Palaeohydrology of the rivers on the East European plain at the Late Glacial and the Holocene.

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The East European occupies a vast territory (4,600,000 km^2) from the shore of the Arctic Ocean in the North to the Caucasus, Crimea and Carpathians. The territory is characterised by temperate climate influenced by Westerlies, so that the continentality increases toward the east. Mean annual precipitation varies mostly within 500 – 700 mm in the north and approximately 500 - 600 mm in the central and north - western part of the Plain, and sharply decreases to 200-250 mm in the southeast on the Plain. The annual runoff decreases from the north to the south of the Plain from 350-400 mm to 20-50 mm.

During the last glaciation, the northwestern part of the Russian Plain was covered by the Valdai (Weichselian) ice-sheet. During the last glacial maximum a vast periglacial zone occupied most of the ice-free area of the Russian Plain (Grichuk, 1989). The northern part of the Plain was covered by periglacial forest steppe with tundra elements, and the central and southern parts by the periglacial steppe. Dry steppe and semidesert zones formed a narrow belt along the coast of the Caspian Sea. Most of the Plain was then within the zone of low temperature continuous permafrost which reached its maximum extent 20-15 K B.P. (Velichko *et al.*, 1982).

The relicts of large paleochannels are found on the lower levels of river terraces and on the floodplains across the territory of the former periglacial zone. The majority of the paleochannels have a meandering pattern and have channel widths as great as 15 times larger than the Late Holocene meanders on the same rivers. Only the territory occupied by the Last Glaciation is devoid of macromeanders. At the north of the Plain macromeanders are situated on low terraces of modern river valleys, and modern channels are incised into the paleochannels. The region with macromeanders at the level of modern floodplain forms a wide belt within the forest - steppe and steppe zones.

The large rivers that formed the paleochannels were active during the Late Valdai. Age estimations in the range 10,000-11,000 years B.P. are typical for the beginning of filling of the paleochannels in Poland in the Vistula River basin (Starkel, 1995). The large periglacial paleochannel of the Vychegda River was abandoned about 10,000 years B.P., but even during the early Boreal (up to 8,500 years B.P.) the river channel was larger than the modern one. The beginning of the filling of the Protva River channel is dated to about 13,000 years B.P. The large channel of the Khoper River was active about 17,000 years B.P. Its filling began about 12,000 year B.P. The large channels of Seim and Svapa Rivers were abandoned about 14,000 years B.P.

Former annual discharges for periglacial rivers were calculated using regime formulae with the help of palaeohydrological analogue with the rivers in modern regions with continuous permafrost (northeastern European tundra). Unlike the modern longitudinal distribution of the runoff depth on the Russian Plain, in the periglacial time its distribution generally followed the shape of the ice - sheet margin. The edge of glacier had northeastern direction in the northwest of the Russian Plain and the latitudinal direction in the east, near the western slopes of Ural Mountains. The maximum runoff depth existed within the area adjacent to the ice-sheet, though none of the rivers used in calculations were fed by glacier meltwater. The excess of annual water flow above the modern one can be explained by greater precipitation and a greater flow coefficient value. The runoff depth reached 800-1200 mm in the basins of the Vaga and Mezen’, and in the upper Pechora River basin. It was about 600-800 mm in the basins of the Oka and upper Volga Rivers. Minimum flow in the rivers of this area was calculated for the basins of the Severnaya Dvina (450-500 mm) and Vychegda (250-400 mm) Rivers.

Runoff depths in the river basins decreased with the distance from the edge of the ice-sheet, presumably with reduction of precipitation and flow coefficient. It was about 450 - 700 mm at the Seim River basin, upper and middle Don and Khoper River basins. Relatively smaller water flow was reconstructed for the rivers of lower Dnieper and Don basins, middle Volga and lower Kama basins. Runoff depths there did not exceed 200 - 450 mm.

The spatial variability of runoff depth in the Late Valdai time was significantly lower (particularly in the east of the Russian Plain) than the modern one. This was caused by much more uniform landscape conditions of flow generation in the periglacial zone, though a zonal pattern of runoff depth was rather distinctive, being correspondent to the shape of the ice-sheet boundary. The hypothetical hydrological conditions in the periglacial zone on the Russian Plain were probably characterised by high spring water flow. The flow coefficient was close to 0.9 – 1.0 due to the permafrost. The flood wave was sharp, and the maximum spring discharge on the periglacial rivers was much higher than current spring discharge peaks. The size of the river channel is determined mainly by maximum discharge rates. The combined influence of greater flow volume and higher maximum discharges caused the formation of very large river channels with macromeanders. The summer was dry and relatively warm with evapotranspiration values of 250 – 350 mm. The ground water input was very low, so the large sandy channels were almost empty of water in summer. The vegetation at the river valleys was scarce, and aeolian processes were active.

Although the flow was not affected by melt water from the ice sheet, the total flow volume from the northern megaslope of the Russian Plain was about 380 km^3 – 1.5 times the modern annual flow volume from the same area. The main water flow increases were in the Pechora and Mezen' River basins. At the southern megaslope in the Volga River basin, the annual flow volume was about 585 km^3. This is more that twice the modern value and can explain the high level of the Caspian Sea during the Late Valdai even without a hypothesis about significant glacial melt water feeding of the Kama River basin. The main water flow increases were in the basins of the Oka and Kama Rivers. They were both 3 – 3.5 times the modern annual flow volume. In the Don River basin, water flow during the Late Valdai was about 110 km^3, this is four times that of today.

In the Holocene the main causes of the dramatic change in the water flow volume, hydrologic regime and river channel morphology were the degradation of permafrost and an increase of soil permeability during the spring. Combined, these factors increased ground water flow throughout the summer and caused a decrease of the runoff coefficient, flood flow, and maximum discharge for a snow thaw period. Changes in the summer ground water regime caused an increase of the average summer flow, and vegetation spread on the bare floodplains and on former sandy bars. Large periglacial channels were abandoned, transformed into floodplain lakes and bogs. New channels were formed under conditions of lower annual flow and a much steadier flow regime. The flood wave became less high and steep, and occurred above the densely vegetated floodplain, so the flow velocities and rate of channel erosion during the high water became significantly reduced. Instead the water level and flow velocities in the channel during the summer became higher, and channel erosion by the low water became more important for channel morphology. Thus new channels had much smaller widths and meander lengths than the ancient periglacial ones.

The degree of this channel metamorphosis was also significantly different in various parts of the Russian Plain due to different levels of the discharge change during the Late Valdai/Holocene transition. The rivers of the tundra zone are still in "periglacial" conditions, and the modern river flow is close to periglacial. In the taiga zone the annual flow in the recent river basins is about 80 – 85% of the periglacial one in the east of the region and 30 – 60% in the west. In the broad – leafed forest zone it is about 40 – 50% of the periglacial annual flow in the eastern part of the region and 20 – 25% in its western part. In the steppe and forest steppe the modern annual flow is about 40 – 60% of the periglacial one in the east of the region and nearly 10% in its western part.