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# Creager and Francou-Rodier envelope curves for extreme floods in the Danube River basin in Croatia

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**Abstract** This paper presents a comparison of Creager and Francou-Rodier envelope curves for average maximum annual discharges, for the highest observed discharges, and for maximum annual discharges of the 10-, 100- and 1000-year return periods in the Danube River basin in Croatia. They were calculated on the basis of 99 available, sufficiently long and homogenous time series of measured discharges.

**Key words** Creager's method; Croatia; Danube River basin; envelope curves; Francou-Rodier's method; maximum discharges

## INTRODUCTION

The Danube River basin is, after the Volga River basin, the second biggest basin in Europe with a size of about 817 000 km$^2$, with 18 riparian states and about 82 million inhabitants.

In Croatia, the Danube River basin (Fig. 1) covers approximately 34 000 km$^2$, roughly 60% of the country's land area, where approximately 65% of the total population of the Republic of Croatia live. Major Croatian rivers, such as the Danube, the Sava, the Drava, the Kupa, the Una and the Mura flow through this area. It is located on the Pannonian plain and its rims, with the water divide separating it from the Adriatic catchments running through the Dinaric karst.

The particular socio-economic significance of this area, not only for the Republic of Croatia, but also for a greater region, emphasizes the importance of efficient flood control. Although certain flood control activities in this area date from the 19th century, systematic development of flood control systems did not begin until after the catastrophic floods on the Sava, the Drava and their tributaries during the 1960s. Gradual development of flood control systems in the last four decades has significantly reduced potential damage, a fact proven by the successful reduction of numerous recent floods. Most of the systems constructed are only partially completed, which results in a continuing significant risk of flooding across large areas. Further development of the flood and torrents control systems remains, therefore, one of the strategic tasks of Croatian water management.

Basic information for further planning and design of flood control systems are maximum discharges of required return periods in adequate locations along the water-courses. These can be estimated by applying stochastic methods for sufficiently long and homogenous time series of measured discharges at gauged locations, or by

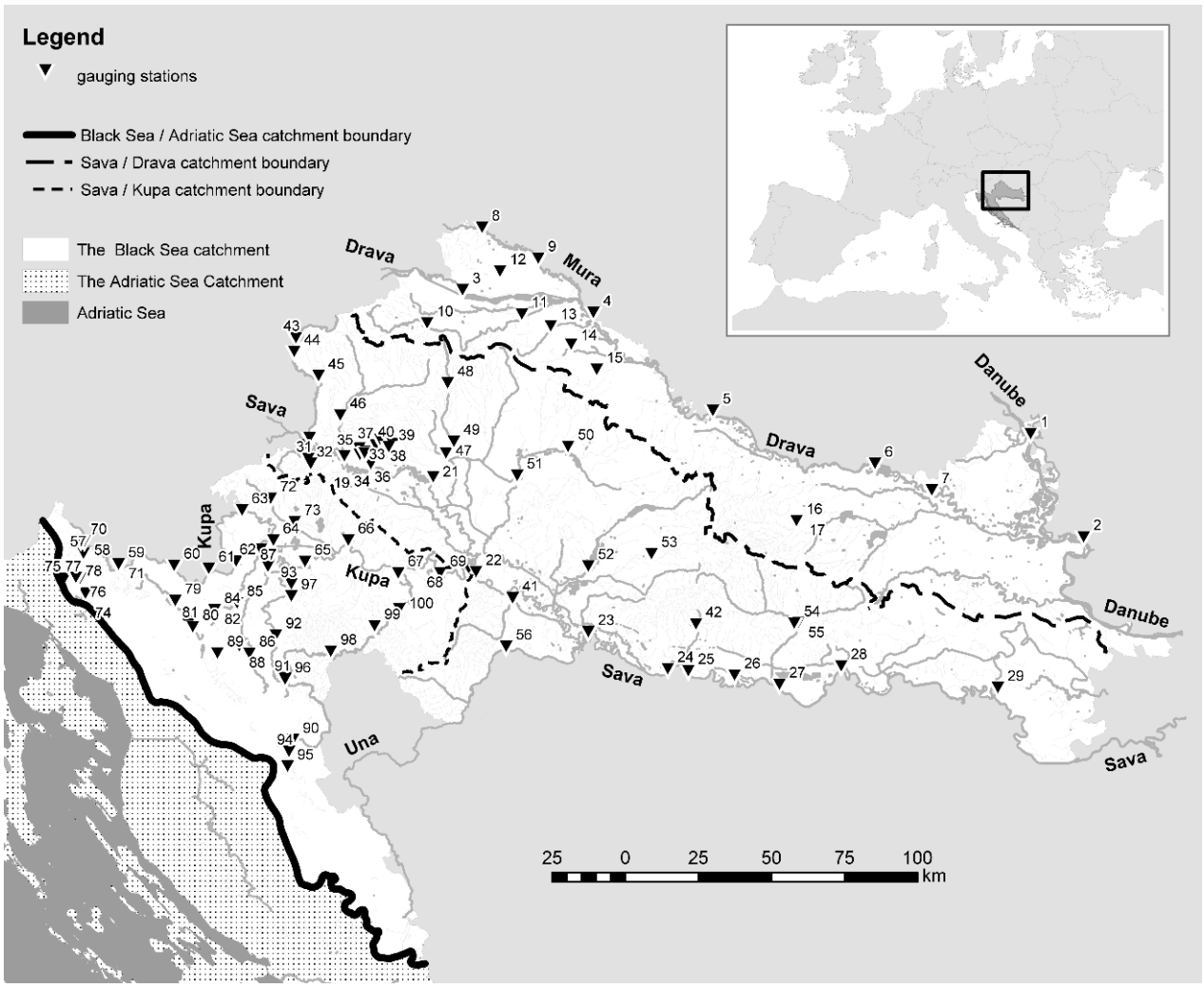


**Fig. 1** Overview map of the locations of analysed gauging stations in the Danube River basin in Croatia

deterministic methods at ungauged locations. Common hydrological practice also recognizes the use of various methods for evaluation of reliability of such calculated values. The aim of this paper is to compare two possible methods for evaluation of the reliability of previously estimated values in the Danube catchment area in Croatia: Creager's and Francou-Rodier's envelope curves for average maximum annual discharges, for highest observed discharges, and for maximum annual discharges of the 10, 100 and 1000-year return periods in the Danube River basin in Croatia. Similar investigations for large floods across the whole of Europe were performed by Stanescu & Matreata, 1997.

## THEORETICAL APPROACH AND INVESTIGATION PROCEDURE

Creager's envelope curves of specific maximum discharges (Creager & Justin *et al.*, 1945) are formulated as follows:

$$q = aA^{bA^c}$$

where $q$ is specific maximum discharge ($m^3 s^{-1} km^{-2}$); $A$ is catchment area ($km^2$); and $a$, $b$, $c$ are regional parameters.

The Francou-Rodier envelope curves of maximum discharges (Francou & Rodier, 1967) are formulated as follows:

$$\frac{Q}{Q_0} = \left(\frac{A}{A_0}\right)^{1-\frac{K}{10}}$$

where $Q$ is maximum discharge ($m^3 s^{-1}$); $A$ is catchment area ($km^2$); $K$ is the Francou-Rodier coefficient; $Q_0 = 10^6 m^3 s^{-1}$; and $A_0 = 10^8 km^2$.

Creager's and Francou-Rodier's envelope curves for the Danube River basin in Croatia are defined on the basis of available time series of daily discharges which are stored in the hydrological database of the Croatian Meteorological and Hydrological Service (Plantić, 1996).

The theoretical approach described above can be applied only when the series are sufficiently long, homogenous and when there are no significant trends. Analyses of time series homogeneity and trends were performed only for the maximum annual discharge series at all gauging stations on the Danube River basin in Croatia that have observation periods longer than or equal to 25 years (108 stations).

The analyses of homogeneity were performed by application of the Wilcoxon test in such a way that the available series was split into two sub-series, depending on the time of replacement of hydrometric equipment at the stations (rods to limnigraphs) and depending on the timing of construction of major hydrotechnical structures with significant impacts on the water regime (reservoirs, main dykes and distribution structures). The presence of trends in the time series of maximum annual observed discharges was tested using Mann's test. On the basis of the homogeneity and trend analyses performed, 100 time series of maximum annual discharges were selected for further analysis.

The next step was probabilistic analysis of selected time series of maximum annual observed discharges. Maximum annual discharges of 10-year return period were calculated by application of an empirical distribution, and maximum annual discharges of 100 and 1000-year return periods were calculated by applications of the normal distribution (6 stations), log-normal distribution (18 stations), Gamma two-parameter distribution (9 stations), Gumbel distribution (11 stations), Pearson III distribution (27 stations) and log-Pearson III distribution (29 stations). The goodness of fit was tested using the Kolmogoroff-Smirnoff test. The results of the probability analysis of the time series are shown in Table 1.

The last step was to calculate the regional parameters $a$, $b$ and $c$ of Creager's formula and $K$ of Francou-Rodier's formula for each envelope curve by means of logarithmic and regression analyses. Because of unreliability of the observed and calculated maximum discharges at Petrina gauging station (No. 59) on the Kupa River, these data were excluded from calculations of the regional parameters.

**Table 1** Basic characteristics of analysed gauging stations in the Danube catchment area in Croatia.

| No. | River | Gauging station | Catch-ment area ($km^2$) | Observing period (no. of years) | Discharges Q ($m^3 s^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | Average max annual | Max obs'd (year of occurrence) | Maximum for return periods (years) | | |
| | | | | | | | | 10 | 100 | 1000 |
| DANUBE RIVER | | | | | | | | | | |
| 1 | Danube | Batina | 210250 | 1951–1989 (39) | 2313 | 4841 | 8360 (1965) | 6322 | 7860 | 9288 |
| 2 | Danube | Erdut | 251593 | 1950–1989 (40) | 2852 | 5443 | 9250 (1965) | 7278 | 9580 | 11952 |
| DRAVA RIVER BASIN | | | | | | | | | | |
| 3 | Drava | Varaždin | 15616 | 1951–1981 (31) | 341 | 1286 | 2843 (1966) | 1811 | 2776 | 3620 |
| 4 | Drava | Botovo | 31038 | 1961–1998 (38) | 514 | 1596 | 2652 (1972) | 2369 | 3083 | 3936 |
| 5 | Drava | Terezino Polje | 33916 | 1961–1998 (38) | 526 | 1506 | 2889 (1972) | 2382 | 3190 | 4420 |
| 6 | Drava | Donji Miholjac | 37142 | 1926–1998 (71) | 543 | 1360 | 2288 (1972) | 1779 | 2269 | 2707 |
| 7 | Drava | Belišće | 38500 | 1962–1993 (31) | 556 | 1405 | 2232 (1972) | 2021 | 2573 | 3242 |
| 8 | Mura | Mursko Središće | 10891 | 1926–1998 (67) | 171 | 732 | 1454 (1938) | 1180 | 1651 | 2179 |
| 9 | Mura | Goričan | 13148 | 1926–1998 (70) | 161 | 642 | 1447 (1972) | 996 | 1372 | 1713 |
| 10 | Bednja | Željeznica | 308 | 1959–1998 (40) | 4.04 | 59.9 | 112 (1959) | 95.7 | 153 | 214 |
| 11 | Bednja | Ludbreg | 547 | 1947–1998 (52) | 7.29 | 80 | 179 (1972) | 128 | 172 | 212 |
| 12 | Trnava | Jendrašiček | 148 | 1956–1998 (42) | 0.405 | 6.64 | 26.6 (1979) | 14.1 | 24.4 | 34.1 |
| 13 | Gliboki Potok | Mlačine | 84 | 1970–1998 (29) | 0.731 | 19.2 | 34.2 (1986) | 29.9 | 36.3 | 41.8 |
| 14 | Koprivnica | Koprivnica | 122 | 1951–1998 (46) | 0.645 | 23.5 | 55.9 (1963) | 45.4 | 72.2 | 106 |
| 15 | Komarnica | Novigrad Podravski | 48 | 1958–1998 (40) | 0.288 | 9.39 | 26.3 (1963) | 19.1 | 35.7 | 59.1 |
| 16 | Voćinka | Mikleuš | 173 | 1960–1998 (39) | 2.18 | 54.5 | 107 (1972) | 93 | 113 | 124 |
| 17 | Vojlovica | Čačinci | 150 | 1968–1998 (28) | 1.9 | 35.9 | 90 (1975) | 61 | 90.1 | 115 |
| SAVA RIVER BASIN | | | | | | | | | | |
| 18 | Sava | Jesenice | 10750 | 1964–1995 (32) | 276 | 1846 | 3489 (1964) | 2680 | 3745 | 4692 |
| 19 | Sava | Podsused | 12316 | 1949–1995 (47) | 306 | 1738 | 3332 (1990) | 2571 | 3485 | 4747 |
| 20 | Sava | Zagreb | 12450 | 1926–1995 (70) | 314 | 1775 | 3126 (1964) | 2348 | 3073 | 3633 |
| 21 | Sava | Rugvica | 12712 | 1926–1995 (67) | 312 | 1502 | 2357 (1990) | 2069 | 2662 | 3327 |
| 22 | Sava | Crnac | 22852 | 1955–1992 (38) | 529 | 1935 | 2331 (1991) | 2145 | 2360 | 2481 |
| 23 | Sava | Jasenovac | 38958 | 1926–1991 (64) | 784 | 1977 | 2716 (1970) | 2291 | 2678 | 3052 |
| 24 | Sava | Stara Gradiška | 40100 | 1937–1991 (54) | 788 | 1899 | 2524 (1974) | 2214 | 2588 | 2921 |
| 25 | Sava | Mačkovac | 40838 | 1951–1990 (40) | 823 | 2115 | 3018 (1974) | 2519 | 3026 | 3438 |
| 26 | Sava | Davor | 47200 | 1958–1993 (36) | 931 | 2321 | 3130 (1974) | 2697 | 3180 | 3560 |
| 27 | Sava | Slavonski Kobaš | 49031 | 1926–1993 (65) | 974 | 2411 | 3260 (1932) | 2974 | 3379 | 3804 |
| 28 | Sava | Slavonski Brod | 50858 | 1945–1993 (49) | 944 | 2466 | 3476 (1974) | 2891 | 3395 | 3751 |
| 29 | Sava | Županja | 62891 | 1929–1998 (65) | 1159 | 2942 | 4161 (1970) | 3763 | 4393 | 5188 |
| 30 | Bregana | Bregana Remont | 88.5 | 1970–1998 (29) | 1.38 | 21.5 | 34.1 (1972) | 31.1 | 41.2 | 51.8 |
| 31 | Lipovačka Gradna | Hamor | 19.11 | 1948–1998 (50) | 0.381 | 4.26 | 7.4 (1989) | 6.1 | 8.75 | 11.3 |
| 32 | Rudarska Gradna | Rudarska Draga | 15.6 | 1957–1994 (38) | 0.255 | 4.49 | 8.79 (1962) | 6.88 | 9.57 | 11.9 |
| 33 | Vrapčak | Gornje Vrapče | 11.7 | 1970–1998 (29) | 0.12 | 3.68 | 15.4 (1975) | 6.79 | 16.1 | 34.9 |
| 34 | Vrapčak | Zagreb | 15 | 1961–1998 (38) | 0.168 | 4.73 | 17.4 (1975) | 7.15 | 13.4 | 18.4 |
| 35 | Črnomerec | Fraterščica | 7.37 | 1953–1998 (46) | 0.084 | 2.18 | 8.42 (1954) | 4.21 | 11.6 | 27.3 |
| 36 | Kustošak | Kustošija | 6.08 | 1956–1998 (32) | 0.054 | 2.58 | 10 (1961) | 6.49 | 12.7 | 25.3 |
| 37 | Medveščak | Mihaljevac | 14.15 | 1971–1998 (28) | 0.135 | 3 | 11.6 (1989) | 4.52 | 11 | 18.1 |
| 38 | Bliznec | Markuševac | 4.97 | 1969–1998 (30) | 0.076 | 1.51 | 5.08 (1995) | 3.75 | 8.52 | 19 |
| 39 | Štefanovec | Dubrava | 8.03 | 1961–1994 (30) | 0.131 | 3.61 | 7.61 (1989) | 5.85 | 8.41 | 11.2 |
| 40 | Trnava | Granešina | 28.95 | 1954–1998 (44) | 0.31 | 7.13 | 27.1 (1980) | 12.6 | 28.2 | 52 |
| 41 | Sunja | Sunja | 225 | 1965–1998 (31) | 2.84 | 87.5 | 141 (1972) | 134 | 177 | 208 |
| 42 | Šumetlica | Cernik | 33.5 | 1972–1998 (27) | 0.291 | 6.45 | 13.7 (1986) | 9.8 | 15 | 19.9 |
| 43 | Sutla | Brezno | 109 | 1946–1975 (30) | 1.34 | 21.8 | 38.6 (1969) | 31.4 | 40.3 | 49.8 |
| 44 | Sutla | Miljana | 263 | 1947–1976 (30) | 4.19 | 65.8 | 77 (1964) | 70.9 | 76.1 | 80 |
| 45 | Sutla | Zelenjak | 455 | 1958–1998 (41) | 7.27 | 123 | 250 (1964) | 184 | 246 | 310 |
| 46 | Krapina | Kupljenovo | 1150 | 1964–1998 (35) | 11.8 | 154 | 268 (1989) | 207 | 274 | 329 |
| 47 | Zelina | Božjakovina | 186 | 1957–1998 (38) | 1.64 | 28.9 | 47.9 (1959) | 44.8 | 64.9 | 86.5 |
| 48 | Lonja | Bisag | 88.8 | 1952–1982 (31) | 0.768 | 15.6 | 22.8 (1966) | 18.9 | 21.5 | 22.9 |
| 49 | Lonja | Lonjica | 326 | 1972–1998 (27) | 1.88 | 21.8 | 52.7 (1976) | 27.7 | 51.3 | 69.6 |
| 50 | Česma | Narta | 881 | 1958–1998 (41) | 5.43 | 51.1 | 104 (1993) | 70.6 | 99.7 | 123 |
| 51 | Česma | Čazma | 2877 | 1963–1998 (36) | 15.1 | 98.3 | 171 (1993) | 147 | 197 | 256 |
| 52 | Ilova | Veliko Vukovje | 995 | 1945–1998 (52) | 7.36 | 71.5 | 151 (1972) | 89.6 | 139 | 169 |
| 53 | Bijela | Badljevina | 170 | 1969–1998 (30) | 1.61 | 23.6 | 36.7 (1980) | 30.5 | 33.7 | 35.1 |
| 54 | Orljava | Pleternica | 745 | 1970–1998 (29) | 5.25 | 63.4 | 117 (1987) | 98.2 | 120 | 139 |
| 55 | Londža | Pleternica | 483 | 1973–1998 (25) | 1.87 | 36.8 | 87.2 (1987) | 64.3 | 101 | 138 |
| 56 | Una | Hrvatska Kostajnica | 8876 | 1926–1991 (65) | 228 | 1138 | 1808 (1955) | 1392 | 1677 | 1823 |

| No. | River | Gauging station | Catch-ment area ($km^2$) | Observing period (no. of years) | Discharges Q ($m^3 s^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | Average max annual | Max obs'd (year of occurrence) | Maximum for return periods (years) | | |
| | | | | | | | | 10 | 100 | 1000 |
| KUPA RIVER BASIN | | | | | | | | | | |
| 57 | Kupa | Kupari | 208 | 1951–1998 (48) | 13.5 | 141 | 195 (1966) | 170 | 199 | 222 |
| 58 | Kupa | Hrvatsko | 370 | 1957–1998 (40) | 20.5 | 287 | 419 (1966) | 384 | 485 | 599 |
| 59 | Kupa | Petrina | 528 | 1951–1992 (42) | 26.6 | 455 | 1079 (1952) | 641 | 898 | 1140 |
| 60 | Kupa | Radenci | 1304 | 1951–1992 (42) | 53.7 | 647 | 920 (1968) | 809 | 945 | 1034 |
| 61 | Kupa | Pribanjci | 1492 | 1949–1985 (37) | 61.8 | 675 | 1021 (1966) | 862 | 1028 | 1167 |
| 62 | Kupa | Ladešić Draga | 1590 | 1956–1998 (42) | 58.4 | 700 | 1010 (1966) | 851 | 975 | 1049 |
| 63 | Kupa | Kamanje | 2192 | 1957–1998 (40) | 73.3 | 811 | 1145 (1966) | 967 | 1139 | 1266 |
| 64 | Kupa | Brodarci | 3405 | 1957–1998 (41) | 110 | 944 | 1237 (1968) | 1160 | 1305 | 1419 |
| 65 | Kupa | Rečica | 5923 | 1948–1982 (35) | 171 | 1137 | 1533 (1966) | 1450 | 1667 | 1791 |
| 66 | Kupa | Jamnička Kiselica | 6805 | 1948–1978 (31) | 180 | 967 | 1581 (1953) | 1416 | 1791 | 2351 |
| 67 | Kupa | Šišinec | 7274 | 1950–1991 (41) | 182 | 949 | 1259 (1974) | 1114 | 1338 | 1503 |
| 68 | Kupa | Farkašić | 8902 | 1965–1992 (26) | 196 | 1048 | 1631 (1974) | 1281 | 1593 | 1839 |
| 69 | Kupa | Brest | 9021 | 1926–1974 (49) | 206 | 1006 | 1523 (1974) | 1204 | 1382 | 1481 |
| 70 | Čabranka | Zamost | 103 | 1950–1998 (49) | 3.72 | 76 | 128 (1984) | 115 | 143 | 169 |
| 71 | Kupica | Brod na Kupi | 291 | 1951–1998 (48) | 13.7 | 146 | 357 (1993) | 194 | 293 | 377 |
| 72 | Kupčina | Strmac | 125 | 1959–1998 (40) | 2.18 | 22.7 | 45.8 (1974) | 38.7 | 57.4 | 88 |
| 73 | Kupčina | Lazina Brana | 169 | 1973–1998 (26) | 2.07 | 22.9 | 28.8 (1989) | 27.7 | 30.8 | 32.4 |
| 74 | Križ Potok | CP Križ | 5.4 | 1963–1998 (36) | 0.312 | 14.3 | 28.3 (1982) | 22.5 | 29.9 | 37.6 |
| 75 | Vela Voda | Crni Lug | 3.7 | 1963–1998 (36) | 0.208 | 7.98 | 12.7 (1965) | 12 | 16.8 | 22.4 |
| 76 | Bela Voda | Crni Lug | 1.8 | 1963–1998 (36) | 0.106 | 5.42 | 9.78 (1963) | 9.13 | 11.5 | 14.3 |
| 77 | Leska | Leska | 0.25 | 1963–1998 (26) | 0.015 | 0.603 | 1.31 (1963) | 0.933 | 1.44 | 1.92 |
| 78 | Klada | Klada | 0.33 | 1963–1998 (26) | 0.018 | 0.443 | 1.2 (1963) | 0.904 | 1.49 | 2.34 |
| 79 | Gornja Dobra | Luke | 175 | 1947–1998 (51) | 7.04 | 109 | 166 (1968) | 135 | 161 | 179 |
| 80 | Gornja Dobra | Turkovići | 296 | 1963–1998 (33) | 10 | 118 | 154 (1998) | 148 | 178 | 205 |
| 81 | Vitunjčica | Brestovac | 34 | 1967–1998 (31) | 3.28 | 31.3 | 40 (1998) | 36.8 | 39.6 | 41.9 |
| 82 | Donja Dobra | Trošmarija | 821 | 1960–1998 (39) | 27.9 | 163 | 246 (1966) | 194 | 226 | 246 |
| 83 | Donja Dobra | Donje Stative | 1049 | 1960–1998 (39) | 34.9 | 249 | 372 (1966) | 309 | 393 | 451 |
| 84 | Ribnjak | Lučanjek | 50 | 1948–1975 (27) | 3.01 | 16.4 | 25.7 (1962) | 22.8 | 28.5 | 33.8 |
| 85 | Globornica | Generalski Stol | 32 | 1949–1975 (27) | 1.02 | 18.8 | 31.4 (1966) | 30.7 | 42.5 | 60.6 |
| 86 | Mrežnica | Juzbašići | 683 | 1947–1998 (46) | 12.4 | 92.4 | 166 (1989) | 122 | 148 | 166 |
| 87 | Mrežnica | Mrzlo Polje | 975 | 1947–1998 (52) | 29.5 | 254 | 373 (1974) | 329 | 390 | 445 |
| 88 | Tounjčica | Ožanići | 118 | 1948–1975 (28) | 10.4 | 70.1 | 95.6 (1952) | 89.4 | 98.8 | 108 |
| 89 | Munjavčica | Josipdol | 44.1 | 1948–1975 (27) | 0.431 | 3 | 5.84 (1968) | 4.85 | 6.78 | 9.06 |
| 90 | Korana | Korana | 232 | 1952–1986 (35) | 3.09 | 19.2 | 36.2 (1957) | 28 | 37.4 | 50.5 |
| 91 | Korana | Slunj | 614 | 1964–1998 (29) | 11.1 | 137 | 271 (1973) | 217 | 298 | 402 |
| 92 | Korana | Veljun | 943 | 1949–1998 (44) | 23 | 264 | 460 (1955) | 363 | 438 | 495 |
| 93 | Korana | Velemerić | 1297 | 1946–1997 (46) | 28.8 | 327 | 571 (1948) | 453 | 616 | 769 |
| 94 | Plitvice – Kozjak | Kozjak Most | 169 | 1953–1991 (33) | 3.55 | 16.2 | 28.9 (1955) | 24.2 | 33.2 | 40 |
| 95 | Plitvice – Matica | Plitvički Ljeskovac | 20.6 | 1952–1991 (37) | 2.42 | 12 | 49.5 (1976) | 14.3 | 23.4 | 29.7 |
| 96 | Slunjčica | Slunj | 220 | 1949–1983 (35) | 9.48 | 58.5 | 80 (1962) | 72.6 | 80.6 | 86.5 |
| 97 | Radonja | Tušilović | 224 | 1967–1998 (26) | 3.32 | 27.5 | 40.7 (1987) | 35.1 | 43.6 | 50.2 |
| 98 | Glina | Maljevac | 183 | 1953–1986 (34) | 3.37 | 38.5 | 90.6 (1959) | 52.7 | 82.4 | 108 |
| 99 | Glina | Vranovina | 889 | 1947–1998 (45) | 14.1 | 146 | 344 (1974) | 275 | 411 | 619 |
| 100 | Glina | Glina | 1145 | 1952–1998 (40) | 18.3 | 178 | 395 (1955) | 290 | 438 | 607 |

## RESULTS

By applying the described methodology, Creager's and Francou-Rodier's envelope curves of maximum specific discharges and maximum discharges were defined for average maximum annual discharges, for the highest observed discharges and for maximum annual discharges of the 10, 100 and 1000-year return periods. The results obtained are shown in Figs 2, 3, 4 and 5.

The summary overview of the calculated regional parameters *a*, *b*, *c* of Creager's formula, and *K* of Francou-Rodier's formula is shown in Table 2.

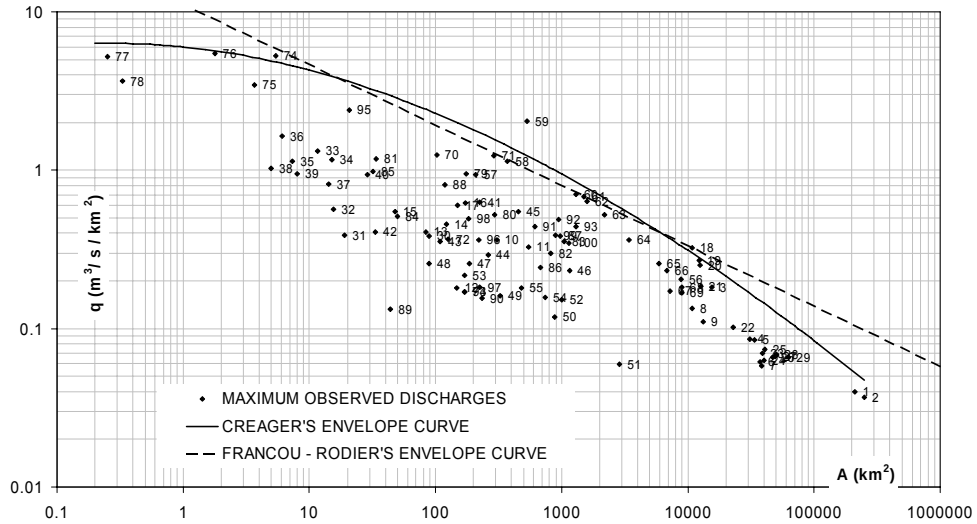


**Fig. 2** Creager's and Francou-Rodier's envelope curves of maximum observed specific discharges in the Danube River basin in Croatia.

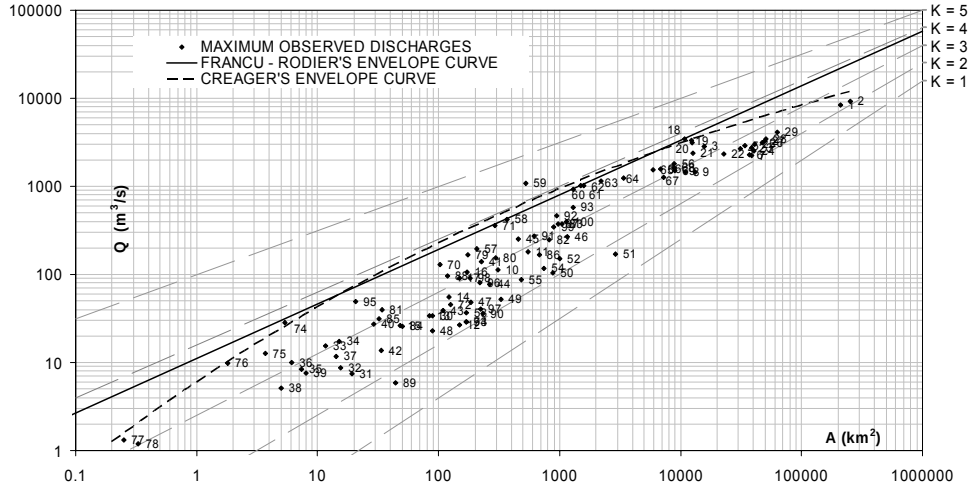


**Fig. 3** Creager's and Francou-Rodier's envelope curves of maximum observed discharges in the Danube catchment area in Croatia

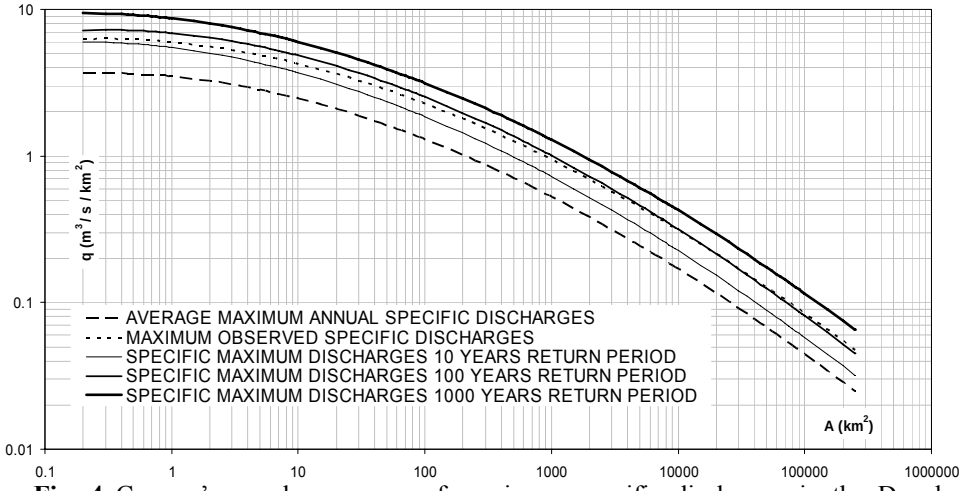


**Fig. 4** Creager's envelope curves of maximum specific discharges in the Danube River basin in Croatia.

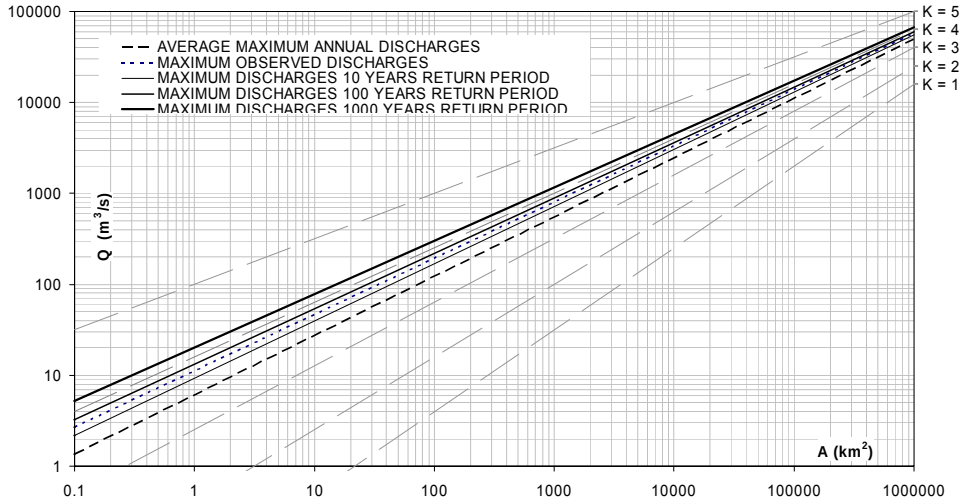


**Fig. 5** Francou-Rodier's envelope curves of maximum discharges in the Danube River basin in Croatia.

**Table 2** Summary overview of calculated regional parameters.

| Discharges | Creager's formula | | | Francou–Rodier formula |
|---|---|---|---|---|
| | *a* | *b* | *c* | *K* |
| Average maximum annual | 3.5 | 0.918 | –0.034 | 3.478 |
| Maximum observed | 6.0 | 0.920 | –0.033 | 3.808 |
| Maximum of 10-year return period | 5.5 | 0.894 | –0.034 | 3.711 |
| Maximum of 100-year return period | 6.9 | 0.919 | –0.035 | 3.899 |
| Maximum of 1000-year return period | 8.7 | 0.903 | –0.032 | 4.132 |

## CONCLUSION

The relationships presented in this paper were calculated on the basis of 99 available and sufficiently long homogenous time series of observed discharges at gauging stations on the Danube River basin in Croatia and can be used for evaluation of the reliability of previously calculated maximum discharges for this area. Comparisons between the calculated envelope curves show that the Francou-Rodier envelopes give smaller values of maximum discharges than Creager's envelopes for all catchment areas except very small and very large ones.

Because of the climate, relief and geological diversity of the investigated area, further studies of envelope curves of maximum discharges in the Danube River basin in Croatia should be directed to sub-regionalization. Further regional studies of flood characteristics in the Danube catchment area in Croatia should be also directed to analysis of flood wave volumes and durations.

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