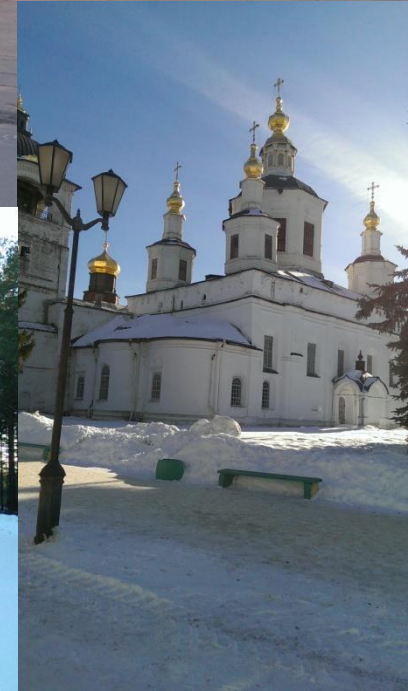
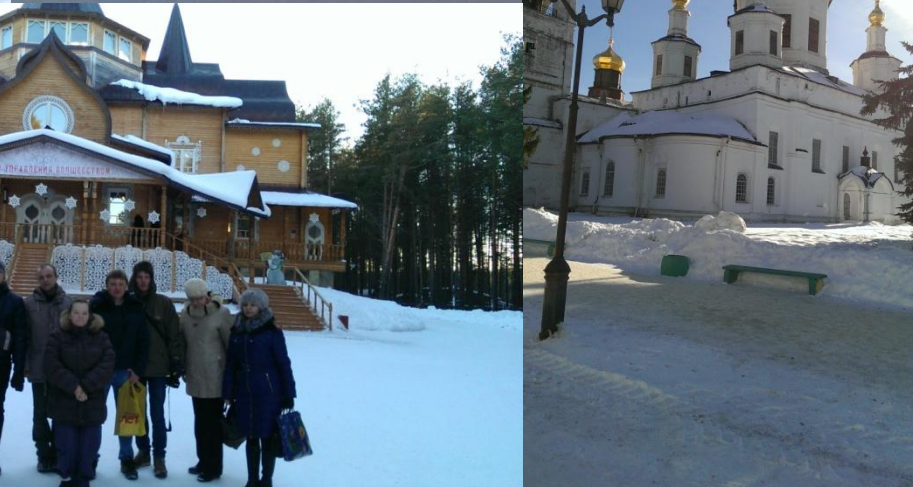
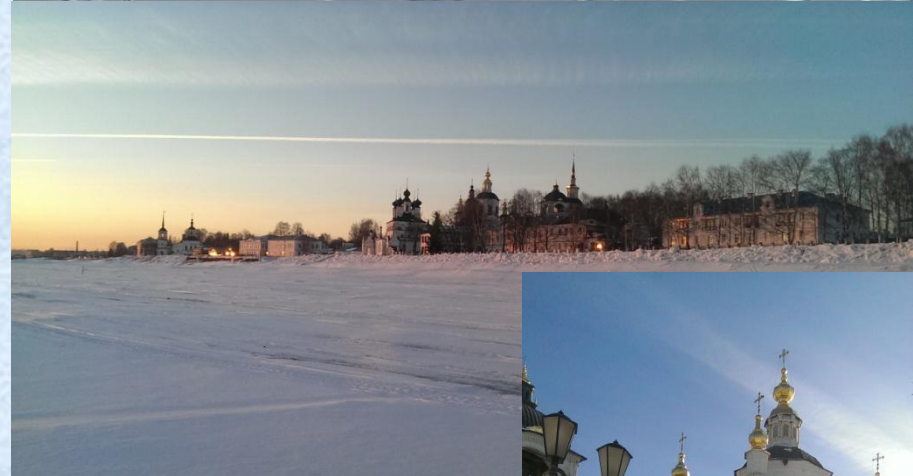
Velikiy Ustyug was first mentioned in a chronicle in 1207.

Velikiy Ustyug has a great historical significance and was one of the major cities of the Russian North.

As of the 2010 Census, its population was 31,665.

There are timber industry enterprises in Velikiy Ustyug, as well as a shipyard, food industry, and enterprises serving the tourist industry — in particular, the jewelry production plant.

Tourism is an important branch of economy in Velikiy Ustyug. It started in the 1960s and got a further boost in 1990s when Velikiy Ustyug started to be marketed as the residence of Ded Moroz, also known as "Grandfather Frost".



Features of formation of ice jams and ice-jam floods at the junction of the Sukhona – Yug – Malaya Northern Dvina Rivers near Velikiy Ustyug

Ice jam events very often occur on the Sukhona, the Yug and the Northern Dvina

WHY?

- Large volume of ice in river channels
- High flow velocity
- A lot of channel obstructions for the movement of ice floes in the form of bends, rifts, islands and so on.

The most frequently flooded area due to ice jams on the Severnaya Dvina is the territory of Velikiy Ustyug and its surroundings located near the confluence of the Sukhona and the Yug Rivers.

Particular danger for this area is a situation when the steady ice cover at the beginning of winter is destroyed due to a long thaw as a result ice jams are formed which remain until the beginning of a spring flood.

Photos of floods in Velikiy Ustyug at the beginning of the 20th century (before Orthographic Reform 1917-18)



В.-Устюгъ.
7. Мироносицкая церковь. Наводненіе



27. г. В. Устюгъ. Ледоходъ



В.-Устюгъ.
1. Соборъ Проконія праведнаго.



В.-Устюгъ.
6. Наводненіе
Мироносицкая площадь.

Имеющиеся в Летописной книге сведения о наводнениях в районе г. Великий Устюг свидетельствует о взаимосвязи зимних паводков и масштабных наводнениях весной следующего года.

Все зимние паводки в районе Великого Устюга в 1515, 1741, 1898 и 1969 г.г. **способствовали небывалым по масштабам разрушений половодьям весной следующего года.**

«24 ноября 1515 г. вода в реке Сухоне была великая, подобная весенней, и стояла в одной мере две недели...»

В апреле 1516 г. шла Сухона весьма грозно. Вода была велика, такова и не бывала. Льдом город стерло и посад по всему берегу обрыло. Много дворов снесло, много людям беды учинило...».



«В последних числах ноября 1741 г. была оттепель и сильный дождь, отчего вода так прибыла, что выше вешних вод восходила.

Вода весной 1742 г. так поднялась, что церковь Иоанна Устюжского заливалась и до Прокопьевского рудника доходила.»



В.-Устюгъ.
7. Миропосицкая церковь. Наводнение



В.-Устюгъ.
1. Соборъ Прокопія праведнаго.

«30 октября 1898 г. вода неожиданно стала сильно прибывать, так что минут за 20 прибыло до двух аршин. Лед со страшной силой стало ломать...»

В апреле 1899 г. начался ледоход на Сухоне. Льдом причинены значительные повреждения деревянным укреплениям.»

A painting in the museum of Velikiy Ustyug history





Embankment in Velikiy Ustyug
1903 or 1905 ??



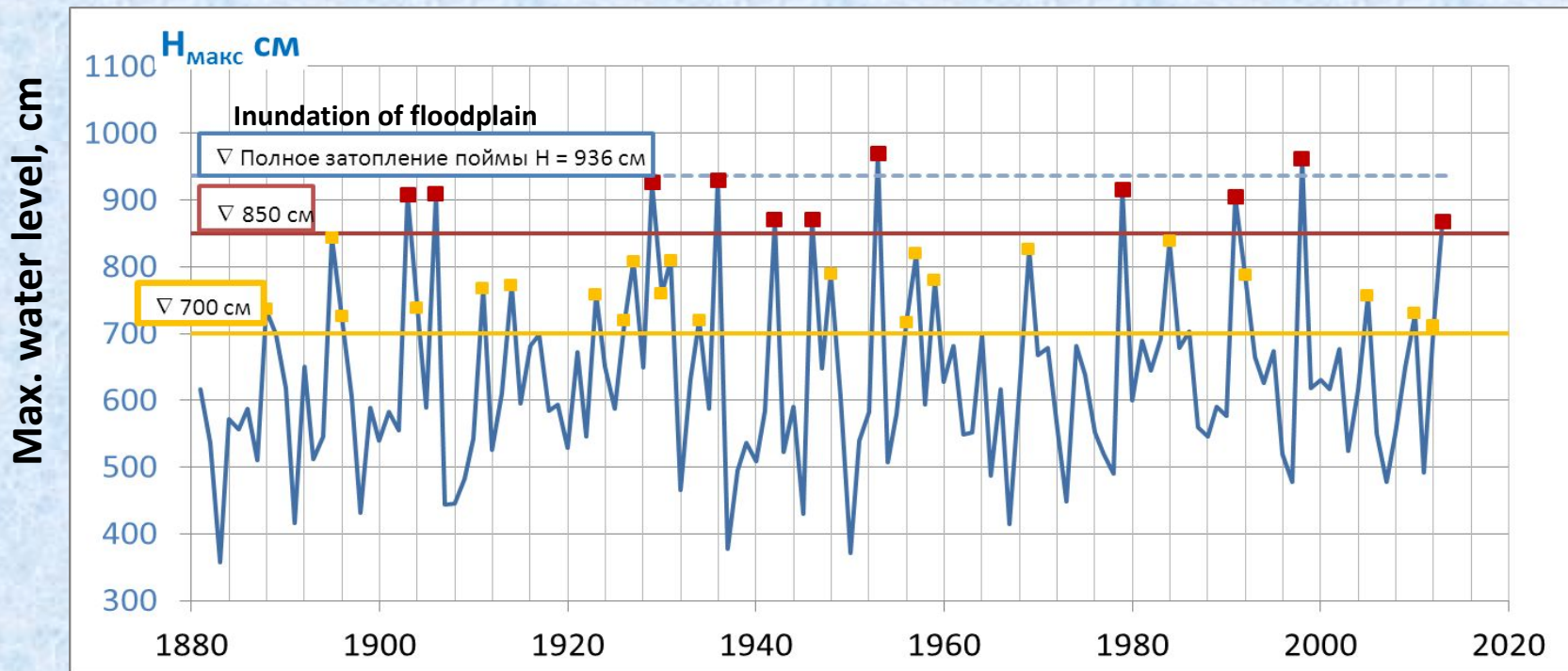
Embankment in Velikiy Ustyug
April 15, 2016

The number of catastrophic floods in Velikiy Ustyug

XVIII century - 5 floods (1723, 1741, 1742, 1761, 1779)

XIX century - 6 floods (1807, 1816, 1817, 1842, 1856, 1873)

During 1877-2013 (observation period) there were 11 floods with the rise of the level above 8.5 m and 22 floods with the level rise above 7 m



Most floods were caused by ice jams

Features of formation of a giant ice jam on the Sukhona river near Velikiy Ustyug in winter 2015-2016

In November 2015 the establishment of freeze-up on the rivers near Velikiy Ustyug

Thaws and mixed rain-snow precipitation in November-December caused several floods in the Sukhona river basin.

In mid-December, the Sukhona and the Yug rivers were broken up almost simultaneously which led to the formation of ice jam at the point of their confluence.

A sharp long cooling in late December 2015 and the first decade of January 2016 contributed to the formation of the main ice jam (“head”) near Velikiy Ustyug as well as formed a cascade of ice jam formations (around 60 km long).

Становление ледостава в районе г. Великий Устюг в декабре 2015 года

На реках Сухона, Юг и Северная Двина в районе г. Великий Устюг в результате формирования серии мощных заторов льда, вызванных аномальными условиями замерзания рек осенью 2015 года, сложилась исключительно сложная ледовая обстановка, которая привела к катастрофическому наводнению весной 2016 года.

Общая продолжительность осеннего ледохода на участке п. Каликино- г.Вел.Устюг составила 15-18 дней.

За весь ряд гидрологических наблюдений такой мощности и на таких высоких уровнях осенних заторов на этом участке реки не наблюдалось. Заторы сохранялись всю зиму. Их укреплению способствовали холодная погода января и понижение уровня, что вызвало уплотнение массы льда.

Наиболее мощный осенний затор льда образовался на выходе реки Сухона на реку Северная Двина, ниже г. Великий Устюг. 23 декабря у г. Великий Устюг был зафиксирован самый высокий уровень воды для декабря за весь период наблюдений 1881-2015 гг. - 674 см, превысивший среднемноголетний ледоставный уровень на 4-5 м.

За последние 100 лет наивысший уровень воды при ледоставе наблюдался осенью 2006 г.



**Ice jam on the Sukhona River
November 26, 2015**



2015/11/26

December 23, 2015

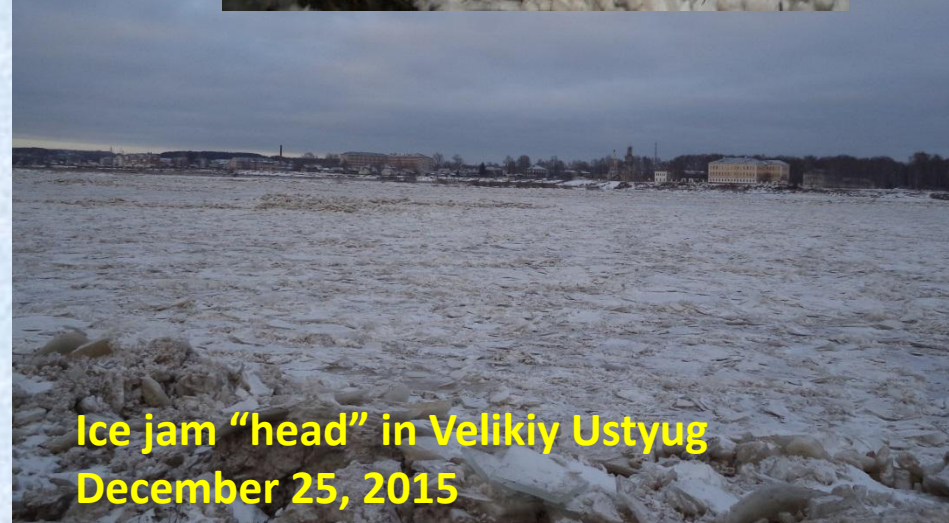


**Ice piles
December 12, 2015**



2015/12/11

**Ice jam "head" in Velikiy Ustyug
December 25, 2015**



Field research of the ice jam in spring 2016

An **extremely dangerous hydrological situation**, leading to the high probability of the formation of a disastrous flood in the spring of 2016, **formed** at the junction of the Sukhona – Yug – Malaya Northern Dvina Rivers near the town of Velikiy Ustyug **during the 2015-16 winter**.

The situation caused a serious public outcry and concern among local residents and the executive authorities of the Vologda region and Velikiy Ustyug.

At the beginning of 2016 the head of Vologda Centre for Hydrometeorology and Environmental Monitoring (Vologda Centre) applied to State Hydrological Institute (SHI) a request for joint field research in order to:

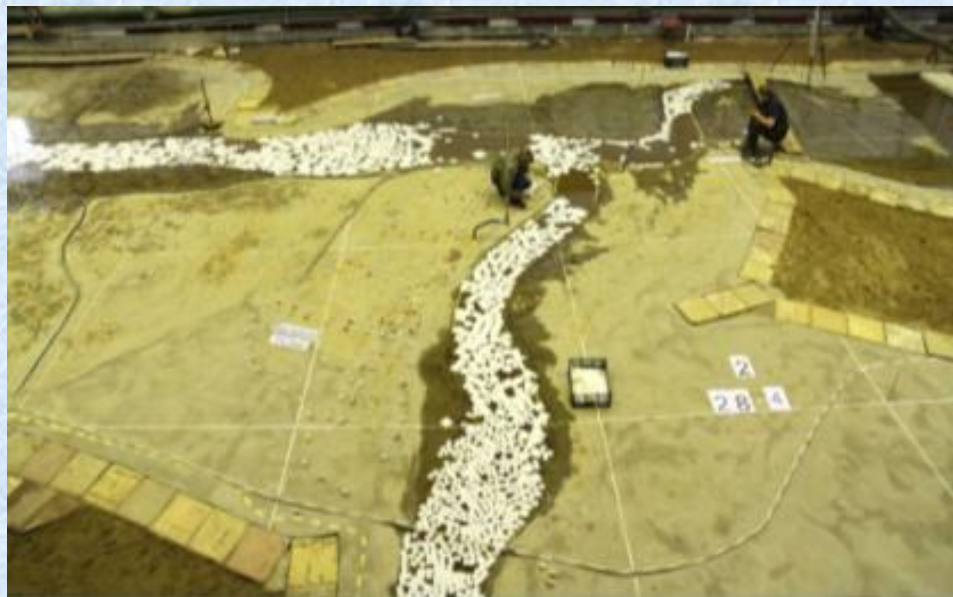
- **estimate the main characteristics of the formed giant ice jam;**
- **specify a forecast of maximum ice-jam water level** at Velikiy Ustyug water gauge station (forecast method was developed in SHI and used now in the Vologda Centre);
- **develop recommendations** on carrying out of ice-jam flood control activities.

Why the Vologda Centre addressed to SHI?

Method of short-term forecasting of ice jams and ice jam floods at the junction of the Sukhona-Yug-Malaya Severnaya Dvina rivers. – Report of State Hydrological Institute (SHI), S. Petersburg, 2011 [in Russian].

Integrated research of river-bed processes and formation of ice jams at the junction of the Sukhona-Yug-Malaya Severnaya Dvina rivers in order to regulate the processes of ice jam formation and develop ice-jam flood control activities near Velikiy Ustyug. – Report of State Hydrological Institute (SHI), S. Petersburg, 2014 [in Russian].

Model of the junction of the Sukhona, the Yug and the Northern Dvina rivers created in the framework of the specialized research project (2013-14) by the department of channel processes of SHI

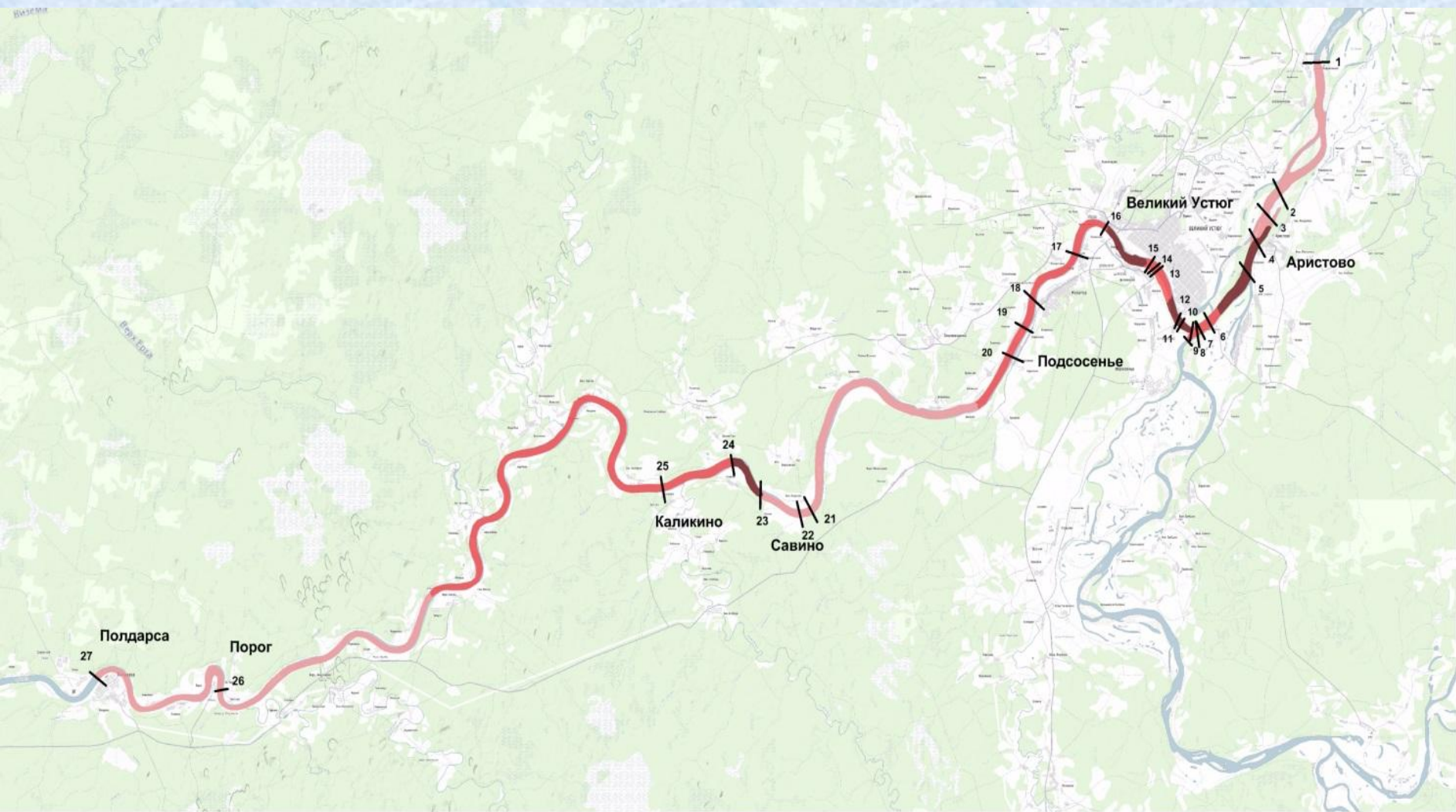


Field research of the ice jam in spring 2016

Field surveys were carried out by specialists of State Hydrological Institute and Vologda Centre for Hydrometeorology and Environmental Monitoring during the periods of 7-15 February and March 24-31, 2016.

At the preliminary stage, 27 cross-sections were planned across the main significant part of the formed ice-jam by the specialists of the Vologda Centre (namely by specialist of the Velikiy Ustyug hydrological station).

27 cross-sections and ice jam structure (dark red – ice jam “heads”)



Field research of the ice jam in spring 2016

In February 2016 a complex of specialized hydrological measurements was made at each of the planned cross-sections.

Ice cover was drilled along a cross-section line usually in 30-50 meters (depending on the width of the river and the state of the ice cover). Then at each point the following characteristics were measured:

- depth of the river (direction and velocity of flow in some cases);
- thickness and structure of ice cover layer;
- thickness of the slush layer (brash ice layer);
- height of snow cover (SWE);
- height of nearby hummocks (torosses);
- photo and GPS fixations.

Formed ice jam



Implementation of hydrological measurements along the cross section No. 16 (red line) (500 m upstream of the road bridge in Velikiy Ustyug)



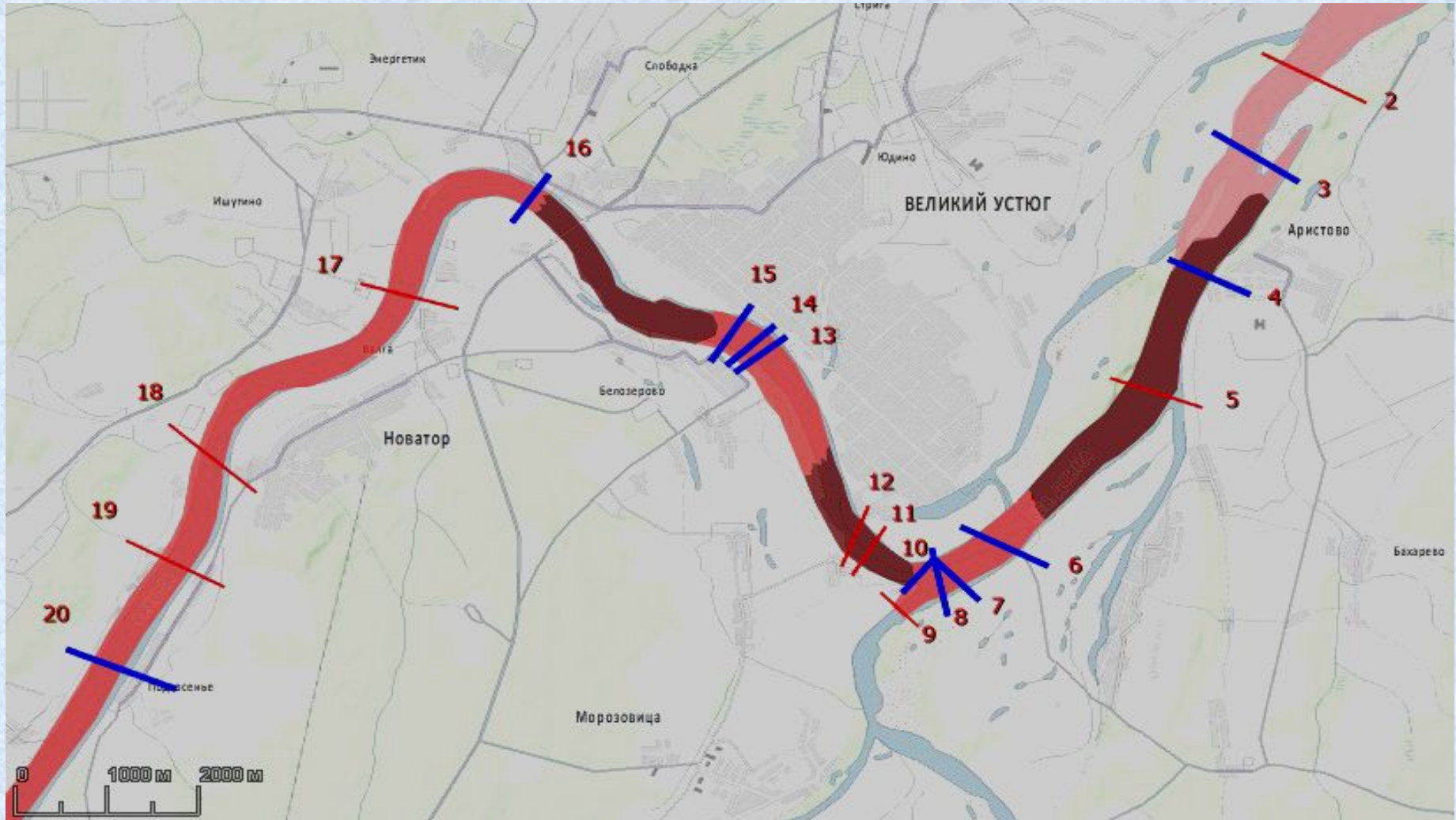
Implementation of hydrological measurements along the cross section No. 14 (red line) (at Velikiy Ustyug gauge station)



Field research of the ice jam in spring 2016



At the end of March 2016, repeated measurements were made at the cross-sections located at the most significant sections of the ice jam.

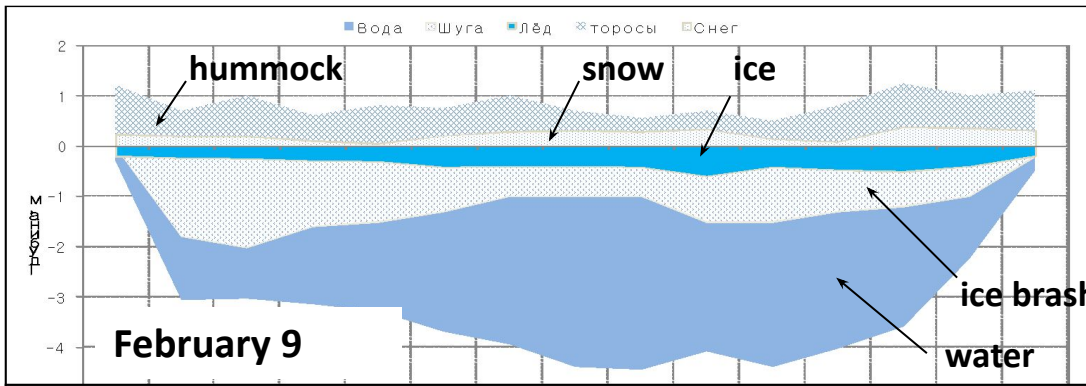


Location of the cross-sections near Velikiy Ustyug. Blue highlighted profiles with repeated measurements in March 2016.

It was found based on the analysis of field research data that:

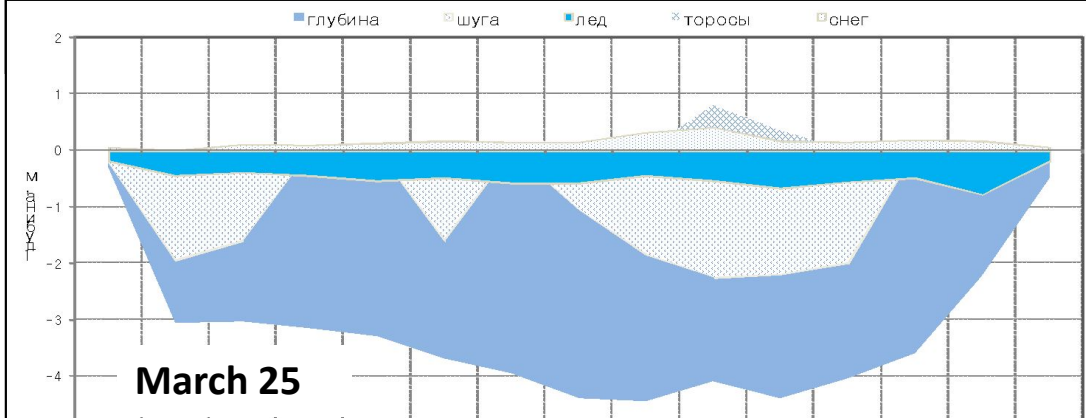
- **The body of the main ice jam was located in the riverbed of the Sukhona River from the village of Syvorotkino to Velikiy Ustyug, the length of the main jam was about 10 km;**
- **A cascade of ice-jam formations was formed upstream of the Sukhona from Velikiy Ustyug (about 60 km);**
- **Height of ice concentrations in the ice jam reached 0.5-1.0 m, height of ice packs on the shores - 1.0-2.5 m;**
- **In the downstream of the Sukhona there was ice cover with hummocks that reached 1,0-2,0 m;**
- **Ice in the ice jam had a complex layered structure;**
- **The thickness of ice cover throughout the whole ice jam was close to the average annual thickness;**
- **Under the ice cover there was a dense sludge (ice brash) layer (everywhere) with thickness from 0.5-1.0 m to 2.0-3.0 m;**
- **During the interval between measurements in February and March, ice thickness increased and the slush layer decreased.**

The analysis of the field research results carried out in February and March on the Sukhona River (profile section No. 4)

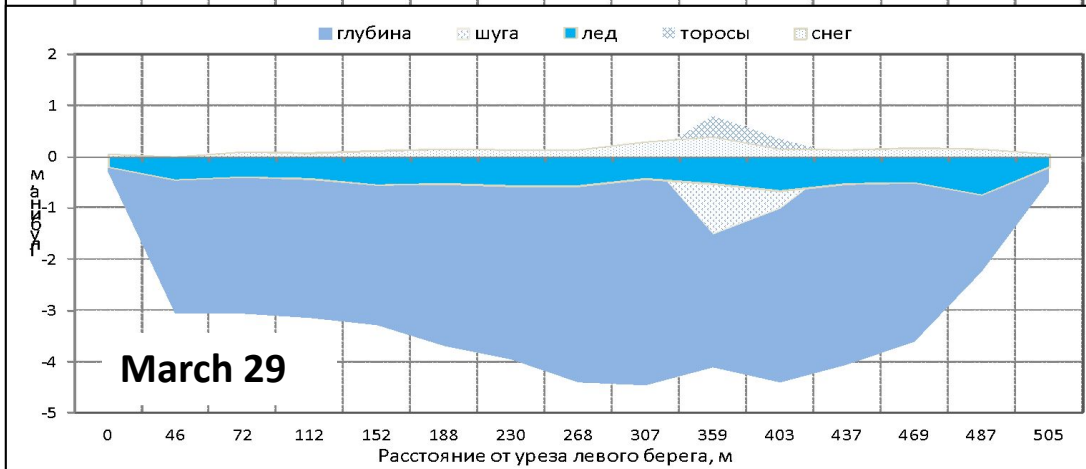


Area of ice:
increased by 56 m²

Area of ice brash:
decreased by 64 m²



March 25, 2016
Implementation of blasting upstream of the river



Area of ice:
didn't change

Area of ice brash:
decreased by 416 m²

Field research. Conclusions.

The monitoring of the development of a powerful ice jam formed in 2015-2016 made it possible to specify the forecasting method of maximum water level developed in SHI and used by the Vologda Center.

The results of the analysis of the obtained expedition data and the updated forecast led to the conclusion that the forecasted maximum water level in Velikiy Ustyug in the spring of 2016 will exceed the dangerous level.

In February, a preliminary forecast of a dangerous hydrological event was reported to the executive authorities – the raising of the level on the Sukhona river in Velikiy Ustyug up to 960 cm.

Recommendations were also prepared on carrying out of ice-jam flood control activities

Comprehensive measures were carried out:

- to prevent the population of the expected flooding;
- to prepare evacuation means from the expected flood zones;
- to prepare accommodations for evacuated population and material values, food supplies and so on.

Прогноз наивысших уровней воды р.Сухоны у г.Великий Устюг в 2016 г.

Период достижения наивысших уровней воды
19-23 апреля 2016 г.

Наивысший заторный уровень –
900÷960 (ОЯ) см над “0” графика-
58,34 ÷ 58,94 м БС

(выпущена консультация в феврале 2016 г.-
заблаговременность 3 месяца).

Catastrophic ice-jam flood in Velikiy Ustyug and its environs during in April 2016 and its consequences

On **April 15** the first ice movements began on the Sukhona river near Velikiy Ustyug.

At 12:25 the beginning of ice drift at the water level 815 cm which is almost 4 m above the normal.

On **April 15**, a **municipal emergency regime** was declared over the territory of the Velikiy Ustyug district, and **on the evening of April 17** the **emergency situation at the regional level** throughout the territory of the Vologda region.

On **April 16 at 12:36** the **water level** at the Velikiy Ustyug water level gauging station **reached 964 cm** (above 960 cm is a dangerous hydrological phenomenon), which is only 5 cm below the historical maximum of 1953.

On **April 19 at 11:00** am there was a **breakdown of the ice jam** and water level started decreasing.

The emergency regime was extended until **May 24, 2016**.

22 settlements (almost 2,000 houses with a population of about 8000 people) were flooded.

The material damage, according to the Government of the Vologda region, amounted to 533 million rubles (9.1 million dollars).

Прохождение половодья в районе г. Великий Устюг в 2016 году

14.04. начался ледоход в нижнем течении Сухоны, который сопровождался заторными остановками на участке Полдарса (79 км) - Каликино (39 км). Уровень воды по г/п Каликино составил 1211 см, что выше максимального наблюдаемого на 159 см. Повторяемость такого уровня составляет 1 раз в 1000 лет.

16.04.2016 в 12.36 уровень воды по в/п Великий Устюг кратковременно достигал отметки 964 см и всего на 5 см был ниже исторического максимума 1953 г. Обеспеченность такого уровня составляет около 1 %, повторяемость 1 раз в 100 лет.

По г/п Великий Устюг уровень воды на отметке близкой к опасной 900-950 см удерживался 5 суток.

По продолжительности сохранения исключительно высоких уровней воды, мощности заторов и масштабу неблагоприятного воздействия, чрезвычайные условия, сложившиеся весной 2016 г. в районе г. Великий Устюг являются экстремальными и не имеют аналогов за историю наблюдений.

За время стояния затора в г. Великий Устюг и населенных пунктах вокруг него было затоплено 22 населенных пункта, почти 3 тысячи придомовых территории с населением 7,5 тысяч человек.

Предварительный материальный ущерб, по оценке Правительства Вологодской области, составил до 533,074 млн. руб.

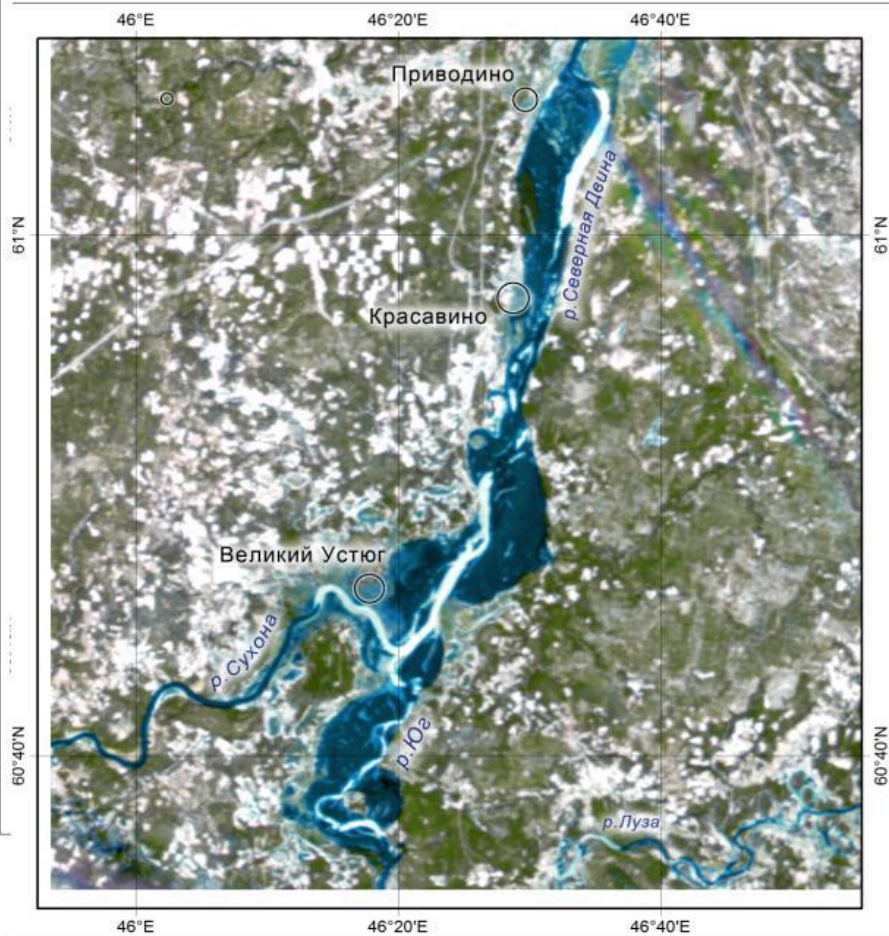


Catastrophic ice-jam flood in Velikiy Ustyug and its environs during in April 2016 and its consequences



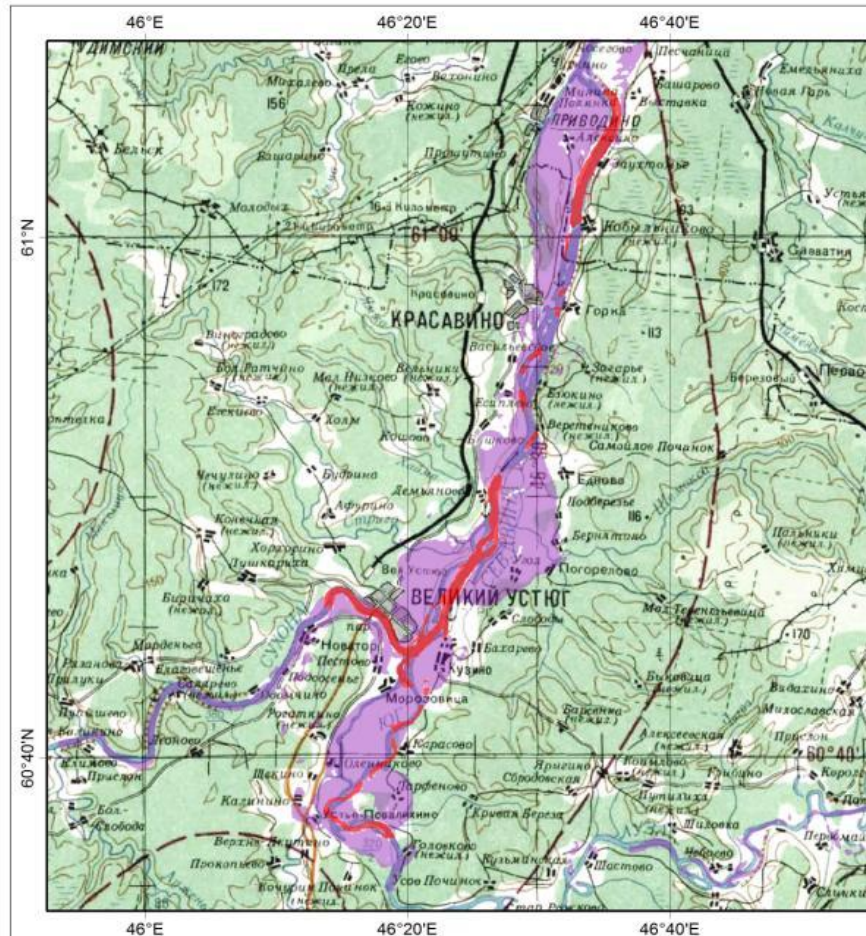
Catastrophic ice-jam flood in Velikiy Ustyug and its environs during in April 2016 and its consequences





ИСЗ "Метеор-М" №2, КМСС, разрешение 50 м, 18.04.2016 06:39 UTC
спектральные каналы R: 0,76-0,90 мкм; G: 0,63-0,68 мкм; B: 0,535-0,575 мкм

Цветосинтезированное изображение р. Северная Двина и ее притоков



Совмещение затопленных и переувлажненных участков пойм рек, выделенных на спутниковом изображении, с топографической картой М 1:500 000

- затопленные и переувлажненные участки пойм рек
- лед на реке

Пойменные разливы рек Вологодской области

Thank you
for your attention!

