Late Glacial - Holocene environmental changes in the Vychegda River Basin, Northern Russia.

Sidorchuk, A., Baslerov, S., Borisova, O., Kovaliukh, N., Panin, A.

The Vychegda River is the main right tributary of the Northern Dvina River. Its length is 1,130 km and the basin area is 121,000 km^2. The river flow begins on the Timan Ridge at the altitudes 200 - 300 m above sea level. The main part of the basin is a dissected plain with mean altitudes 140 - 160 m. The precipitation is 700 mm per annum, of this 350 mm falls during the winter-spring period. The mean annual air temperature is 1.2 °C. Mean annual water discharge at the mouth of the Vychegda is 1160 m^3/s with the mean maximum value of 7500 m^3/s. The runoff depth is 300 mm, including 200 mm for the winter - spring period (which is the flood). On average about 56% of the river flow passes during the flood.

The morphology of the lower Vychegda valley was investigated within a 120 km reach near the confluence. Valley bottom width increases here from 8 - 10 up to 35 - 50 km at which point valley of the Vychegda joins that of Northern Dvina. Several terraces and a floodplain with complicated morphology, and a system of palaeochannels are distinguished in the area.

After recession of the Last Glacial ice sheet about 12,500 years ago the erosion base level for Vychegda River lowered considerably. River incision had begun, and the sequence of erosion terraces was formed. The most ancient surface of the second terrace on the lower reaches of Vychegda corresponds to the initial stage of the valley evolution, which has begun after 12,500 years ago. The large size of the palaeochannel A on this step indicates a high channel-forming discharge during that period. The most probable age of this ancient palaeochannel is 12,500 to 10,000 years ago. Fossil flora shows that tundra and forest-tundra in north - eastern European Russia represent the region-analogue for that period. The annual discharge variability was rather high during the Late Glacial, so that the mean maximum discharge of 10,300 m^3/s corresponds to the relatively low mean annual discharge of 900 m^3/s. The depth of the mean annual runoff was 235 mm. According to the same analogue, the depth of winter-spring runoff was 180 mm. In conditions of continuous permafrost, the runoff coefficients were very high, the mean annual value being about 0.7, and that for a flood period up to 0.9. The mean annual precipitation depth was 335 mm, that of the winter-spring period was 200 mm, and that of the summer-autumn period was 135 mm.

On the basis of palaeobotanic data the Late Glacial time is usually characterised as an extremely dry period (Khotinskiy, 1977). The palaeohydrological information allows some amplification this supposition. For the Vychegda River basin the annual precipitation was half the recent value. Such a deficit of humidity was probably related almost entirely to summer – autumn time. The palaeobotanical data on the Late Glacial show the presence of typical xerophytes in the vegetation of this period. Their spread can be explained by a relatively warm and dry summer, though it was short (not longer than three months). The precipitation (mainly in the form of snow) during a long winter – spring period was not lower than in recent tundra. In combination with low permeability of the ground due to the permafrost spread, the snow thaw during the spring led to sharp high floods on the rivers and to formation of large wide river channels.

The palaeochannel B on the lower step of the second terrace was abandoned about 8400-8600 years ago. It was still active during early Boreal time 8500-9000 years ago. According to palaeofloristic reconstruction, the region-analogue for that time is situated at the south -eastern part of the middle taiga. The territory was already free of permafrost, and the depth of seasonal freezing of the ground was close to the contemporary one. The annual distribution of the water flow during the early Boreal was also close to the present-day one. Large and wide palaeochannel in the conditions of low variability of the river flow corresponds to relatively high mean annual discharge 1500 m^3/s. Mean maximum discharge was about 9900 m^3/s. The depth of mean annual runoff was 390 mm, the depth of spring runoff was 265 mm. In conditions of seasonal ground freezing the runoff coefficients were close to recent ones: they were about 0.45 for the whole year and up to 0.63 for a flood period. The air temperature and evapotranspiration at the lower Vychegda valley were close to those in the region-analogue. That gives a rather high estimate for the mean annual precipitation: 860 mm. Precipitation in the winter-spring period was doubled compare to the previous time interval (415 mm), and that of summer - autumn period increased even more - up to 445 mm.

Palaeochannel C on the first terrace of the lower Vychegda was abandoned about 8200 years ago. It was active during late Boreal time 8200-8500 years ago. According to the palaeobotanical reconstruction the region - analogue is situated at the eastern part of the southern taiga. The depth of seasonal freezing of the ground was close to the contemporary one. Annual distribution of the water flow during the late Boreal was more variable than at present, and humidity at that time was significantly lower. The palaeochannel on the first terrace is smaller than all other palaeochannels. Its width and curvature corresponds to mean annual discharge about 440 m^3/s, the mean maximum discharge was about 3700 m^3/s. The depth of mean annual runoff was 115 mm, the depth of spring runoff was 90 mm. This corresponds to the minimum value of the winter-spring precipitation depth (260 mm) for the whole period studied. Mean annual precipitation was about 555 mm. The minimum water flow occurred at the lower Vychegda at the end of Atlantic, about 6000 years ago.

The latest palaeochannel D at the lower Vychegda valley is well preserved on the oldest steps of the floodplain. This channel evolved during the Subboreal period and was abandoned at the beginning of Subatlantic, about 2500 years ago. The geometry of natural levees and chutes on the floodplain shows the main paths of the meandering channel migration. The rate of channel migration down the valley was estimated as 1.6 m per annum near Durnitsino village for the period 4200-4500 years ago, according to radiocarbon dating of a sequence of natural levees and depressions between them. Migrating channel reworked deposits of the first terrace. Several remnants of this surface were preserved within the floodplain. Development of curved omega-shaped meanders shows low erosivity of the flow on the floodplain. It probably indicates a relatively low annual variability of the water discharge.

Subboreal palaeochannels were formed during a time of significant decrease in climate continentality. The last palaeochannel morphology corresponds to these climatic conditions. Its width and curvature were formed by a mean annual discharge about 840 - 670 m^3/s, and the mean maximum discharge was about 5000 – 6700 m^3/s. Annual distribution of the water flow was characterised by low variability at the beginning of the period. It increased at the end of the palaeochannel formation. The depth of mean annual runoff was 175-220 mm, the depth of winter - spring runoff was 115 - 150 mm. Together with the evapotranspiration value for the region–analogue, that gives a mean annual precipitation depth equal to 600-690 mm. Precipitation of the winter-spring period was about 290 – 330 mm.

At the beginning of the Subatlantic period the morphological type of the river channel was altered again: it became braided-meandering. The stream then abandoned the omega-shaped meanders of palaeochannel D, which are preserved now as oxbows. This was connected with an increase of the maximum discharge at the end of Subboreal and with the general humidity of the climate in Subatlantic. Calculations show that the water flow and precipitation reached their maximum about 1500 years ago, at the period of lowest variability of the flow during the year. By recent times both the calculated mean annual discharge and precipitation depth decreased to 1170 m^3/s and 700 mm correspondingly, and the mean maximum discharge increased to 7900 m^3/s due to a greater discharge variability within a year.