An Assessment of Water Deficit and Design Characteristics of Low Flows along the River Vistula

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IUGG BERLIN 2023
THE 28TH GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

humdrought

The scope of the presentation

1. Some information about the River Vistula
2. Hydrological drought characteristics assessment by the means of flow-duration-frequency (QdF) modelling.
3. Timing of low flows.
4. Areas exposed to droughts in the Vistula basin.
5. Water deficit during the most severe low flows.

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The River Vistula basin

Mean annual runoff to the Baltic Sea 33.4 km^2

The River Vistula basin in Poland (87%)

The River Vistula basin abroad (13%)

Station	Vistula reach	Area	Water regime
Skoczów	Little Vistula	296.7	Quasi-natural
Sandomierz	Upper Vistula	50731.8	Altered
Zawichost	Middle Vistula	31846-5	Altered
Warszawa	Middle Vistula	84539.5	Natural
Toruń	Lower Vistula	181033.4	Altered

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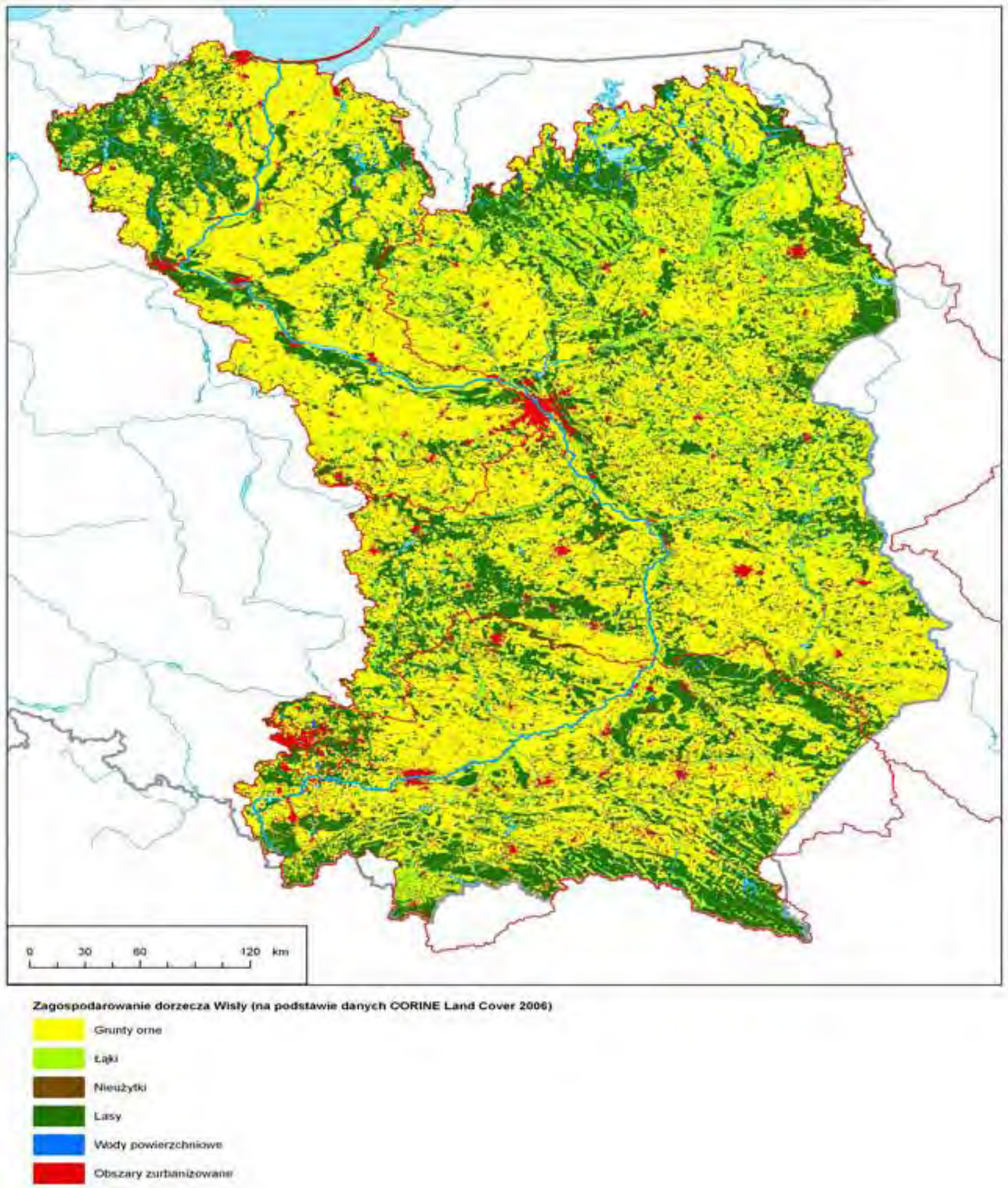
Land cover

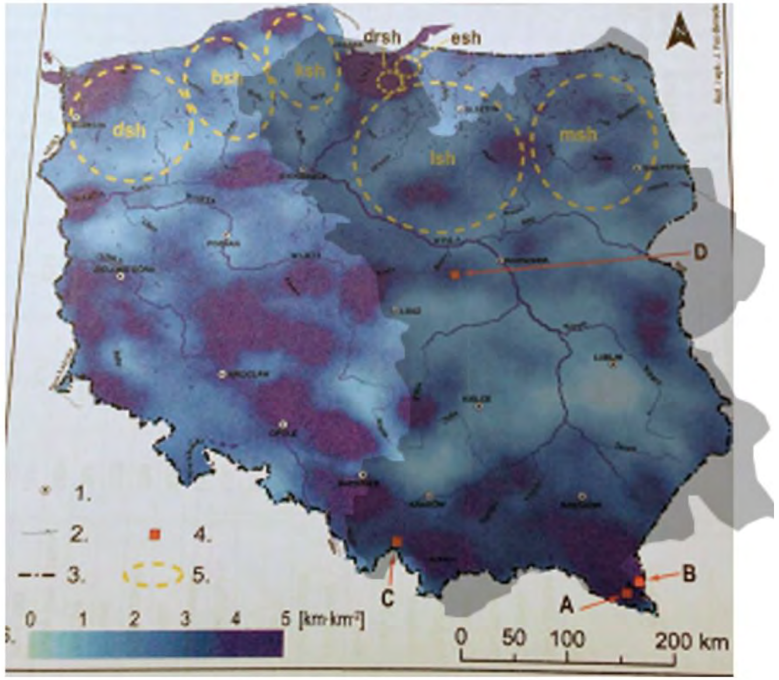


- The Upper Vistula basin: agricultural lands over **60%** of the area, approx. **34%** are forests and semi-natural ecosystems, and less than **5%** of the area is anthropogenic land, water areas and wetlands together account for about **1%**.

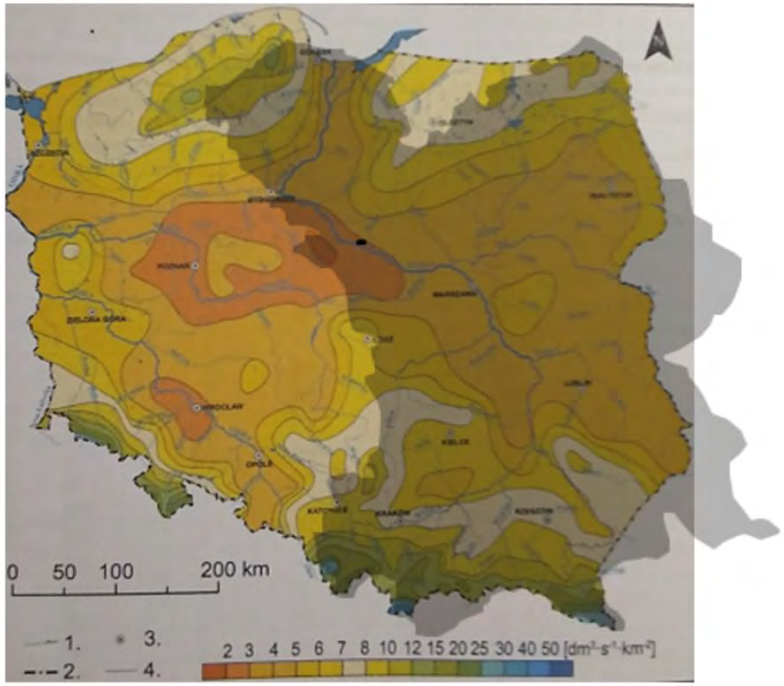
- The Middle Vistula basin: agricultural lands over **70%**, forests and semi-natural ecosystems, water areas and wetlands occupy less than **30%**, anthropogenic areas occupy less than **3%.**

- The Lower Vistula basin: agricultural lands over **75%**, forests and semi-natural ecosystems, water areas and wetlands occupy less than **25%**, anthropogenic areas occupy less than **2%.**

Exposure to drought – climate, land and groundwater impacts



River network density (km km^{-2})



The runoff module (dm^3 s^{-1} km^{-2}) in Poland.

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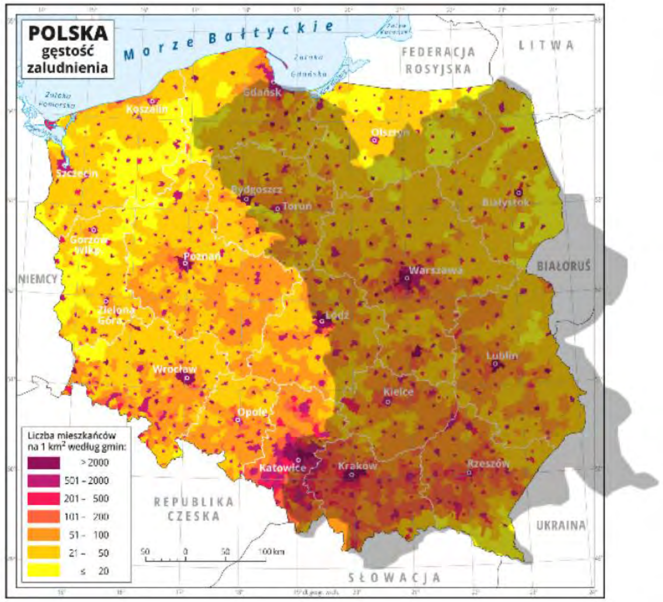
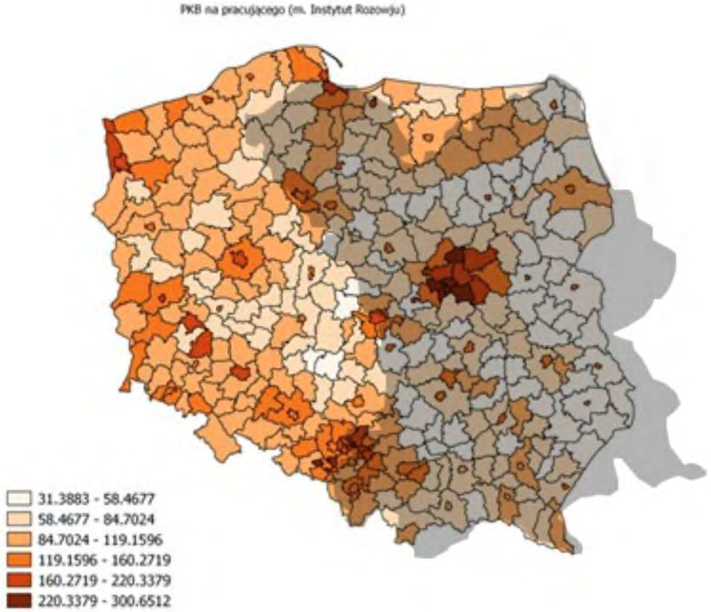
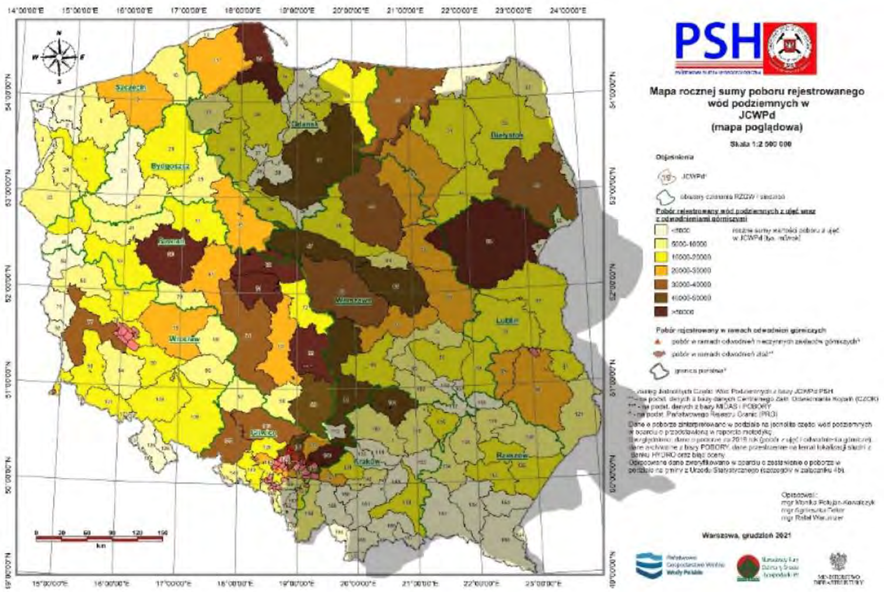
Exposure to drought - human impact



Population density
(persons per 1 km^2 in Poland
by communes).



Gross Domestic Product (GDP) per capita
in poviats
as a percentage of Total Polish GDP.



Annual water withdraw (thousand cubic m/year)
from groundwater bodies
(colours from light yellow- <500
to darkest brown>5000)

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The deepest low flows on the Vistula and on its reaches and the main tributaries.

Rank	Vistula		Little Vistula		Upper Vistula		Midlle Vistula		Lower Vistula	
	Year	Mean rank	Year	Mean rank	Year	Mean rank	Year	Mean rank	Year	Mean rank
1	1959	5,5	1959	7,8	1953	1,3	1951	3,0	1961	2,7
2	1951	7,3	1957	8,5	1957	3,0	1963	3,2	1959	3,3
3	1961	8,9	**1994**	12,3	1954	3,3	**1984**	3,8	1992	4,0
4	1963	8,9	1951	13,3	1956	6,0	1959	4,2	1951	5,7
5	1954	10,3	1958	14,0	1959	7,0	1961	6,2	**2015**	6,0
6	1953	10,5	**1993**	14,3	1963	7,3	1952	7,2	1952	7,0
7	1952	11,1	1963	15,3	1951	8,0	1954	7,2	1954	7,0
8	**2015**	11,5	**2003**	15,3	1961	8,3	**1993**	8,2	1953	7,7

Rank	Przemsza	Soła	Skawa	San	Wieprz	Pilica	Wyszków
	Jeleń	Oświęcim	Wadowice	Radomyśl	Kośmin	Białobrzegi	Bug
1	1951	1959	1994	1959	1992	1992	1959
2	1953	1957	2015	1951	1952	1994	2015
3	1954	1983	2011	1961	1962	1954	1951
4	1952	1958	2012	1963	1963	1963	1952
5	2017	1963	1960	1962	1964	1995	1953
6	2015	1961	1955	1952	1961	2006	1963
7	2016	1953	1961	1967	1995	2015	1961
8	1962	2003	2003	1968	1994	2008	2016

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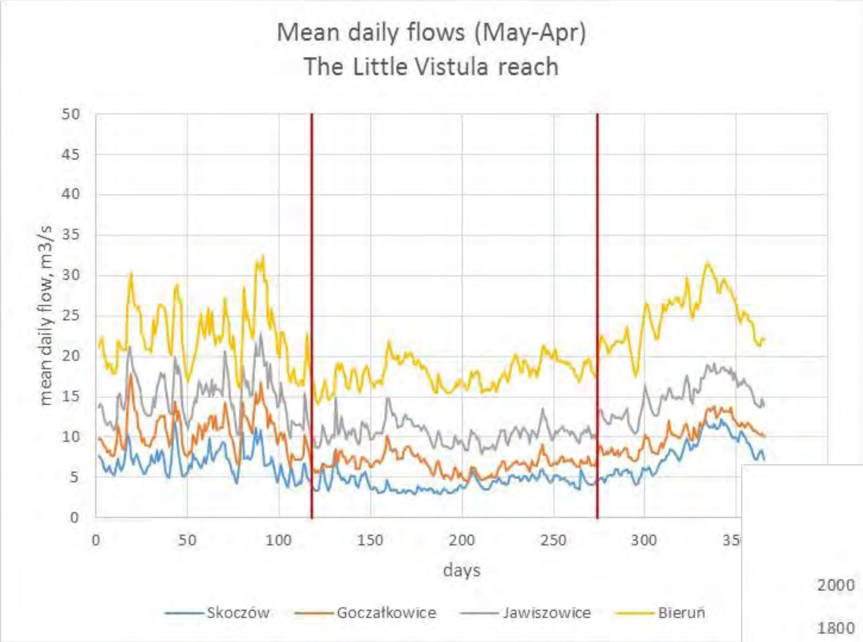
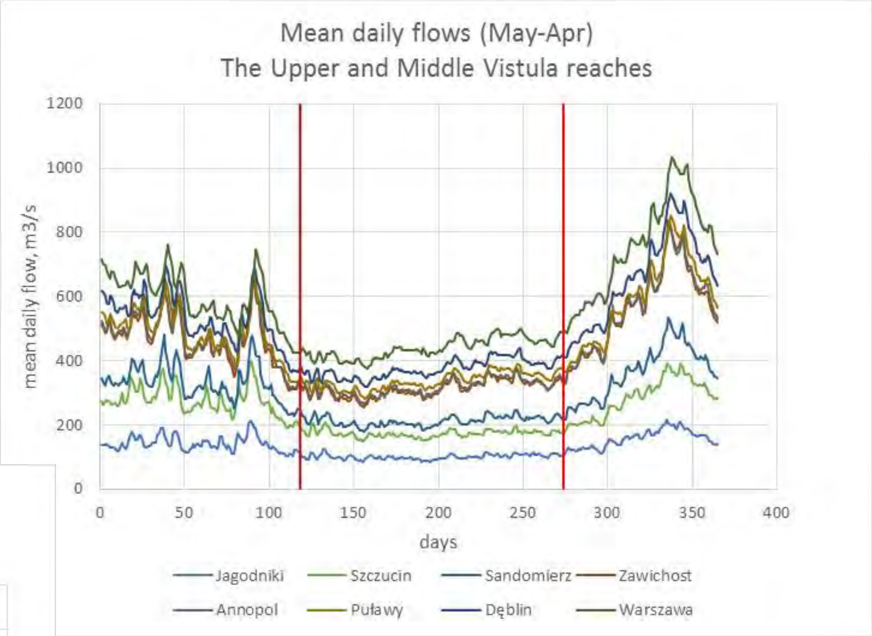
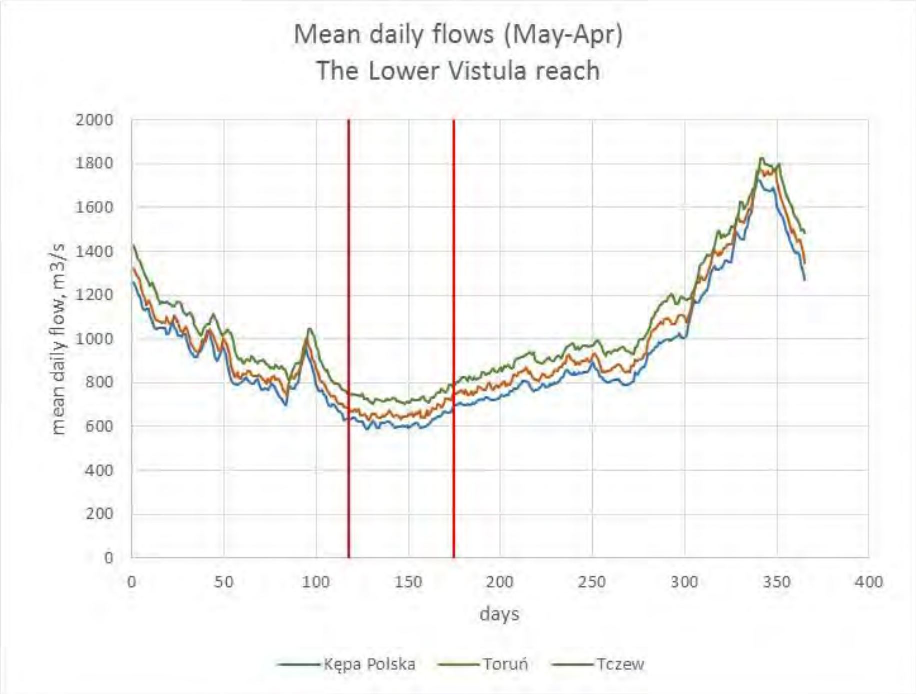
Timing of the low flow



The end of August –
the end of January





The end of August –
the end of October

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Drought design characteristic

QdF model

Low flows

Quantile function :

$$Q(d,F) = Q(0,F) \cdot \left(1 + \frac{d}{D}\right)$$

Distribution of the flow non-exceeded in *d* days

Annual minima distribution

D parameter of low flows dynamics

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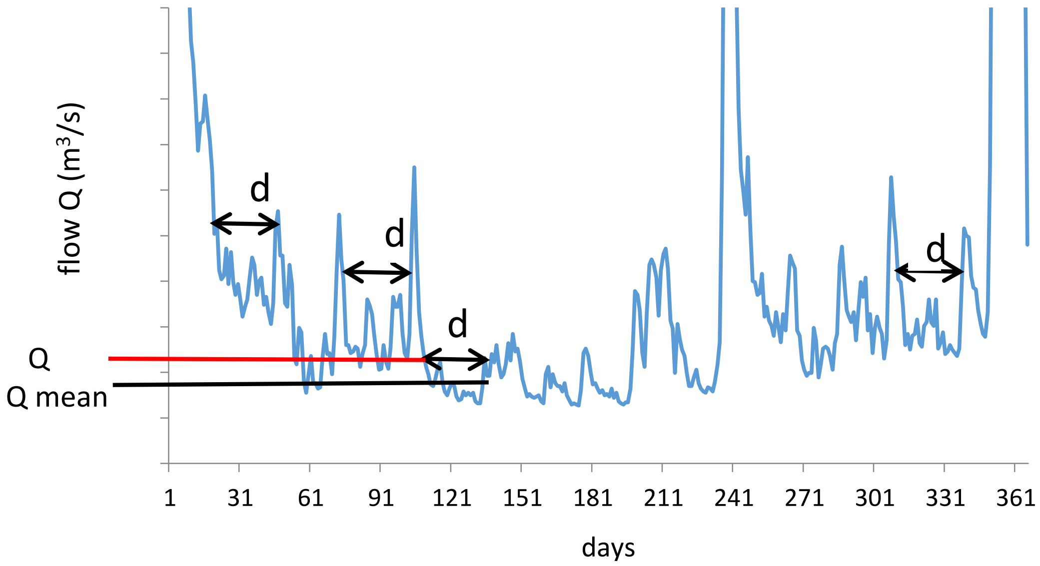
Data preparation procedure

Low flows

QdF approach



Estimation procedure

Quantile function : $$Q(d,F) = Q(0,F)\cdot\left(1+\frac{d}{D}\right)$$

putting $$x(d_j,i) = \frac{Q(d_j,i)}{\left(1+\frac{d_j}{\mathrm{D}}\right)}$$

we find D as the value that minimizes the sum of the relative square deviations

$$e = \sum_{j=1}^{N}\sum_{i=1}^{T}\left(\frac{x(d_j,i)-\bar{x}(i)}{\bar{x}(i)}\right)^2$$

where $$\bar{x}(i) = \frac{1}{N}\sum_{j=1}^{N} x(d_j,i)$$

Fitting a probability distribution to $\bar{x}(i)$ we obtain $Q(0,F)$. (3-parameter Weibull distribution was adopted here)

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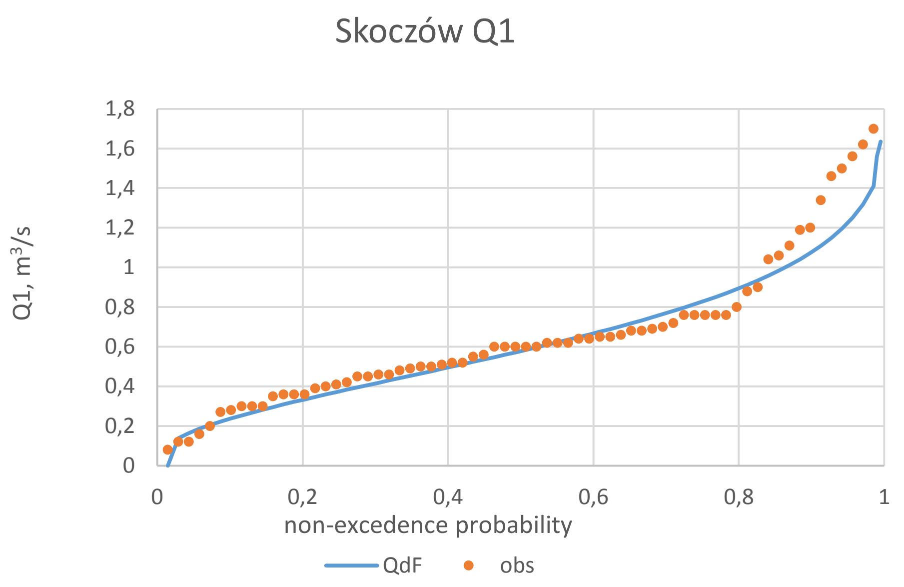
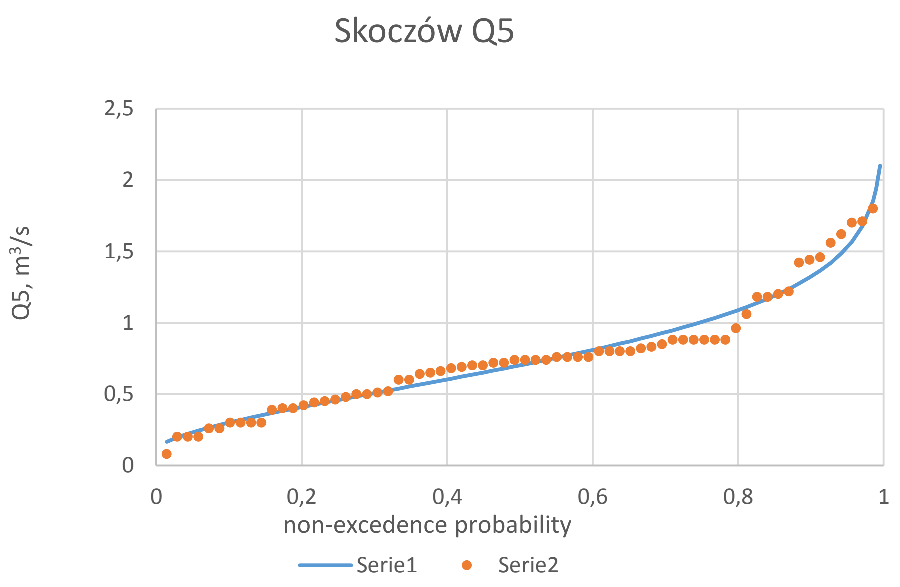
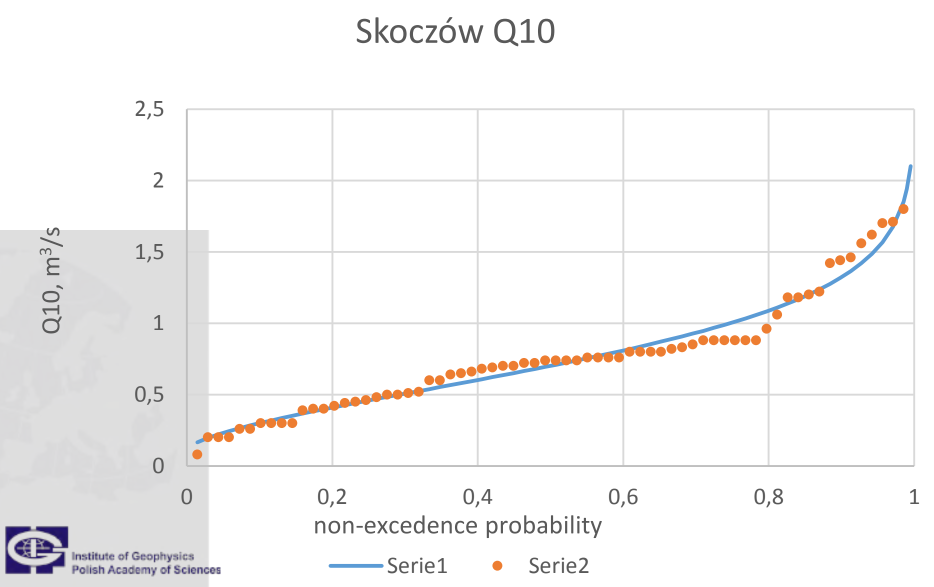
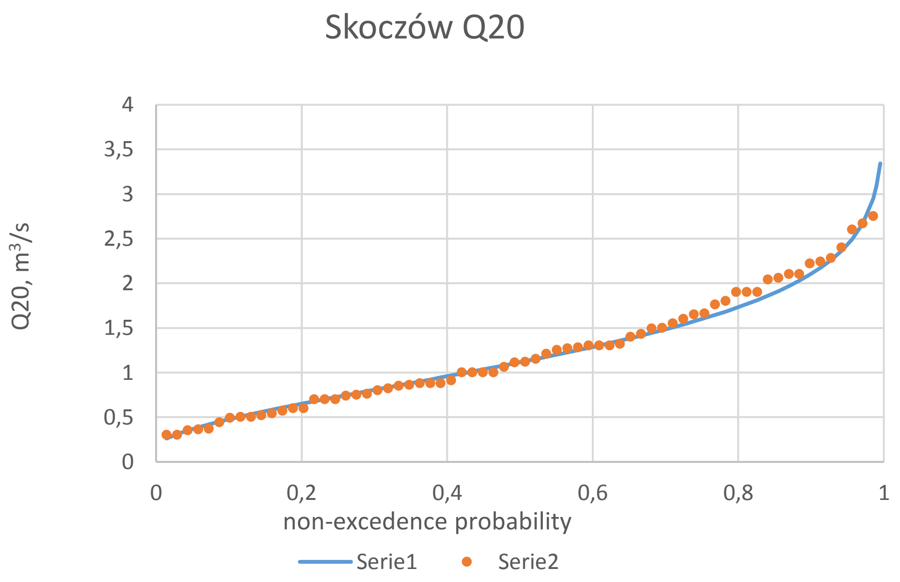
QDF model – results Skoczów; D=20,33

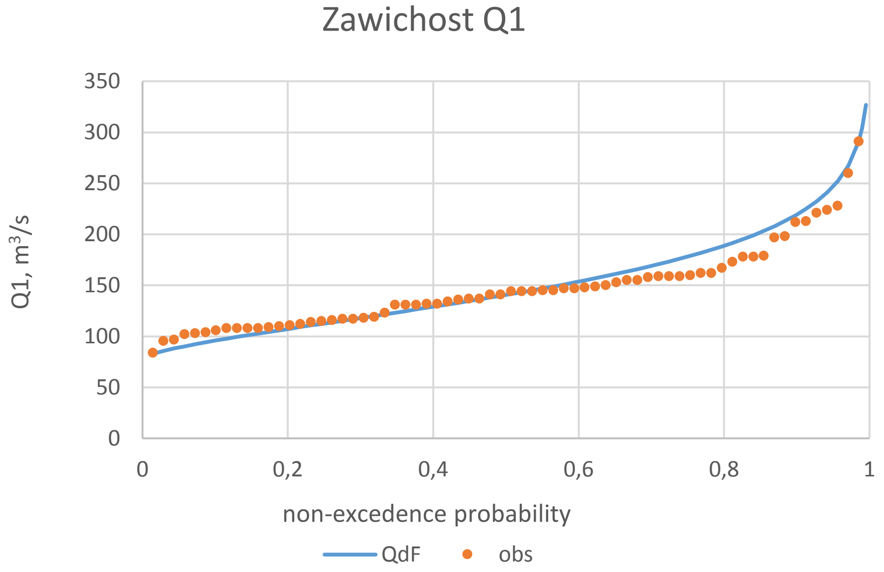


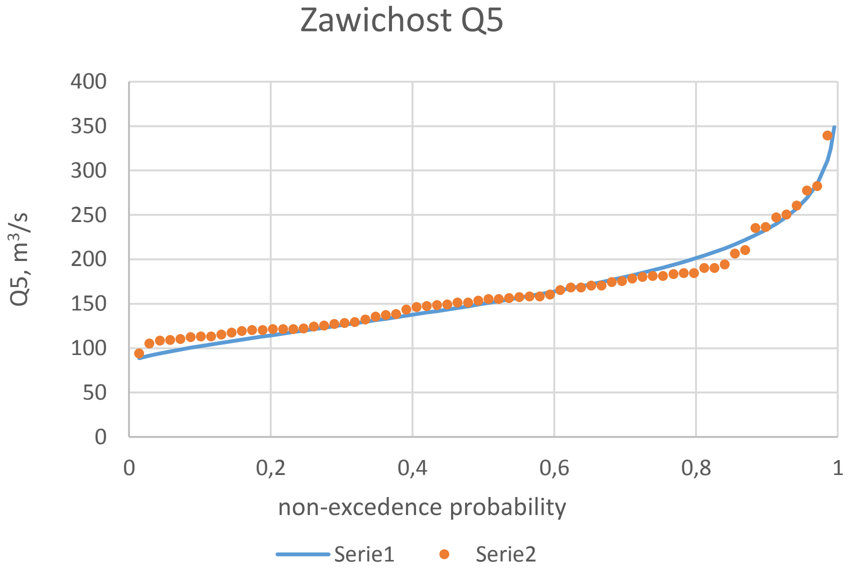


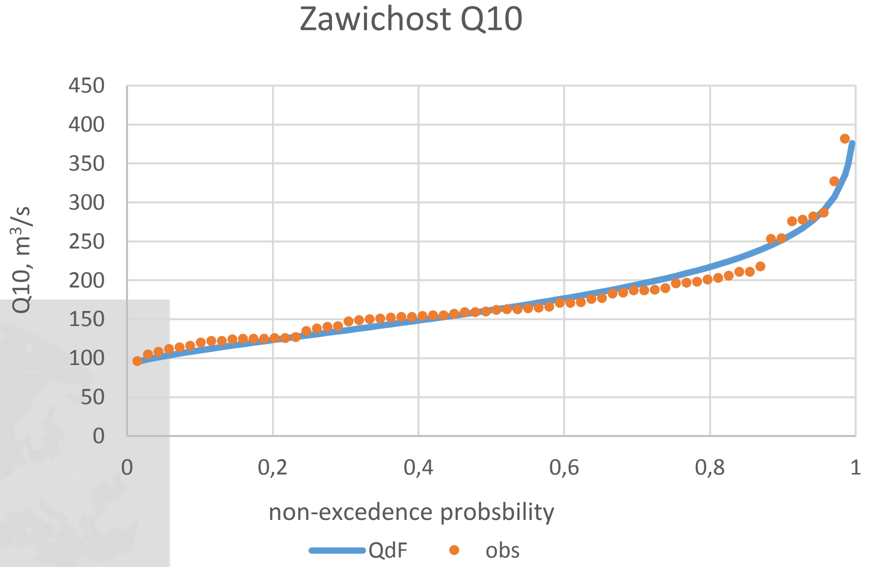


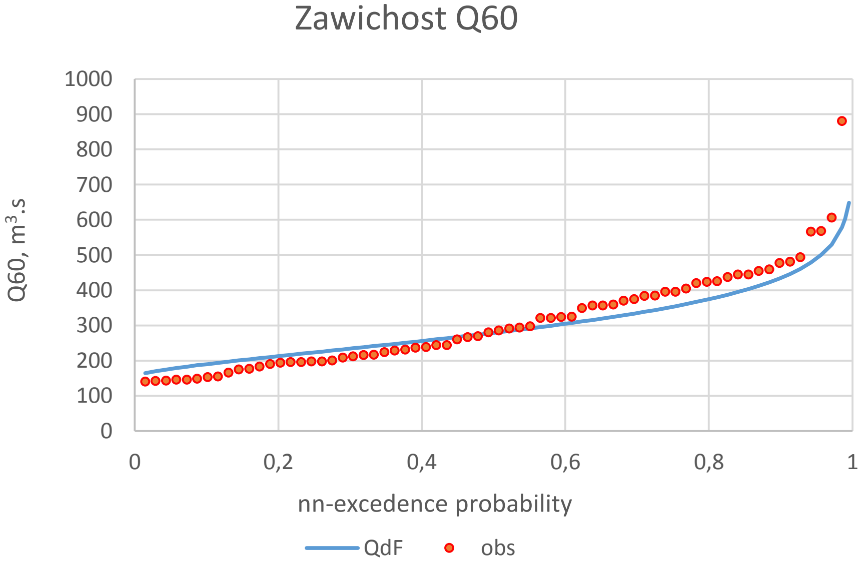


QDF model – results Zawichost; D=59,06









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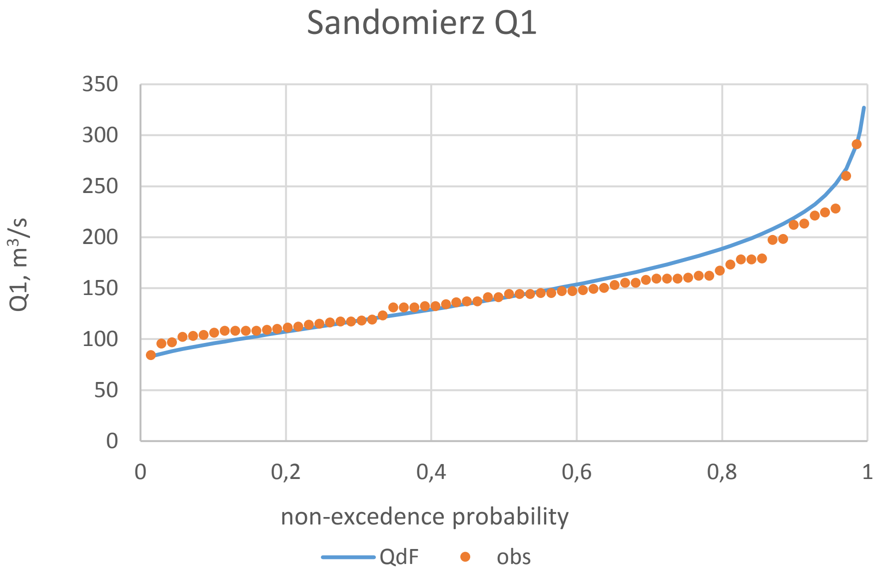
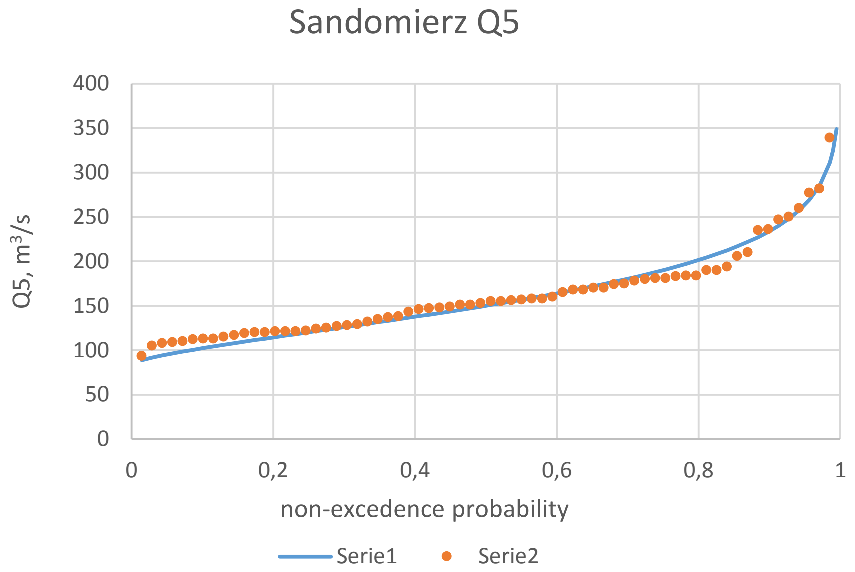
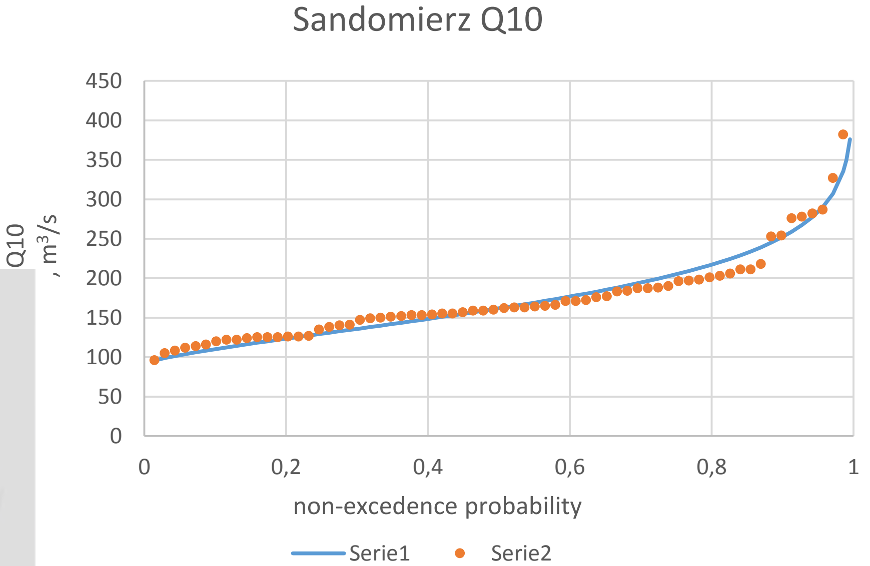
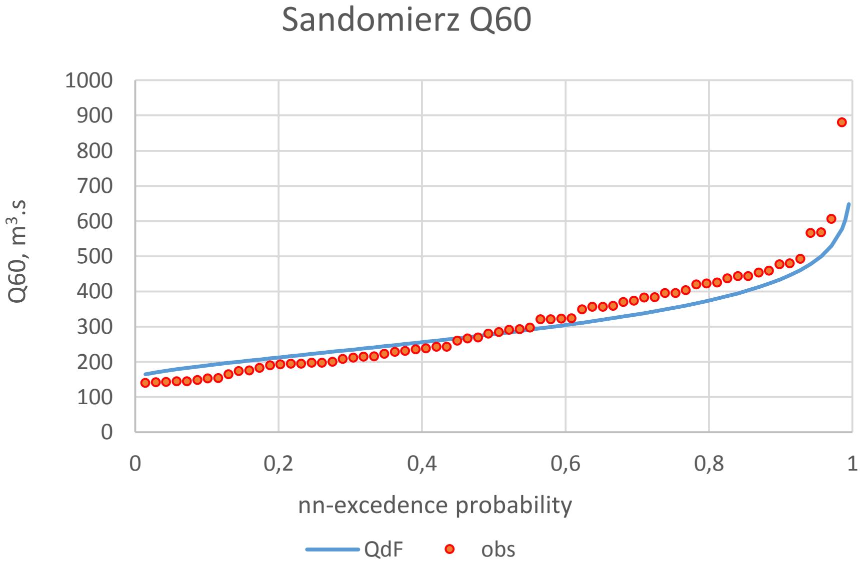
QDF model – results Sandomierza; D=62,31









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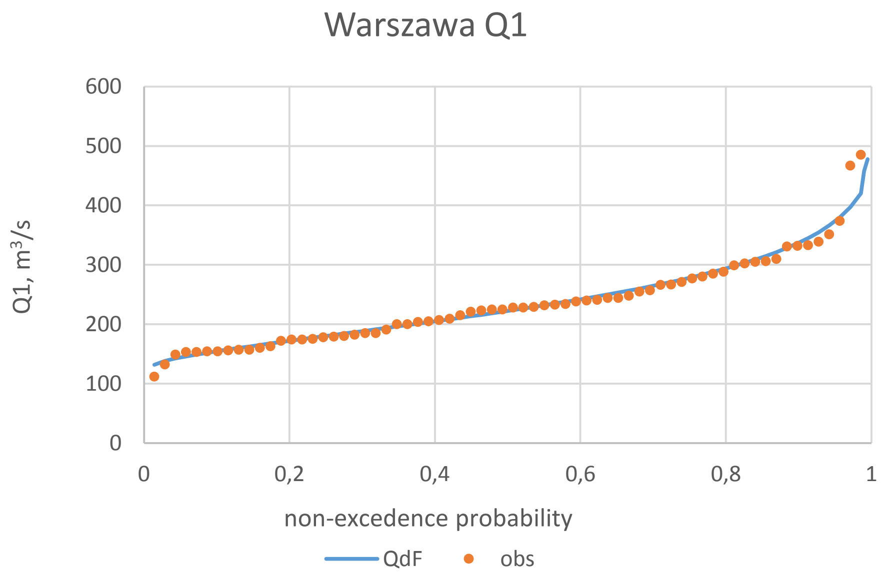
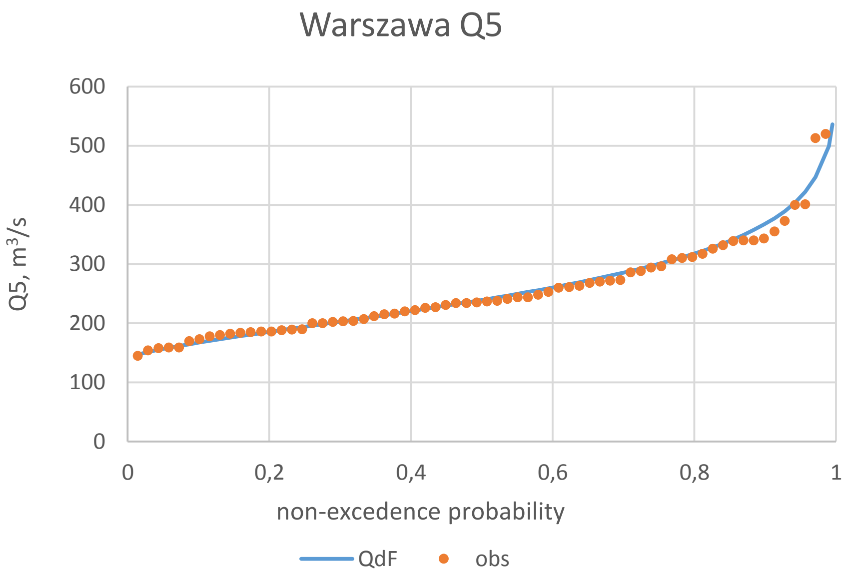
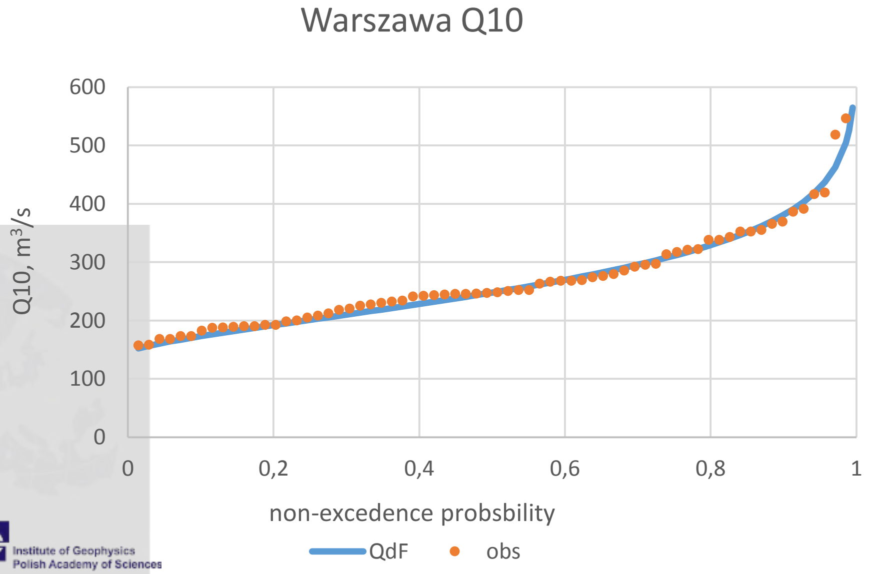
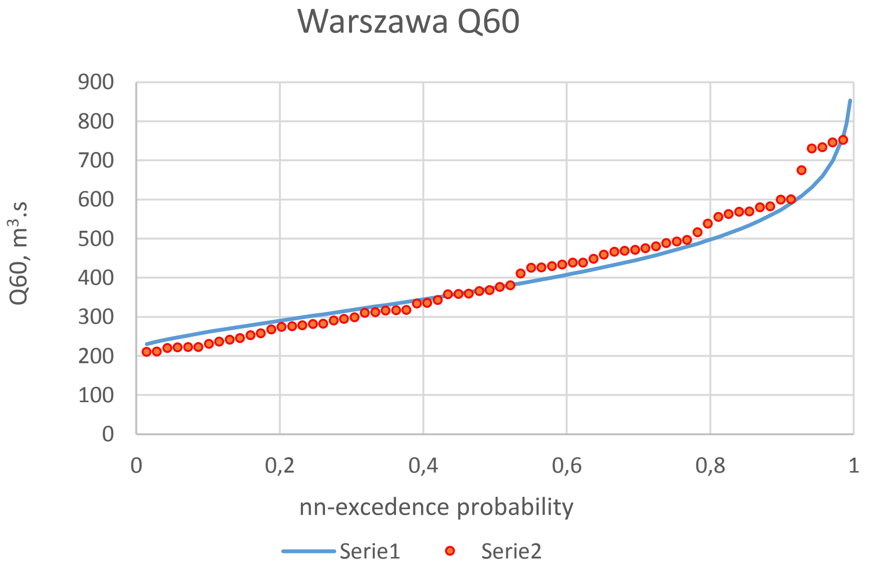
QDF model – results Warszawa; D=87,79









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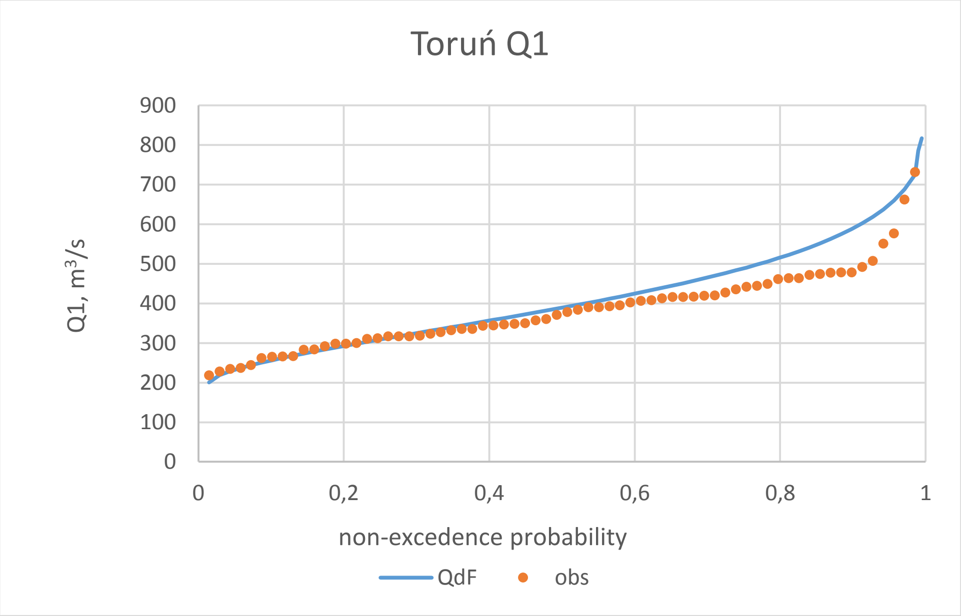
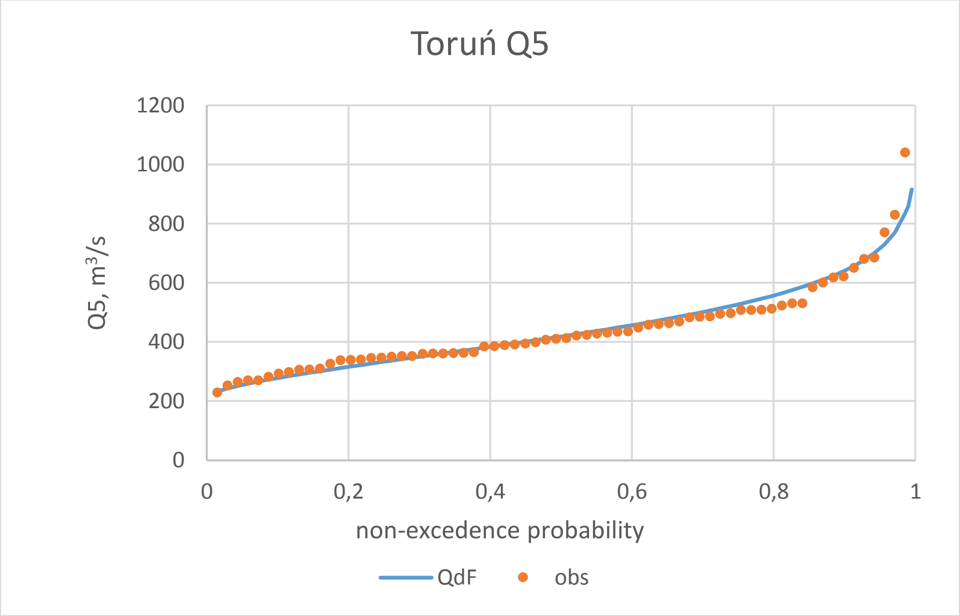
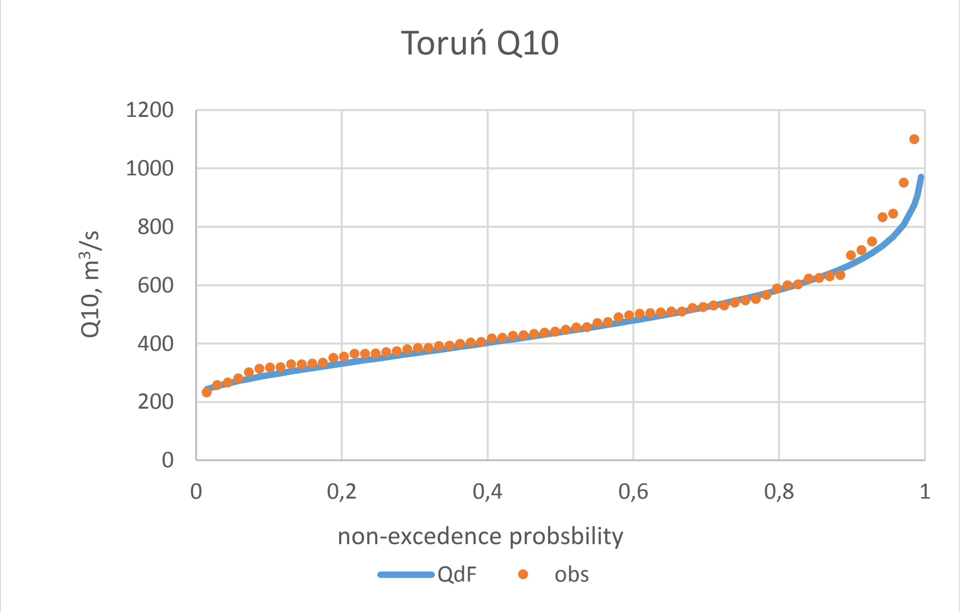
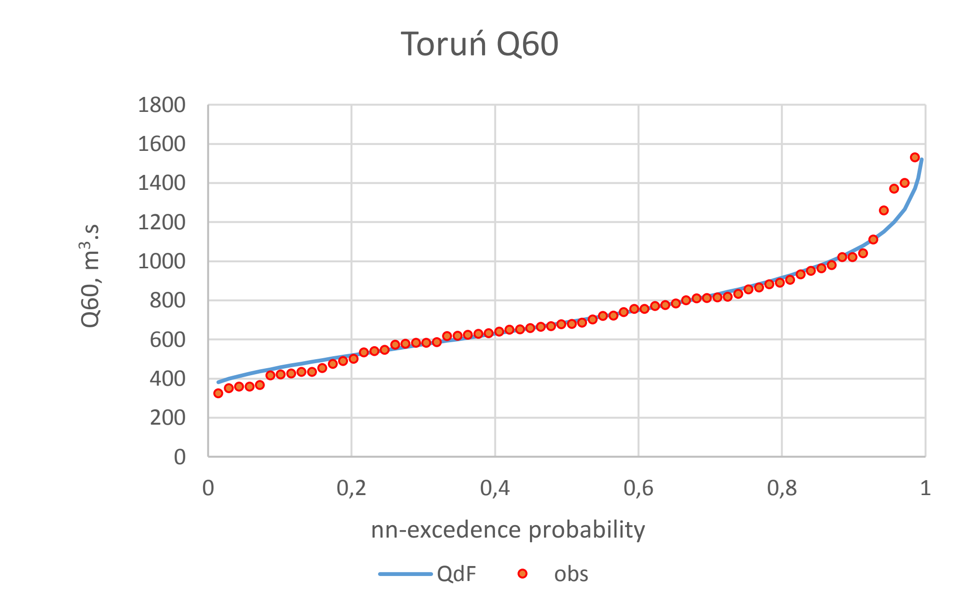
QDF model – results Toruń; D=78,22

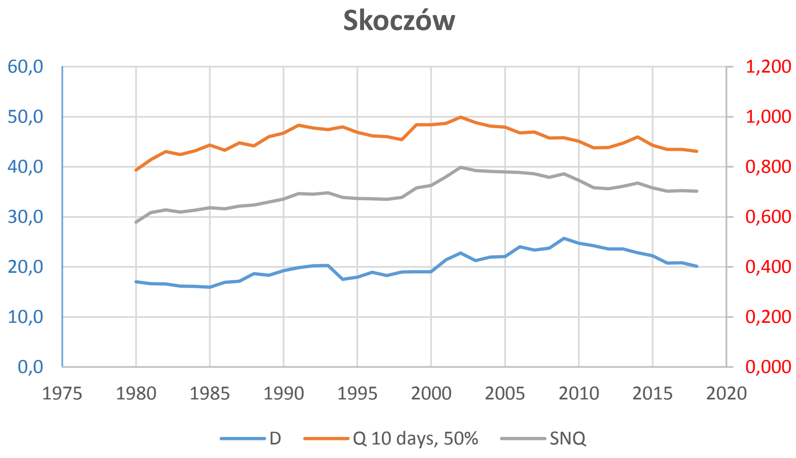


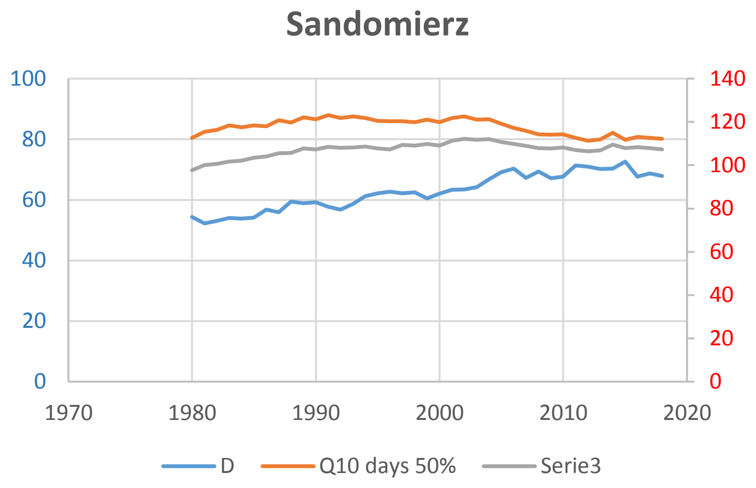


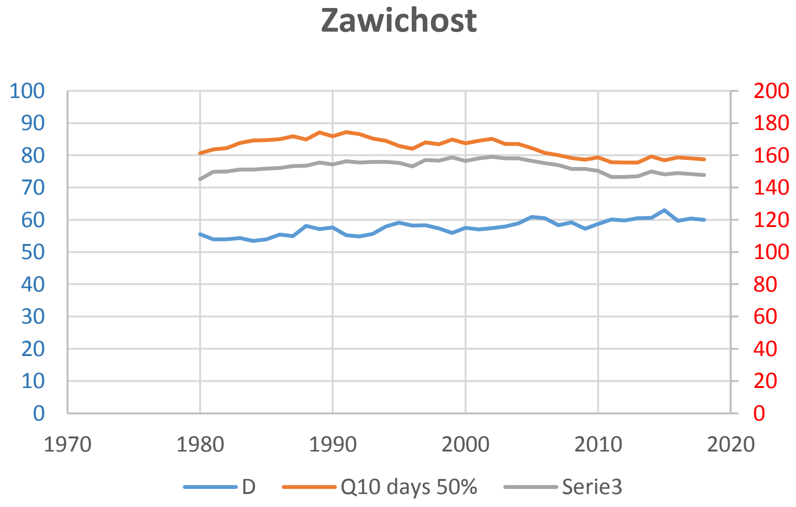


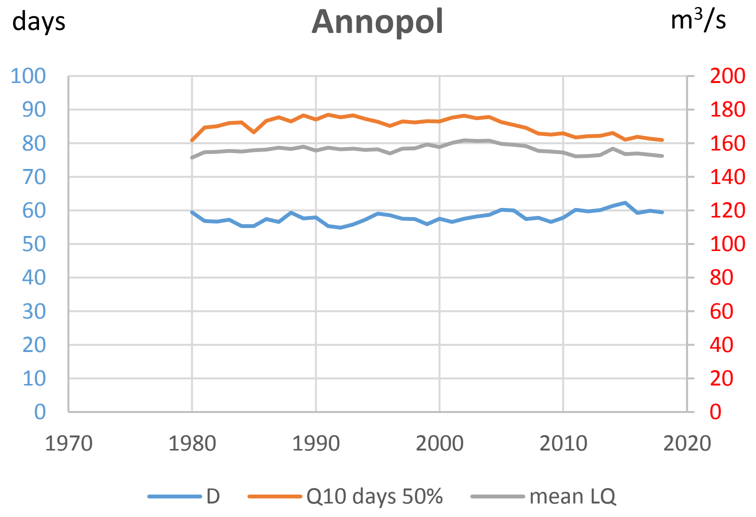


QDF model – results for moving 30 year window









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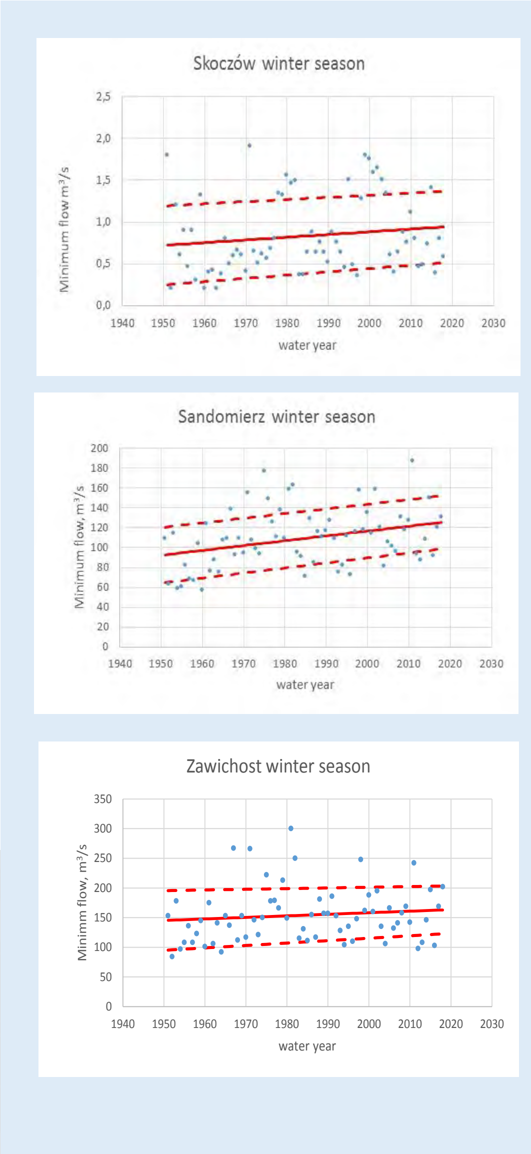
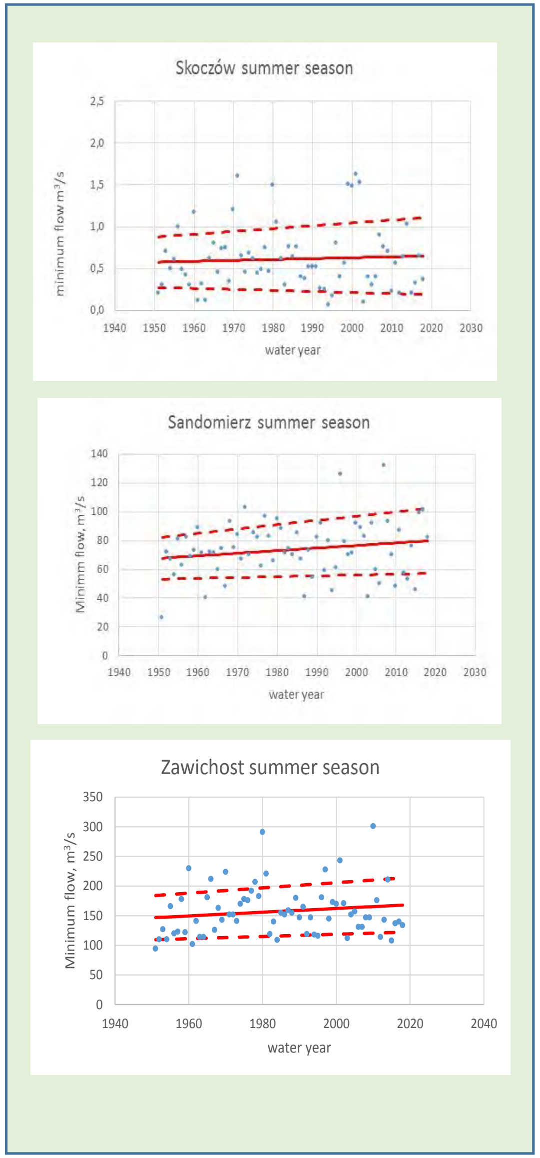
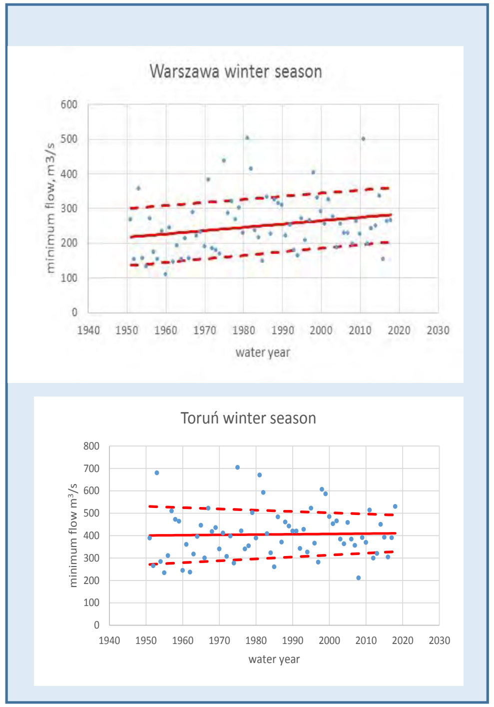
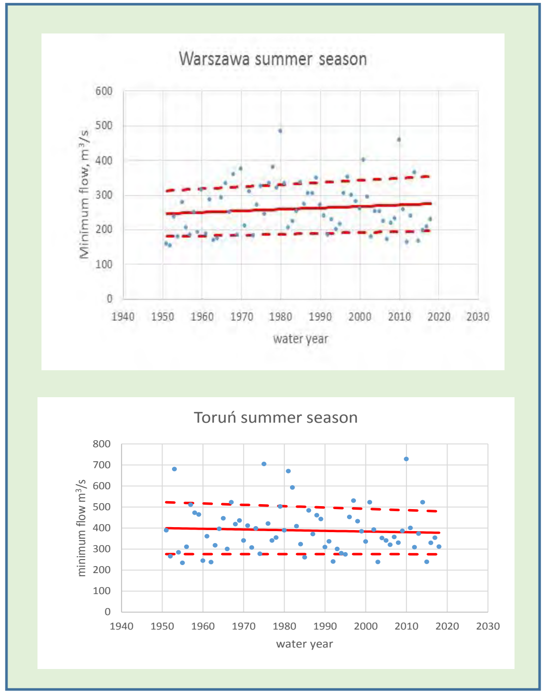
Trends in seasonal minima









Analyzes of trends in many runoff characteristics have shown, *inter alia*, that the minimum winter flows increased in the period 1951-2018.

In general, the summer minima do not show a downward trends.

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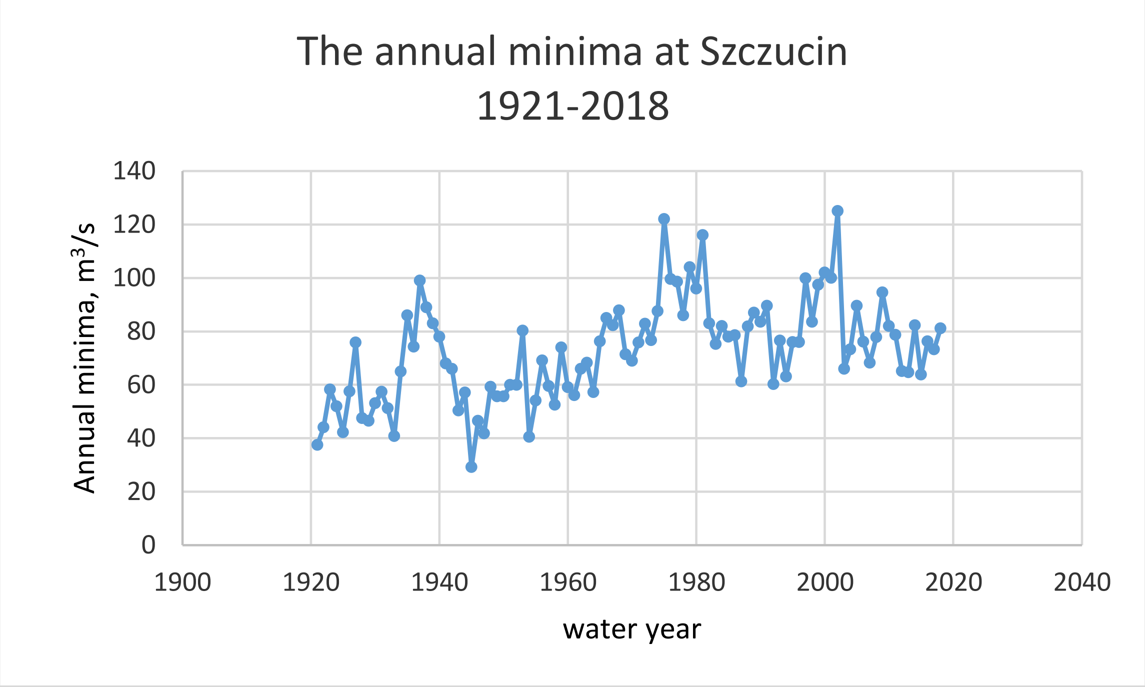
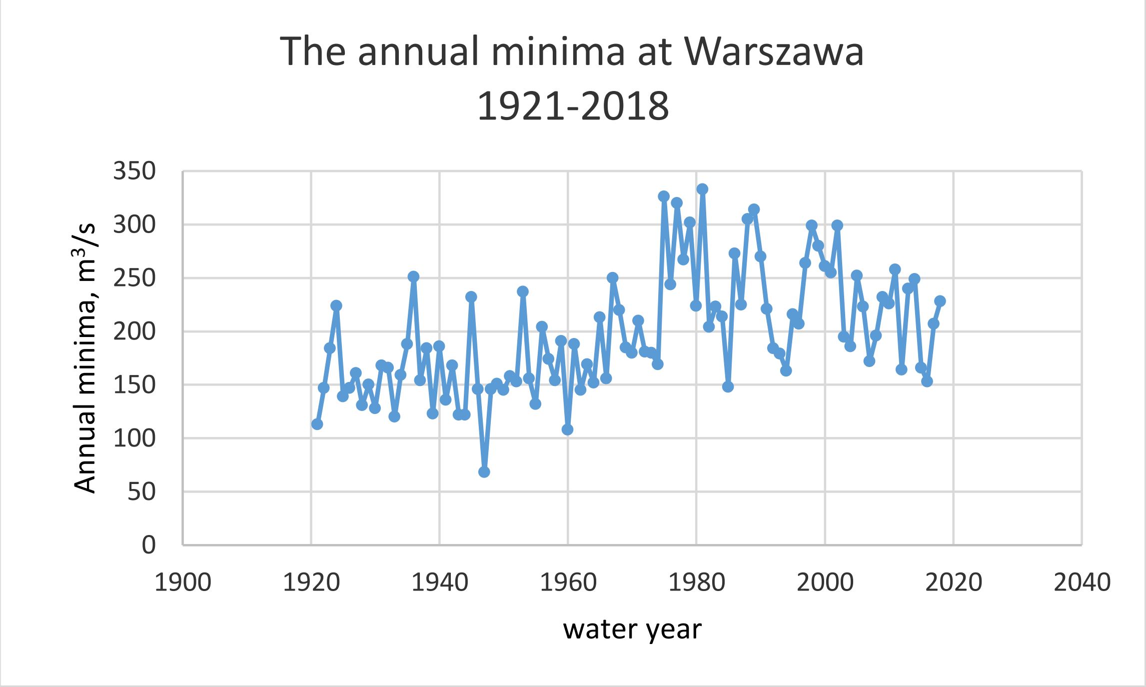
The trends in annual minima for longer period





Flow deficit in years of severe low flows (10^3 m^3)

Year	Szczucin	Warszawa
1951	59 883,84	226 195,2
1992	29 376,00	15 724,00
2003	19 699,20	42 249,50
1921	303 583,69	791 769,60

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Conclusions

- No significant decreasing trends in the lowest seasonal minimum flows have been found.
- Low flows in 50-ties and 60-ties still on the top of the most severe along the Vistula and its main tributaries.
- The design characteristics of low flows do not change significantly.
- The analysis of low flows and their characteristics used in the design should be supplemented with an analysis of the water level. Material losses do not always result from the lack of water - low flows, but from the difficulty of its intake.
- It is worth developing a hypothetical low flow hydrograph with a given probability of not exceeding it based on the recession curve and the results of QdF models.

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Thank you for your attention

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