Data Collection, hydraulic and morphological modelling of the Danube River and the Sava River in the Republic of Serbia
Lot 1: Hydraulic and morphological modelling of the SRB-HRV common stretch of the Danube River

404-02-00086/2022-06

REPORT ON HYDROLOGICAL ANALYSIS AND UPDATE OF ENRs

Version: **Final**
Date: 31 October 2024
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Content

Tables

Figures

Abbreviations

Abbr.	Meaning
DHMZ	State Hydro-meteorological Service of Croatia
H	Stage (water level)
HNWL	High Navigation Water Levels
HRV	Croatia
km	Kilometer
LNWL	Low Navigation Water Levels
m	Meter
m^3/s	Cubic meters per second
Max	Maximum
Min	Minimum
Q	Discharge
RHMZ	Republic Hydro-meteorological Service of Serbia
SRB	Serbia
ToR	Terms of Reference

Introduction

This report provides support in preparing hydrological input for the development of the hydrodynamic model of the common Serbian-Croatian stretch of the Danube River. It is aimed at characterizing water regime at this stretch of the Danube and conditions for navigation during low flows, mean flows and flood flows.

All analyses in the report are performed having in mind the requirements of ToR related to the assessment of low and high navigable water levels (LNWL and HNWL, respectively). More specifically, the Danube Commission (Glossary of the Danube navigation, 2015) defines LNWL as the water level having duration of 94% in a year that is computed from data on the observed river discharges over a period of 30 years, excluding the periods with presence of ice. Similarly, HNWL is defined as the water level with duration of 1%, based on the discharges observed during a period of 30 years, excluding the ice periods. Starting from this definition, the study is focusing on the hydrological data on discharges in the last 30 years (1994-2023).

The following section reviews data used in the hydrological analysis, followed by the section which provides preliminary considerations of the available data. This step in the report was necessary in order to check consistency of data at twin Serbian and Croatian stations along the common stretch of the Danube. After this preliminary analysis, the three aspects of water regime (low, mean, flood flows) are described. The final section provides hydrological assessment of low and high navigable water levels.

1. Data Used in the study

The common Serbian-Croatian reach of the Danube between the Hungarian border and Backa Palanka (chainage from km 1,433 to km 1,295) is covered by 4 hydrological stations operated by Republic Hydrometeorological Service of Serbia (RHMZ) and 9 stations operated by Croatian Meteorological and Hydrological Service (DHMZ). The stations are shown in Figure 1 and listed in Table 1. Of additional importance are the stations on the Drava River, which can help in assessing water balance before and after its confluence with the Danube. These stations are also listed in Table 1.

Discharge is measured at 3 stations in Serbia and 5 stations in Croatia. Only two stations in Serbia (Bezdan and Bogojevo) have discharge records of 30 years or longer, while the Croatian stations generally have only 22 years of record. The length of record on stages (water levels) is generally longer.

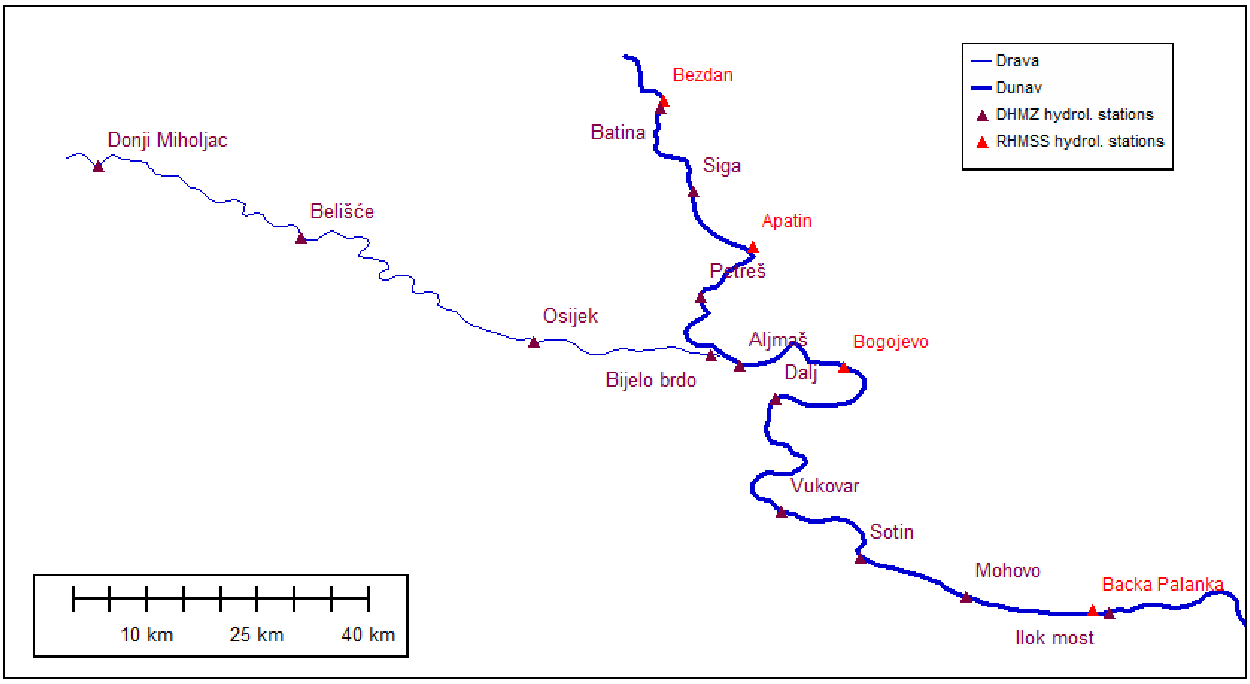


Figure 1: Hydrological stations in the study area

Table 1: Hydrological stations on the Danube River from rkm 1.433 to rkm 1.295 and on the Drava River

Hydrological station	Approx. chainage (rkm)	Year of establishment	Gauge zero (m)	Measurements (H – stage, Q – discharge)	Data available
		Danube – Serbia			
Bezdan	1425.59	1856	80.64	H, Q	Yes
Apatin	1401.90	1876	78.84	H	Yes
Bogojevo	1367.25	1871	77.46	H, Q	Yes
Backa Palanka	1298.56	1888	73.97	H, Q	Yes
		Danube – Croatia			
Batina	1424.60	2001	80.45	H, Q	Yes
Siga	1412	2017	78.51	H	No
Petres	1393	2017	77.275	H	No
Aljmas	1380.25	1909	78.08	H, Q	Yes
Dalj	1353.7	1985	75.204	H, Q	Yes
Vukovar	1333.4	1856	76.188	H, Q	Yes
Sotin	1322	2017	74.021	H	No
Mohovo	1311	2017	73.912	H	No
Ilok / Ilok most	1298.70	1856	73.968	H, Q	Yes
		Drava – Croatia			
Bijelo Brdo	1.0	1964	78.324	H	Yes
Osijek	18.96	1827	81.481	H	Yes
Belisce	53.8	1962	83.993	H, Q	Yes
Donji Miholjac	80.5	1988	88.57	H, Q	Yes

Source: internet sites of RHMZ and DHMZ

Note: Gauge zero elevations for all stations are according to the Adriatic Sea level

For the purpose of this analysis, the following data from 3 hydrological stations operated by RHMZ (Bezdan, Bogojevo, Backa Palanka) were requested and obtained from RHMZ:

- Daily water stages and flows for last 30 years (1994-2023);
- Annual minimum and maximum stage and flow for the complete observational record; and
- Data on ice phenomena for the complete observational record.

Data on stage-discharge relationships for these stations were also requested, but were not delivered by RHMZ. They have been made available unofficially from "Plovput".

The following data were made available for the stations operated by DHMZ:

- Daily water stages and flows for the period of record, ending with year 2022; and
- Stage-discharge rating curves.

Table 2 gives an overview of data from Serbian stations available for this study. The record of daily stages and discharges for Bezdan is continuous throughout the last 30 years, while the record for Bogojevo has gaps. Data for Backa Palanka start only in 2013, and have a gap in 2015. Data on annual extremes of stage and discharge was obtained for the complete period of record to facilitate valid statistical analysis. The record of extremes is longer for stages (from 1894 at Bezdan and from 1921/1922 at Bogojevo and Backa Palanka), while the extreme discharges are available from 1950 at Bezdan and Bogojevo and only from 2013 at Backa Palanka. Data on ice phenomena have some gaps.

Table 2: Data from hydrological stations operated by RHMZ available for the study

Station	Data				
	Daily water levels	Daily discharges	Annual max/min water levels	Annual max/min discharges	Ice phenomena
Bezdan	1994-2023	1994-2023	1894-2023	1950-2023	1994-2023
Bogojevo	1994-28.2.2010, 1.3.2011-2023	1994-1995, 1998-2009, 1.3.2011-2023	1921-1940, 1943, 1946-2009, 2012-2023	1950-1995, 1998-2009, 2012-2023	1994-2023
Bačka Palanka	2013-31.5.2015, 7.7.2015-2023	2013-28.2.2015, 7.7.2015-2023	1922-1943, 1946-1988, 1990, 1999-2002, 2004-2014, 2016-2023	2013-2014, 2016-2023	1999-2023

Table 3 shows the availability of data at Croatian stations operated by DHMZ. Unfortunately, none of the Croatian stations has data that covers the complete 30-year period 1994-2023.

Table 3: Data from hydrological stations operated by DHMZ available for the study

Station	Data on daily water levels	Data on daily discharges
Batina	9.3.2001-2022	2002-2022
Aljmaš	1.7.1998-2022	2001-2022
Dalj	1.7.1998-2003, 2005-2022	2001-2003, 2005-2022
Vukovar	4.6.1998-8.7.2018, 10.10.2018-2022	2001-8.7.2018, 10.10.2018-2022
Ilok	1.7.1998-2022	2001-2022

Station	Data on daily water levels	Data on daily discharges
Bijelo Brdo	1964-2013	
Osijek	1946-2023	
Belišće	1962-2022	1962-2022
Donji Miholjac	1993-2022	1994-2022

2. Preliminary Analysis of Available Data

Hydrological analyses in this study are based on data from the latest 30 years, focusing on the 1994-2023 period. However, due to different lengths of time series at Serbian and Croatian stations, the results of various statistical analyses in this study may not be directly comparable among the stations. For this reason, it was necessary to perform preliminary analysis of data in a common period with available data and to get an insight into possible uncertainties stemming from using short data series.

To understand relative magnitudes of discharges at the stations, a 10-year period of 2013-2022 with data available at all stations (with smaller gaps at Backa Palanka and Vukovar) is considered. Box plots showing distributions of daily discharges at all stations over 2013-2022 are given in Figure 2, together with mean flows in the same period. The figure shows that the measurements at stations Bezdan and Batina, which are virtually at the same chainage, are in good agreement, except for the lowest flows which are lower at Batina. Mean flows over 2013-2022 at these two stations differ by about 2%. Distributions of discharges at two stations located downstream of the confluence of the Danube and Drava, Aljmas and Bogojevo, also show good agreement except for the lowest flows. Mean flow at Bogojevo for 2013-2022 is slightly lower (by 2.5%) than the mean flow at Aljmas despite being a downstream station. At the end of the SRB-HRV sector, stations Ilok and Backa Palanka (located at the same chainage) show similar ranges and their mean flows over 2013-2022 differ by 2.5%.

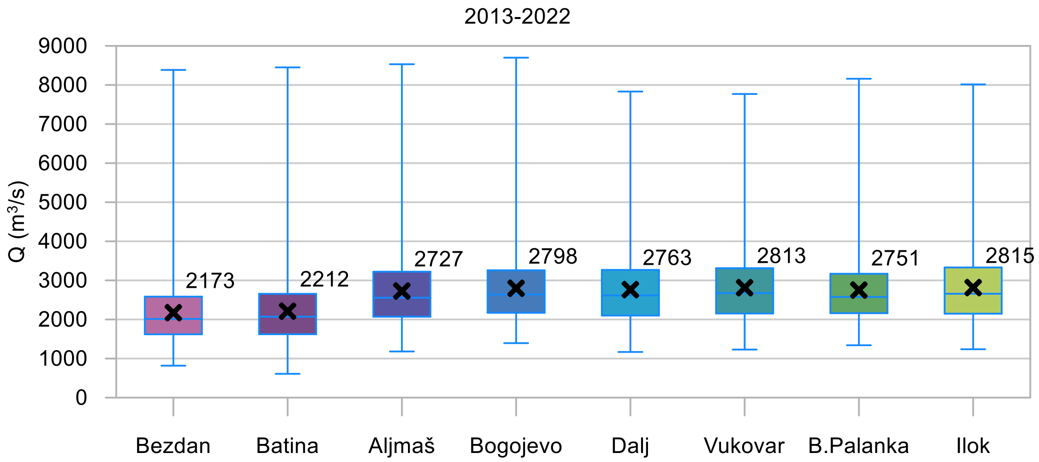


Figure 2: Ranges and distribution quantiles of daily flows (box-plots) and mean flows (black crosses) for 2013-2022

Overall comparison of mean flows for 2013-2022 shows slight inconsistencies at the stations downstream from the Drava confluence since they do not systematically increase in downstream direction. Despite the small differences in mean flows (about 2%), much greater differences may arise during specific periods. An example is given in Figure 3, which shows significant divergence of discharges at Backa Palanka and Ilok during the low-flow season in 2018, while the water level measurements are in agreement.

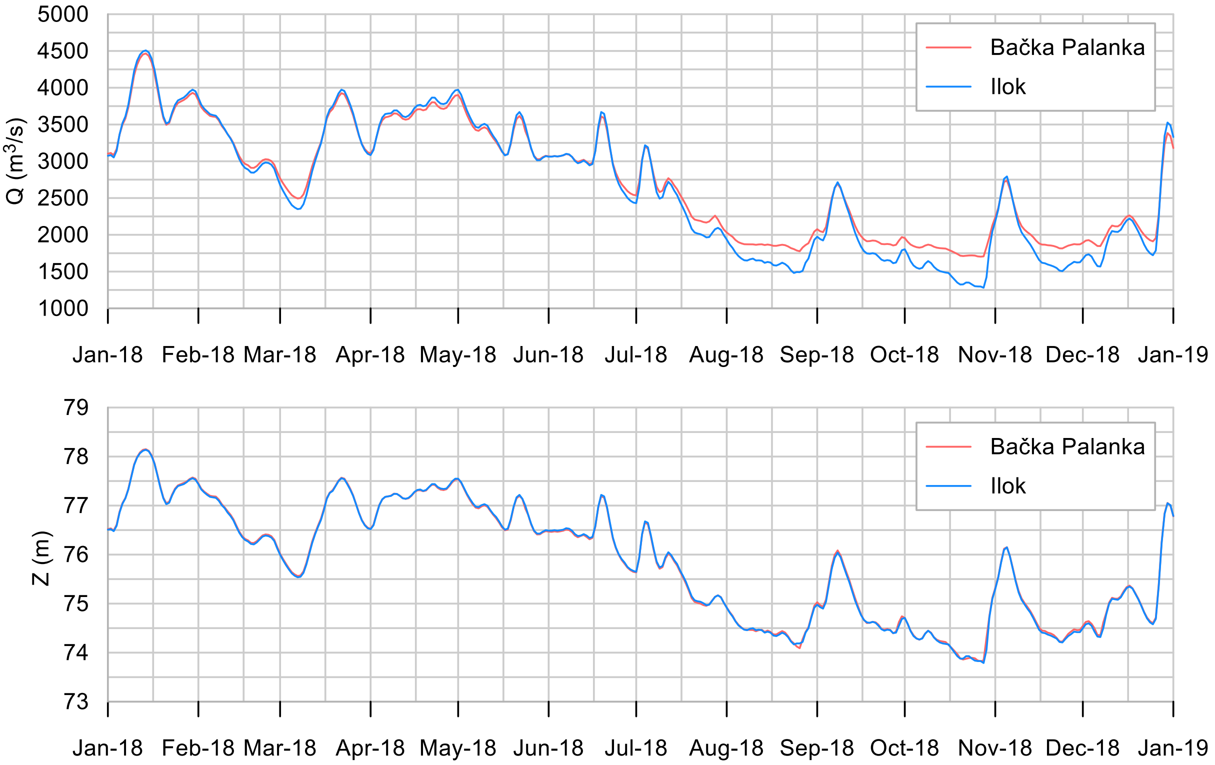


Figure 3: Annual hydrograph (top: discharges, bottom: water levels) at Backa Palanka and Ilok for 2018, showing significant differences in estimated river discharges during the low-flow season

By comparing discharges at twin stations, it was found that the greatest differences are attributed to low flows and below-average flows in general (Figure 4). Differences in discharges can generally originate from discrepancies in either water level measurements, or in stage-discharge relationships employed by RHMZ and DHMZ to convert measured stage into discharges. Differences in water level measurements at twin stations are mostly small or reasonable, but in few cases are substantial, indicating some kind of error (

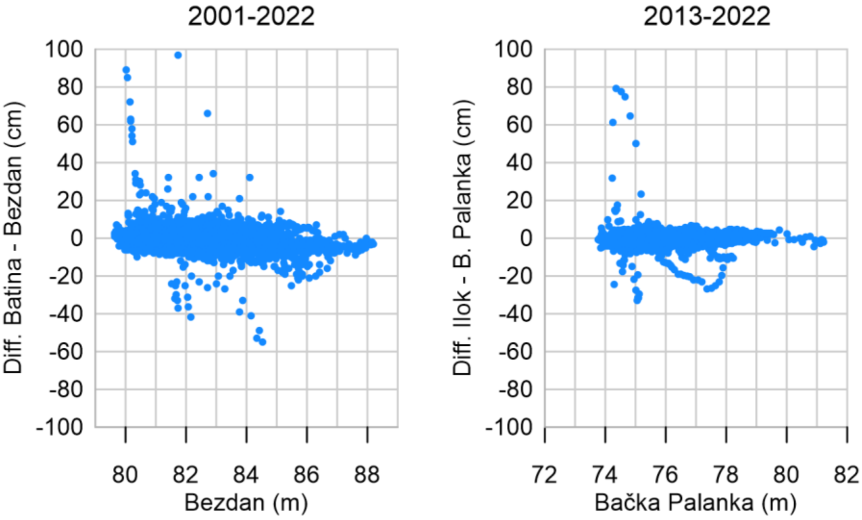


Figure *5*). On the other hand, stage-discharge relationships at twin stations are different in a complex manner (Figure 6). For the same water level, they produce discharges that could be either greater or smaller than those at the twin station. It should be noted that stage-discharge curves for Croatian stations were obtained from DHMZ in a functional form of quadratic regression, while the curves for the Serbian stations were reconstructed from the simultaneous data on stages and discharges.

From this preliminary analysis, it is obvious that there are two main factors that bring uncertainties into the hydrological analyses: short records and inconsistencies in measurements and data processing techniques at Serbian and Croatian stations. Having in mind that one of the goals of this study is to define low and high navigable water levels by analyzing the discharges, the uncertainties related to discharges at twin stations have to be understood and taken into account.

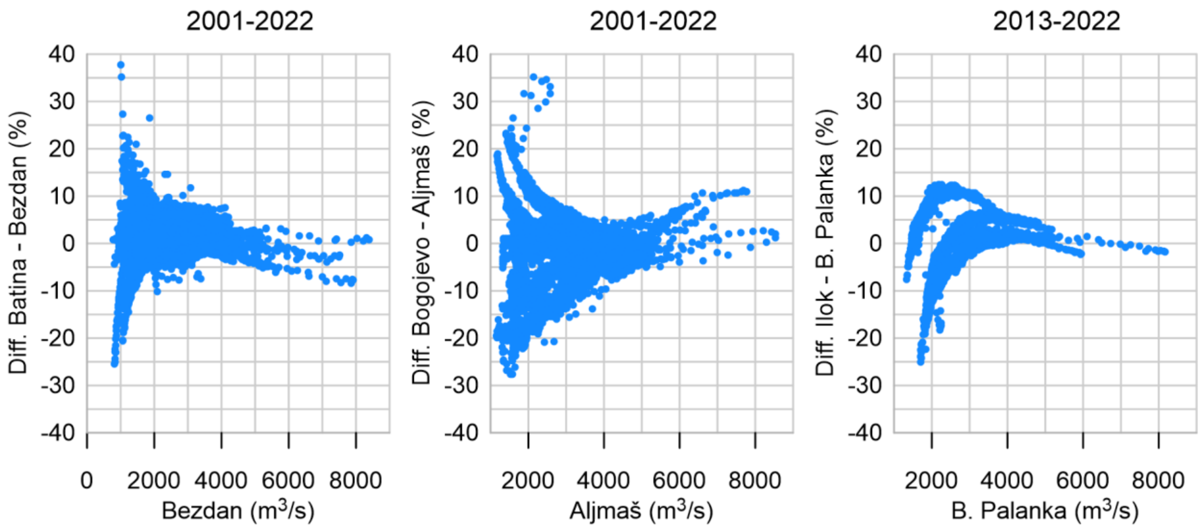


Figure 4: Percentage differences in daily discharges measured at twin stations (left: Bezdan and Batina, middle: Aljmas and Bogojevo, right: Backa Palanka and Ilok) in relation to the magnitude of discharge

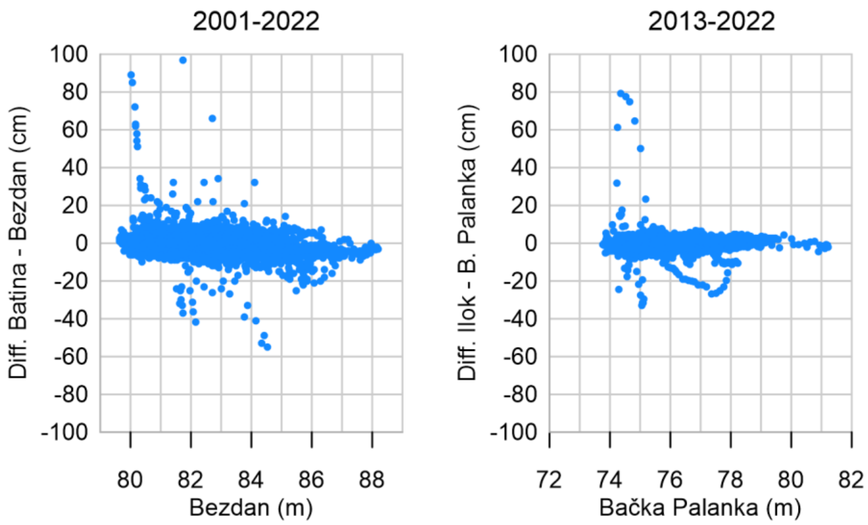


Figure 5: Differences in daily water levels measured at twin stations (left: Bezdan and Batina, right: Backa Palanka and Ilok)

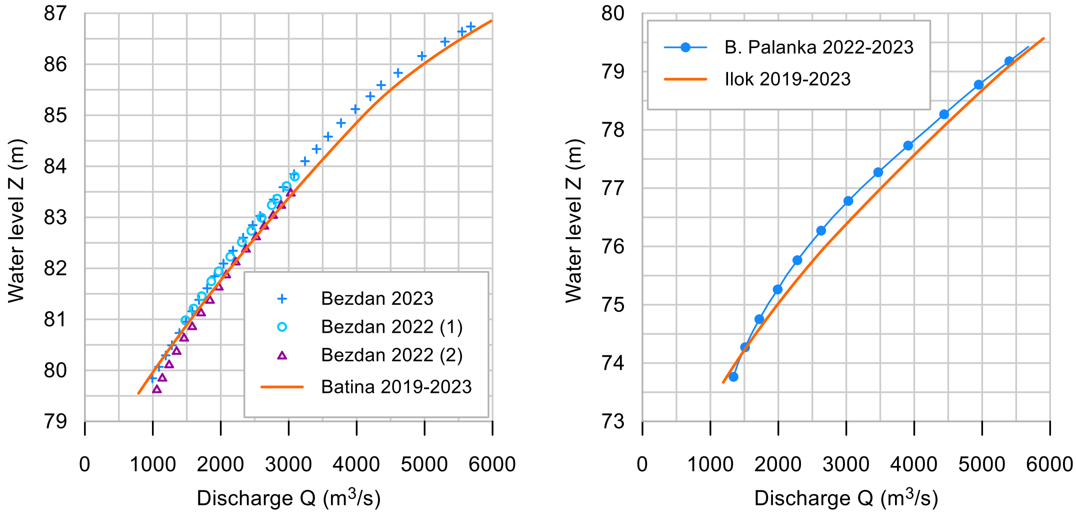


Figure 6: Stage-discharge curves at twin stations (left: Bezdan and Batina, right: Bačka Palanka and Ilok)

3. Mean Flows

3.1. Mean Flows for 1994-2023

Characteristic discharges at hydrologic stations along the Danube are computed for all stations with discharge data regardless of the series length within the 1994-2023 period. This is justified by small differences (up to 5%) in mean flows over 1994-2023 and over 2013-2022 at stations having (almost) complete record, thus confirming an assumption that the partial records may be used for the assessment of mean flows at stations with incomplete data.

Frequency distributions of daily discharges at all stations along the SRB-HRV sector of the Danube during 1994-2023 are shown in Figure 7. Table 4 shows average discharge and maximum and minimum observed discharges at each station. For Serbian stations, absolute minimum and maximum discharges are shown, while the minimum and maximum daily discharges are shown for the Croatian stations. Figure 8 shows the evolution of the mean flows with the chainage along the Danube.

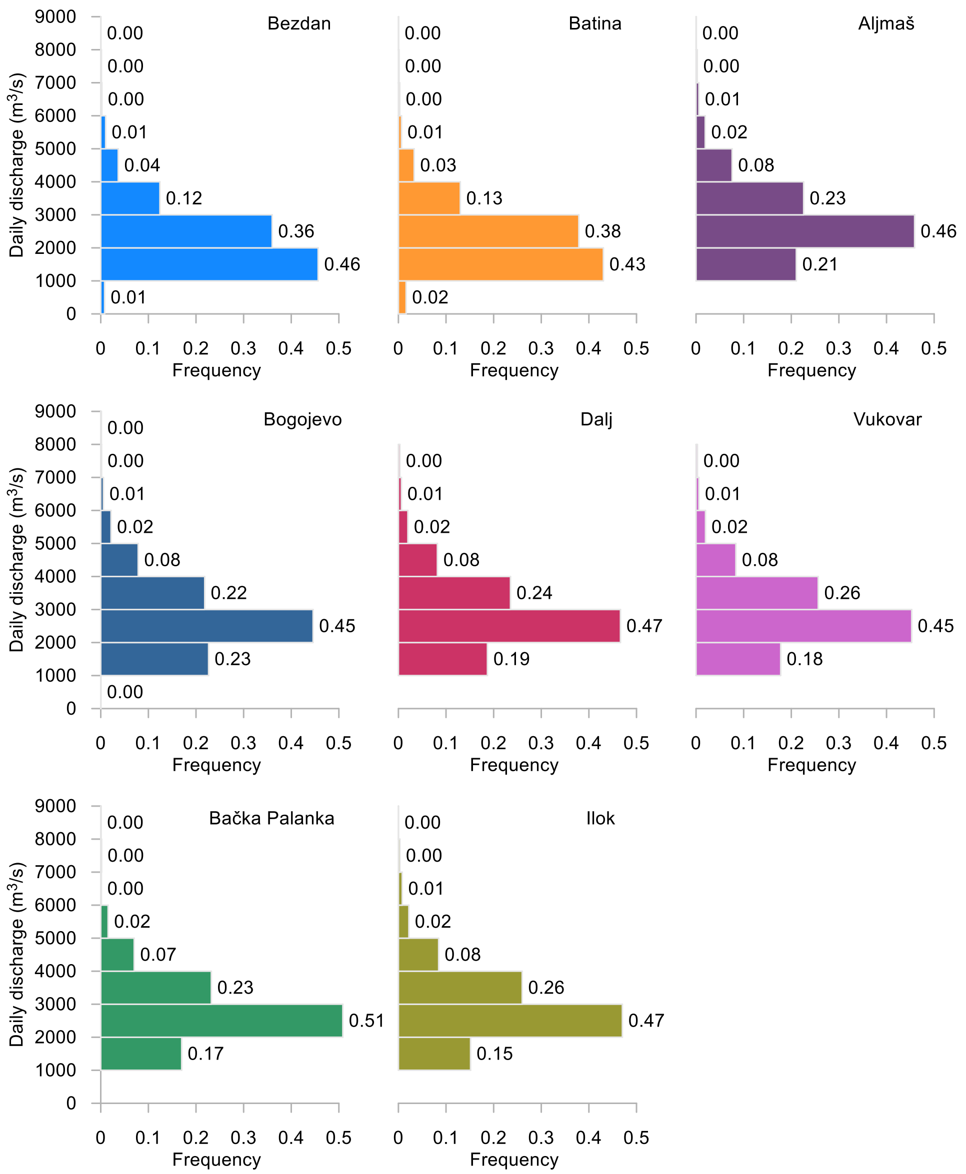


Figure 7: Frequencies of daily discharges of the Danube at hydrological stations for 1994-2023

Table 4: Range of discharges of the Danube and Drava at hydrological stations for 1994-2023

Station	Years with complete data	1994-2023		
		Mean flow (m^3/s)	Minimum observed flow (m^3/s)	Maximum observed flow (m^3/s)
Danube				
Bezdan	30	2280	784 (2003)	8410 (2013)
Batina	21	2274	609 (2018)	8450 (2013)
Aljmaš	22	2775	1149 (2003)	8531 (2013)
Bogojevo	26	2756	915 (2003)	8710 (2013)
Dalj	21	2822	1168 (2022)	7832 (2013)
Vukovar	21	2844	1029 (2003)	7770 (2013)
Ilok	22	2887	1192 (2003)	8015 (2013)

Station	Years with complete data	1994-2023		
		Mean flow (m^3/s)	Minimum observed flow (m^3/s)	Maximum observed flow (m^3/s)
Bačka Palanka	10	2755	1340 (2022)	8180 (2013)
Drava				
Donji Miholjac	29	508	175 (2022)	2166 (2014)
Belišće	20	516	205 (2002)	2017 (2014)

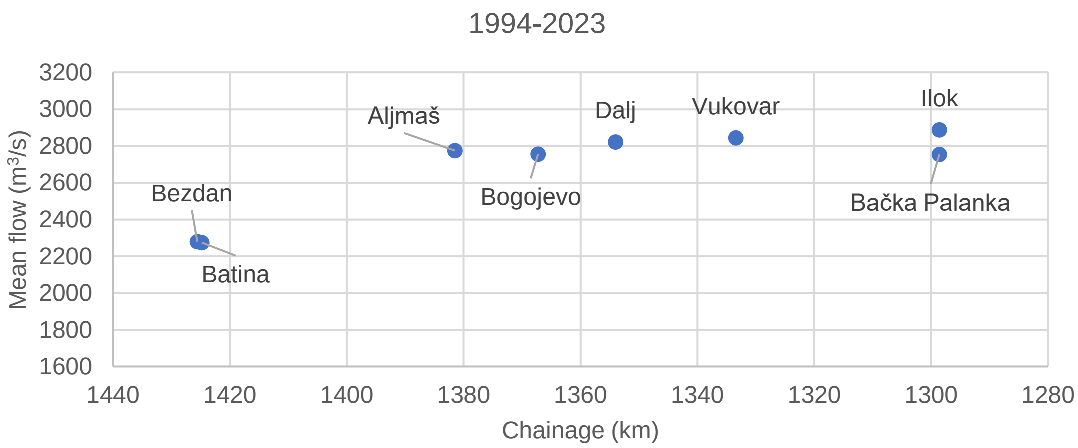


Figure 8: Mean flows at hydrological stations along the SRB-HRV sector of the Danube

3.2. Annual Flows

Figure 9 shows the series of annual discharges at all stations for the last 30 years (1994-2023). Data on annual discharges for Serbian stations Bezdan and Bogojevo are available from 1950 and these long-term series are shown in Figure 10. The long-term series indicate that the Danube regime along this stretch after 1980 is less variable than before 1980. Both the lowest and the highest annual discharges were recorded before 1980. Since this study is based on the data from the last 30 years (1994-2023), the series of mean annual discharges at Bezdan and Bogojevo was tested for homogeneity with a break point in 1994, i.e., periods 1950-1993 and 1994-2023 were compared. Several parametric and non-parametric homogeneity tests were applied (t-test and Mann-Whitney test for means, F-test for variances). The results shown in Table 5 indicate that the variance of the mean annual discharges is significantly different in the second period compared to the first period (as per F-test at 5% significance level). Change in mean discharge from one period to another is not significant (t-test for means with unequal variances and Mann-Whitney test at 5% significance level). Trend in the mean annual discharge series was not detected (non-parametric Mann-Kendall test and parametric test for significance of the slope of linear regression).

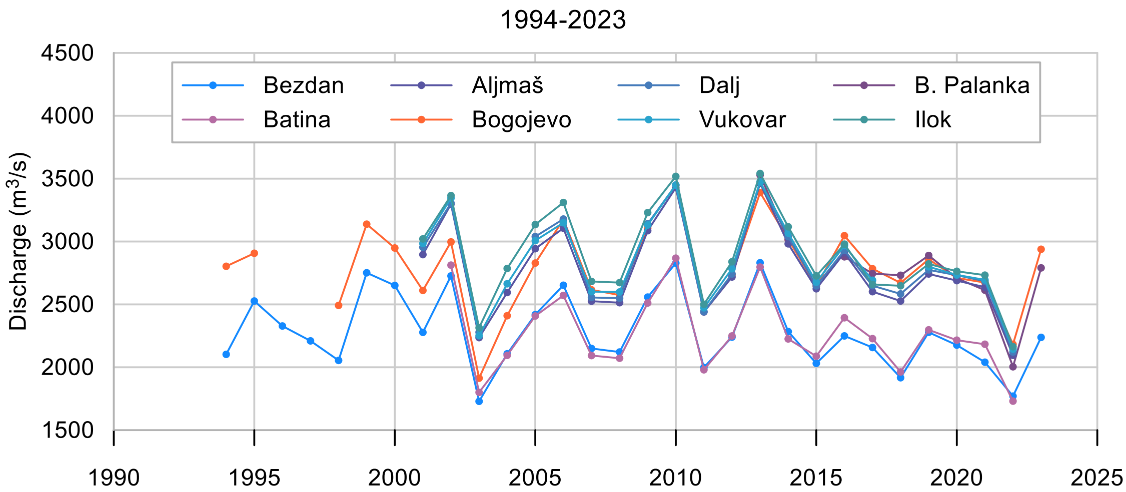


Figure 9: Mean annual discharges of the Danube for 1994-2023

Table 5: Results of statistical tests on homogeneity and presence of trend for the series of mean annual discharges

Station	**Bezdan**		**Bogojevo**	
Period	1950-1993	1994-2023	1950-1993	1994-2023
No. of data	44	30	44	26
Mean	2255	2280	2806	2776
Stand. dev.	463	296	525	316
F-test	F statistic = 2.445 p-value = 0.007 < 0.05 H_0 (equal variances) rejected		F statistic = 2.769 p-value = 0.004 < 0.05 H_0 (equal variances) rejected	
t-test	t statistic = -0.278 p-value = 0.782 > 0.05 H_0 (equal means) not rejected		t statistic = 0.301 p-value = 0.764 > 0.05 H_0 (equal means) not rejected	
Mann-Whitney test	t statistic = -0.859 p-value = 0.390 > 0.05 H_0 (equal means) not rejected		t statistic = -0.352 p-value = 0.724 > 0.05 H_0 (equal means) not rejected	
Mann-Kendall test	z statistic = -0.056 p-value = 0.955 > 0.05 H_0 (absence of trend) not rejected		Test cannot be applied due to gaps	
Linear regression slope test	Correlation coefficient = -0.066 t statistic = -0.560 p-value = 0.577 > 0.05 H_0 (absence of trend) not rejected		Correlation coefficient = -0.086 t statistic = -0.708 p-value = 0.481 > 0.05 H_0 (absence of trend) not rejected	

Long-term variability of mean annual discharges at Bezdan and Bogojevo was also examined by means of moving average with a 11-year window (Figure 10). Smoothed series indicate almost two cycles of long-term periodicity (the first one ending in the beginning of 1990s, while the second one is not finished). The length of the cycles could roughly be estimated at about 40 years. Figure 11 shows normalized cumulative periodogram for Bezdan resulting from spectral analysis. It does not reveal any significant harmonics in the series of annual discharges, but the harmonic with the greatest amplitude (accounting for about 11% of total series variance) has frequency of 1/37 years^{-1}, what corroborates visual identification of the 40-year cycles. The above conclusion is important for consideration of discharges of the Danube at the given stretch over the last 30-year period, which obviously belongs to an unfinished cycle that is expected to end within the next decade.

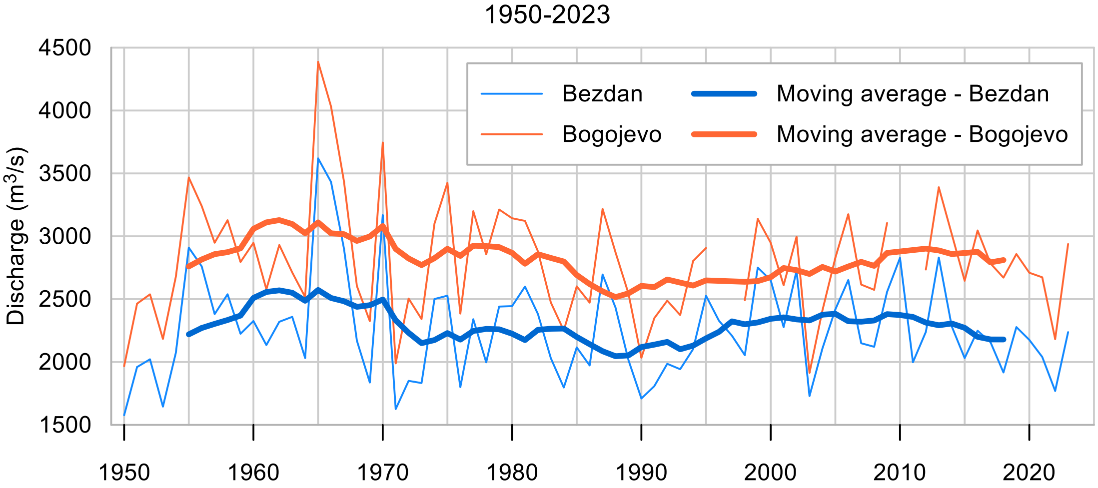


Figure 10: Long-term series of mean annual discharges of the Danube at Bezdan and Bogojevo with 11-year moving average

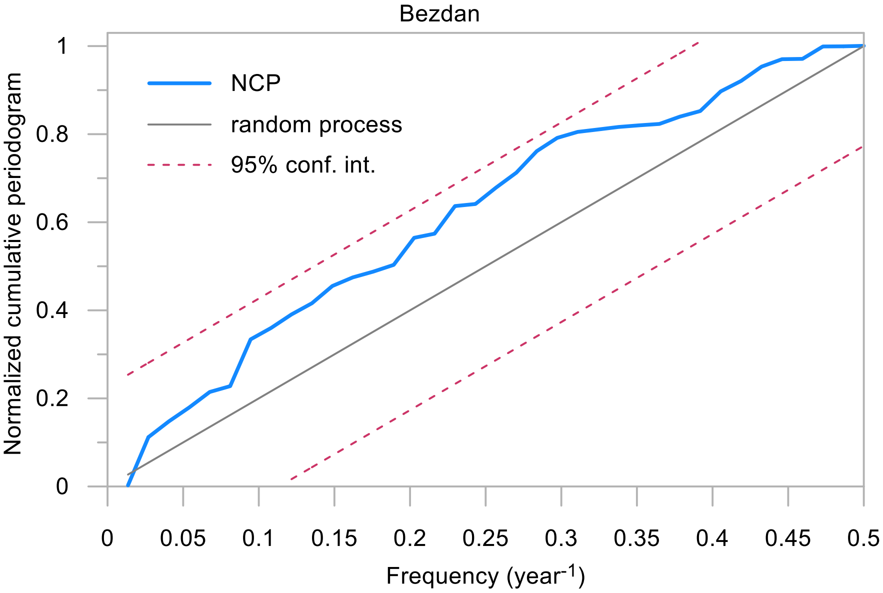


Figure 11: Normalized cumulative periodogram (NCP) for the series of annual discharges at Bezdan

To get an insight into the influence of the Drava River on the Danube discharges upstream and downstream of the confluence, Figure 12 shows normalized mean annual discharges at Bezdan, Bogojevo and Donji MIholjac (discharges are normalized in respect to the long-term means for 1950-2023). This figure also shows 11-year moving averages for the three stations, suggesting that the relative contribution of the Drava River between 1995 and 2010 was lower than in other periods. This resulted in somewhat different relative average discharges upstream and downstream of the Drava confluence, with Bezdan having discharge slightly above the long-term mean and Bogojevo exhibiting average discharges slightly below the long-term mean.

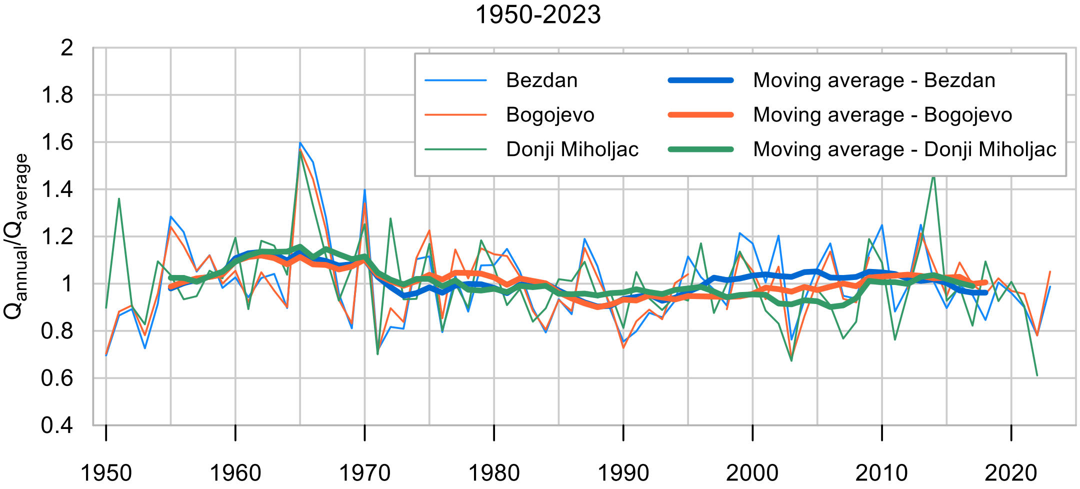


Figure 12: Long-term series of normalized mean annual discharges of the Danube at Bezdan, Bogojevo, and Drava at Donji Miholjac with 11-year moving average

Figure 13 and Table 6 provide the results of frequency analysis of long-term series of annual discharges at Bezdan and Bogojevo. For both stations, log-Pearson type 3 distribution is used to fit empirical distribution. The analysis was not performed for the short series at Backa Palanka and at Croatian stations.

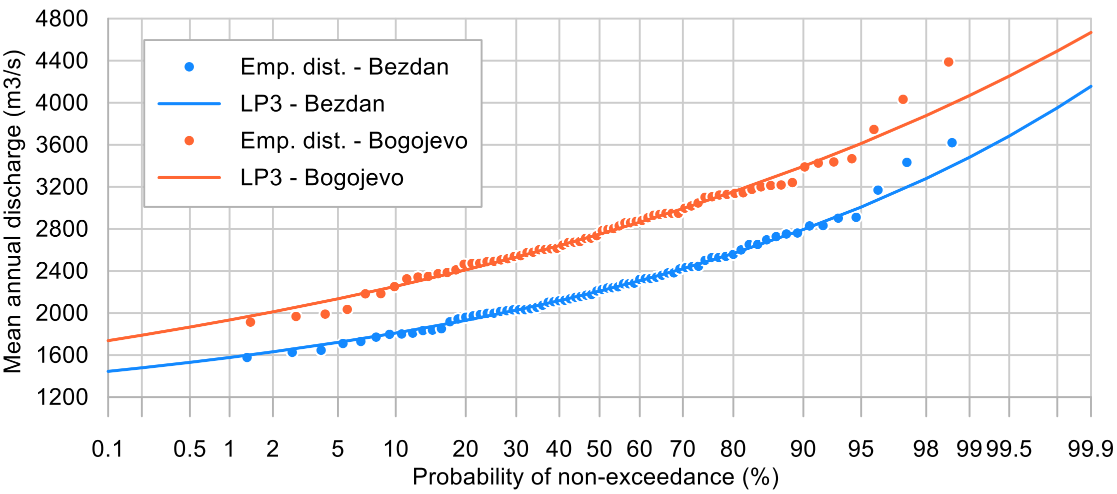


Figure 13: Distributions of mean annual discharges at Bezdan and Bogojevo: empirical distribution and log-Pearson type 3 (LP3) fit based on the complete record 1950-2023

Table 6: Mean annual discharges at Bezdan and Bogojevo for characteristic probabilities

Station	Probability of non-exceedance										
	0.1%	1%	5%	10%	20%	50%	80%	90%	95%	99%	99.9%
	Discharge (m^3/s)										
Bezdan	1445	1577	1720	1809	1930	2208	2566	2794	3007	3481	4156
Bogojevo	1737	1933	2135	2254	2410	2749	3153	3395	3612	4068	4668

3.3. Seasonal Distribution

Seasonal (intra-annual) distributions of discharges are shown in Figure 14 for stations Bezdan and Bogojevo, which have the longest record and provide representative results. On average, the highest water at Bezdan and Bogojevo occur in May, and the lowest in October and November. Figure 14 also shows the 90% confidence interval for the seasonal distribution for Bezdan and Bogojevo.

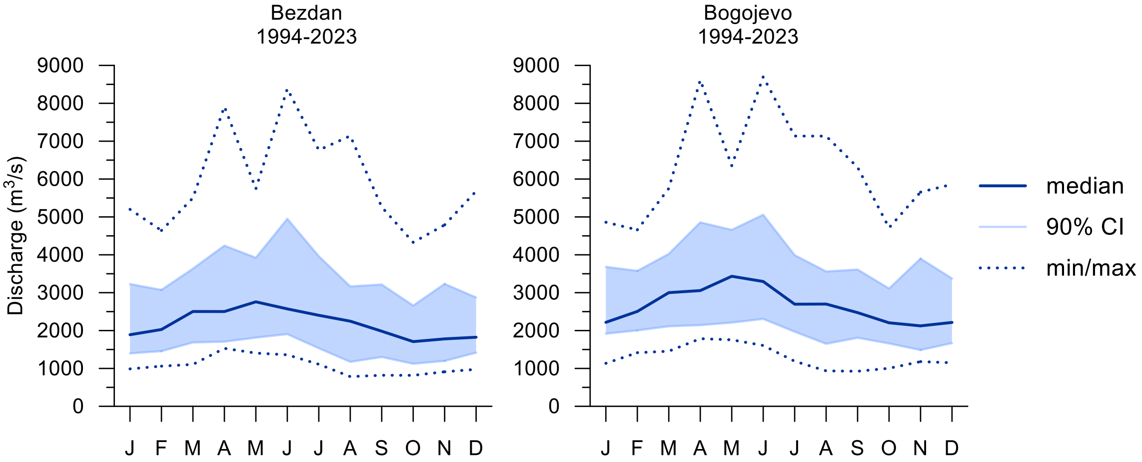


Figure 14: Seasonal distribution of flow (monthly discharges) at Serbian stations, showing long-term median (thick line), 90% confidence interval (shaded area) and envelopes of minimum and maximum monthly discharges (dashed line)

Due to short records, other stations exhibit similar but somewhat more variable pattern of the seasonal regime (Figure 15). Table 7 provides mean monthly discharges for all stations.

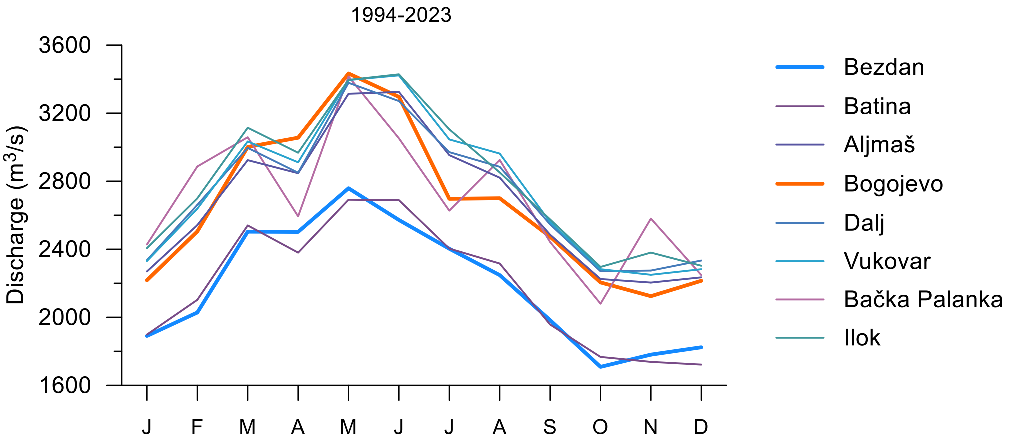


Figure 15: Median seasonal distribution of flow (monthly discharges) over 1994-2023 at all hydrological stations, computed for available record lengths

Table 7: Mean monthly discharges at Bezdan and Bogojevo

Station	Mean monthly discharges (m^3/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bezdan (1994-2023)	2067	2166	2509	2724	2796	2891	2432	2132	2056	1781	1894	1915

Batina (2002-2022)	2165	2254	2531	2614	2694	2954	2379	2188	2059	1795	1824	1851
Aljmas (2001-2022)	2574	2674	2964	3157	3279	3548	2915	2684	2571	2277	2331	2333
Bogojevo (1994-2023)	2489	2644	3007	3297	3370	3440	2867	2543	2498	2204	2387	2331
Dalj (2001-2022)	2646	2734	3022	3181	3322	3551	2933	2743	2627	2329	2385	2396
Vukovar (2001-2022)	2626	2746	3045	3240	3341	3588	2998	2778	2647	2331	2384	2388
Backa Palanka (2013-2023)	2642	2896	2938	2812	3334	3520	2626	2617	2540	2267	2481	2479
Ilok (2001-2022)	2688	2805	3118	3344	3396	3629	3020	2768	2641	2373	2432	2443

3.4. Duration Curves

Computation of flow duration curves in this study is performed having in mind the requirements related to the assessment of low and high navigable water levels (LNWL and HNWL, respectively) by the Danube Commission (Glossary of the Danube navigation, 2015). LNWL is defined as the water level having duration of 94% in a year that is computed from data on the observed river discharges over a period of 30 years, excluding the periods with presence of ice. Definition of HNWL is analogous except it is related to the discharge having duration of 1%.

To serve the purpose of determining LNWL and HNWL in line with the above definition, flow duration curves are assessed from daily discharge records during the last 30 years (1994-2023) with the periods with ice excluded from the record. This kind of assessment of flow duration was possible only for Serbian stations for which data on ice phenomena was available.

It should be noted that excluding ice days results in less than 365 (366) daily discharges per year. This means that it is not possible to estimate flows with durations longer than the number of non-ice days in a year. For this reason, duration is treated as the relative time ranging from 0 to 100% over non-ice period in each separate year.

In this study, flow duration curves are assessed using the so-called annual framework, meaning that duration curves are computed for each year of the record separately. This approach provides duration curves that are less sensitive to the choice of the period at the extreme tails than the period-of record approach, and also provides a possibility to quantify the hydrological uncertainties (Vogel and Fennessey, 1994). Duration curves for the Danube stations are therefore computed for each year in the 1994-2023 period (except for years with data gaps). Based on all duration curves within the given period, mean duration curve is derived as well as the 90% confidence interval. This confidence interval shows the range where possible variation of discharges for a given duration (or variation of duration for a given discharge) can be found with probability of 90%. For example, discharge at Bezdan having 94% duration has mean (expected) value of 1344 m^3/s, but based on the last 30 years it is expected to be in the range between 1025 and 1634 m^3/s with probability of 90%. Figure 16 shows mean flow duration curves for Bezdan and Bogojevo with the 90% confidence intervals, and

Table *8* shows discharges at these two stations for some characteristic durations.

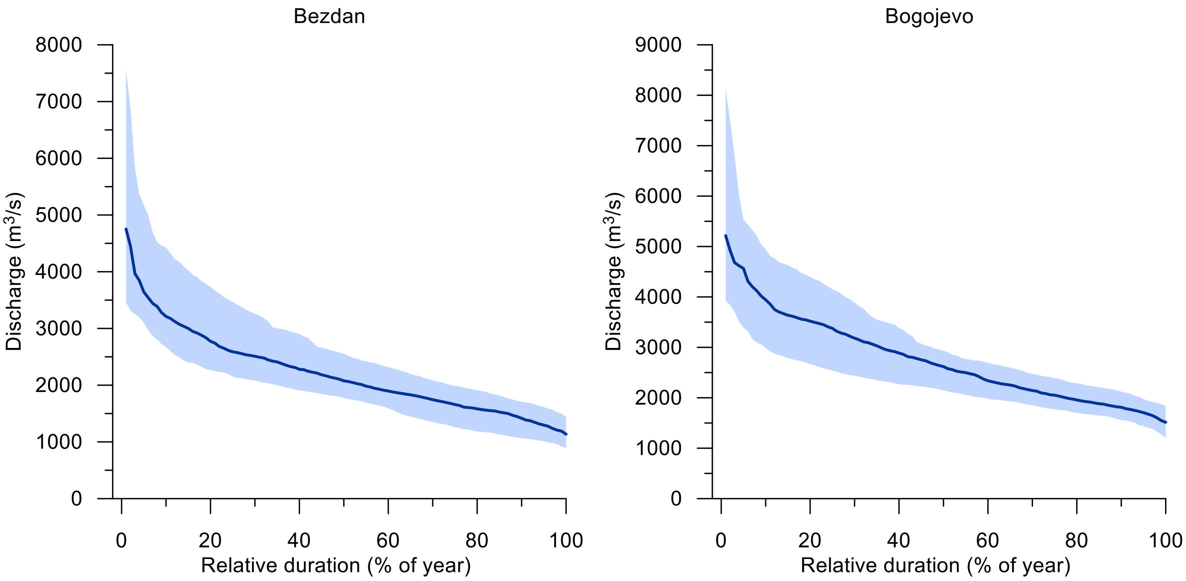


Figure 16: Flow duration curves for Bezdan and Bogojevo for 1994-2023 based on non-ice periods: long-term median (thick line) and 90% confidence interval (shaded area)

Table 8: Mean discharges with 90% confidence intervals at Bezdan and Bogojevo for characteristic durations for 1994-2023 based on non-ice periods

Duration (%)	**Discharge at Bezdan (m^3/s)**			**Discharge at Bogojevo (m^3/s)**		
	Mean	90% Conf. int.		Mean	90% Conf. int.	
		Lower limit	Upper limit		Lower limit	Upper limit
1	4920	3465	7565	5395	3925	8119
2	4576	3313	6885	5130	3836	7491
5	3902	3101	5175	4507	3395	5540
10	3406	2678	4426	4051	2989	4942
20	2927	2269	3736	3546	2668	4398
30	2621	2079	3261	3180	2437	3887
40	2348	1908	2903	2874	2268	3377
50	2105	1771	2555	2592	2146	2934
60	1901	1593	2321	2351	1981	2693
70	1729	1353	2086	2153	1852	2471
80	1580	1183	1913	1978	1702	2287
90	1422	1066	1709	1805	1558	2120
94	1344	1025	1634	1707	1455	2020
95	1316	1010	1615	1685	1437	1972
98	1231	960	1526	1584	1331	1900
99	1193	917	1495	1543	1272	1871
100	1153	894	1446	1501	1203	1839

Flow duration curves for other stations with shorter records were computed based on the available data. Due to the lack of data on ice phenomena for Croatian stations, some preliminary analysis was conducted to address the following two questions: (1) are there significant differences between the estimates of flow duration when estimated by excluding or including days with ice phenomena, and (2) are there significant differences when the flow duration is estimated from the 30-year record or a shorter one? To answer these questions, mean flow duration curves for Bezdan and Bogojevo are computed by both excluding and including ice days, and also computed for complete record 1994-2023 and for two shorter periods, 2001-2022 (period of available data at Croatian stations) and 2013-2023 (period of available data at Backa Palanka). The results have shown (Figure 17) that the flow duration curves differ slightly when computed with ice days included or excluded. However, the differences in computed mean duration curves may be more significant if the record shorter than 30 years is used. The differences are the most pronounced for the high extremes (high flow with 1% duration), but can also be noticeable for the low extremes (low flow with 94% duration).

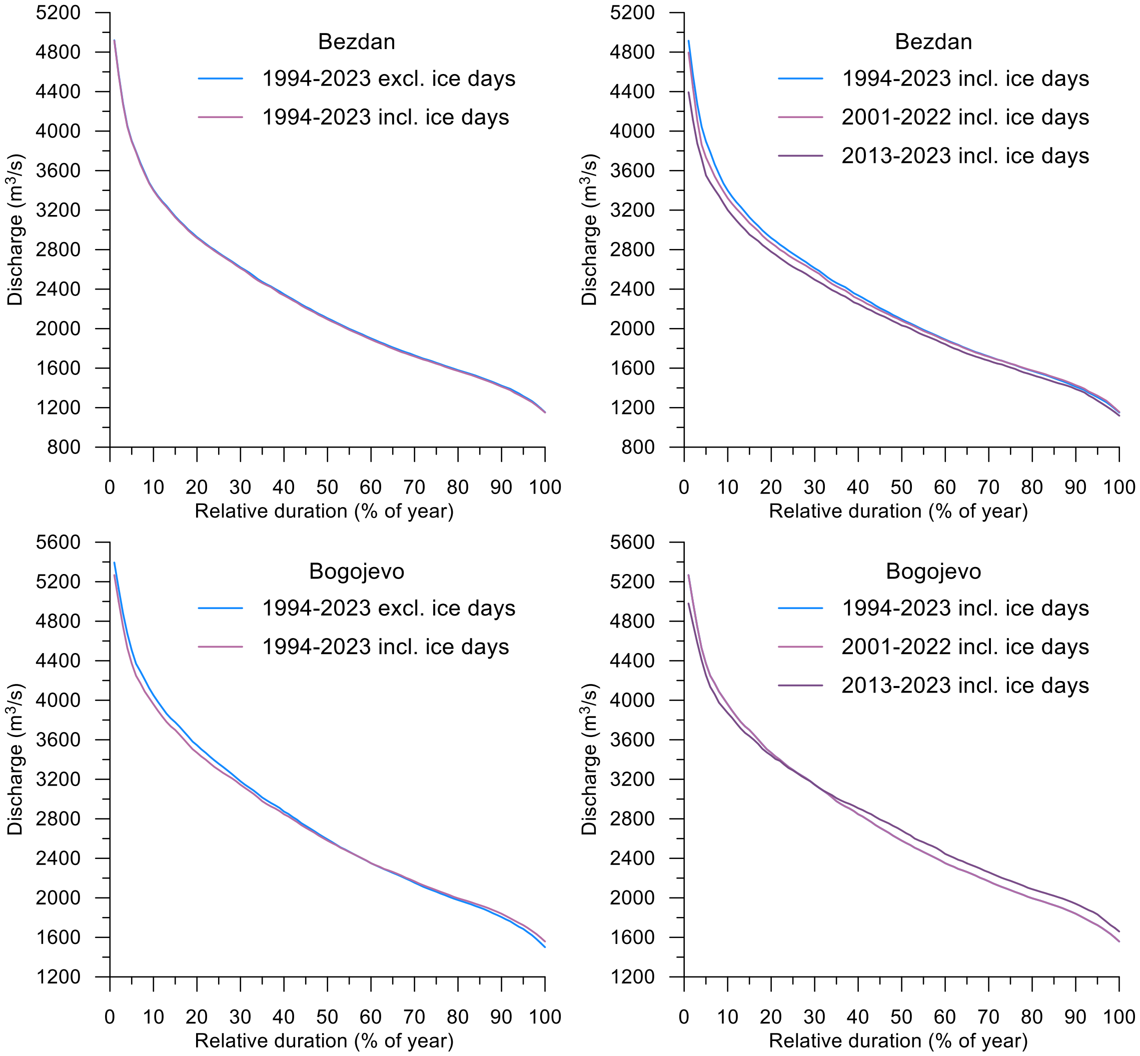


Figure 17: Mean flow duration curves for Bezdan and Bogojevo computed with excluding/including days with ice (left panels) and for different subperiods (right panels)

Based on these conclusions and also having in mind the sources of uncertainties identified in the preliminary analysis of data in section 2, it is concluded that the flow duration curves for stations having record shorter than 30 years should be adjusted in order to get comparable results along the given Danube sector. Adjusting flow duration curves based on short records to represent longer periods is recommended by US Geological Survey (Searcy, 1959) because such duration curves are considered unreliable for predicting the future pattern of flow.

For each station with short record, a transfer function between discharges at that station and a neighboring station with longer record is defined. This transfer function is aimed at adjusting the discharges of given duration from a shorter period to the 1994-2023 period. The transfer function is derived on the basis of mean flow duration curves for the station with shorter record and the station with the longer record, but for the timeframe corresponding to the shorter record. Because all the stations with shorter records are located downstream of the Drava confluence, Bogojevo is selected as the station with complete record over 1994-2023. Since the flow duration curve for Bogojevo is computed by excluding data on ice days, the transfer function effectively adjusts the flow duration curves from Croatian stations not only for shorter record but also for including ice days in computation. The transfer functions are defined by creating a regression relationship between the discharges at the two stations having duration from 1% to 100% in steps of 1% (total of 100 discharges). Transfer functions were developed for stations Aljmas, Dalj, Vukovar, Ilok and Backa Palanka (Figure 18). The regressions obtained are shown in Table 9.

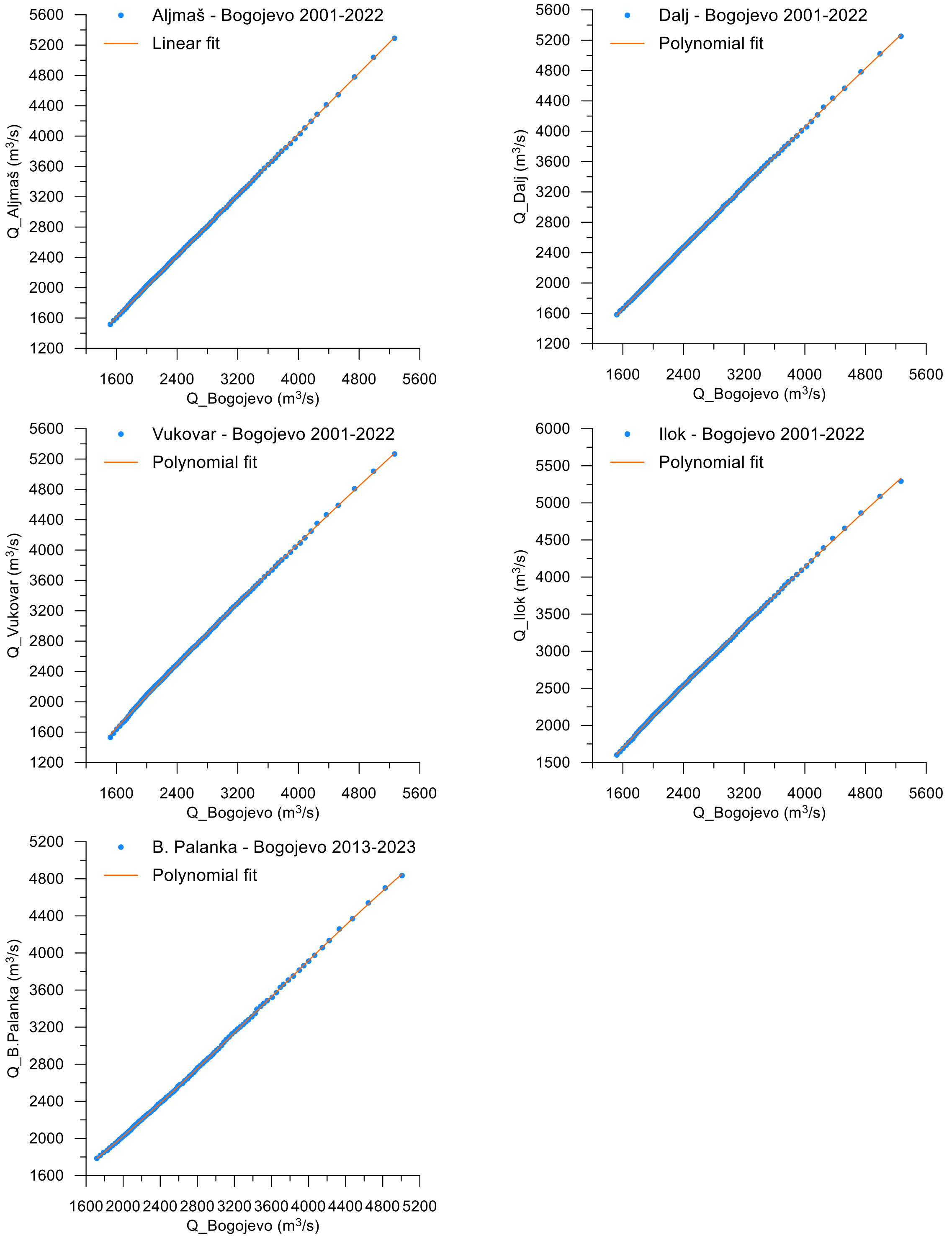


Figure 18: Transfer functions to adjust flow duration curves at stations with short record

Table 9: Regression fits used as transfer functions for adjustment of flow duration curves (Y denotes discharge for given duration at the station with short record, and X denotes discharge for the same duration at Bogojevo; both X and Y are in m³/s)

Station	Regression equation	Coefficient of determination
Aljmas	$Y = 1.00655 \cdot X$	$R^2 \approx 1$
Dalj	$Y = -13.6 + 1.0625 \cdot X - 1.12 \cdot 10^{-5} \cdot X^2$	$R^2 = 0.99993$
Vukovar	$Y = -101.88 + 1.13 \cdot X - 2.1 \cdot 10^{-5} \cdot X^2$	$R^2 = 0.99982$
Ilok	$Y = -52.74 + 1.126 \cdot X - 1.97 \cdot 10^{-5} \cdot X^2$	$R^2 = 0.99986$
Backa Palanka	$Y = 728.9 + 0.366 \cdot X + 0.000173 \cdot X^2 + 1.64 \cdot 10^{-8} \cdot X^3$	$R^2 = 0.99991$

For each station with the short record, discharges having duration 1% and 94% (Q1% and Q94%, respectively) are adjusted by using the transfer function with the discharge of given duration at Bogojevo over the complete 1994-2023 period as the input variable. Table 10 shows the results and compares them with corresponding values before the adjustment. It can be seen that, after the adjustment, low flows Q94% mostly have consistent values along the Danube stretch of interest. On the other hand, this is not the case with flood flows Q1%, but this kind of inconsistency is expected having in mind well-known inherent uncertainties in stage-discharge curves during floods. However, to have consistent input for hydrodynamic modelling, low flows Q94% at Aljmas and Ilok are adopted to have the same values as at Bogojevo and Backa Palanka respectively, while high flows Q1% between Aljmas and Vukovar are adopted to have the same value as at Bogojevo (as shown in Table 10).

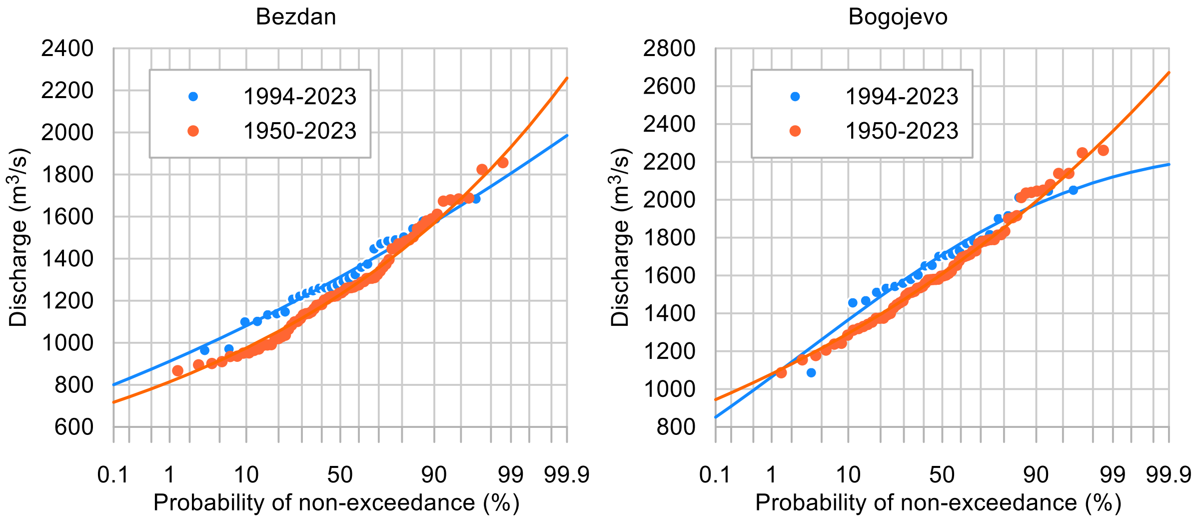
Table 10: Comparison of characteristic discharges assessed from flow duration curves, before and after the adjustment with the transfer function

Station	Q94% (m³/s)			Q1% (m³/s)		
	Before adjustment	After adjustment	Adopted	Before adjustment	After adjustment	Adopted
Bezdan	1344	–	1344	4920	–	4920
Batina	1316	1349	1349	4817	4940	4940
Aljmas	1735	1719	1707	5290	5430	5395
Bogojevo	1707	–	1707	5395	–	5395
Dalj	1791	1768	1768	5252	5392	5395
Vukovar	1774	1769	1769	5266	5391	5395
Ilok	1821	1813	1778	5292	5449	5449
Backa Palanka	1897	1778	1778	4835	5173	5449

4. Low Flows

The regime of low flows is considered by undertaking frequency analysis of annual minimum discharges with durations of 1, 7, 10, 20 and 30 days. For this analysis, data on daily discharges during the 1993-2024 period are used to establish the series of annual minima for all durations. The resulting series are shorter than 30 years, especially at the Croatian stations. After preliminary analysis, log-Pearson type III distribution was selected as the best fit for all annual minima series.

Short series are known to bring high uncertainty into frequency analysis. The degree to which the short series could affect the results of frequency analysis was analyzed for stations Bezdan and Bogojovo, for which long term data was available. Figure 19 shows that the probability distributions of 30-day annual minimum discharges at these two stations differ significantly for shorter and longer record.



Note: dots: empirical distribution, lines: log-Pearson type III distribution fit

Figure 19: Frequency analysis of 30-day annual minimum discharges for 1994-2023 vs. 1952-2023

When focusing on the 1994-2023 period only, the concerns about the uncertainty are even more emphasized for the Croatian stations, for which only 21 or 22 years of record are available. After computing low flows for characteristic probabilities at all Serbian and Croatian stations, inconsistencies in the results arise along the SRB-CRO Danube reach. Figure 20 shows a considerable difference in results for Bezdan and Batina stations (with 30 and 21 years of record, respectively), as well as illogical ratio between Aljmas and Bogojevo (with 22 and 26 years of record, respectively). For the latter pair of stations, it was already discussed that the differences in stage-discharge rating curves also contribute to the significant differences in discharges at these two stations.

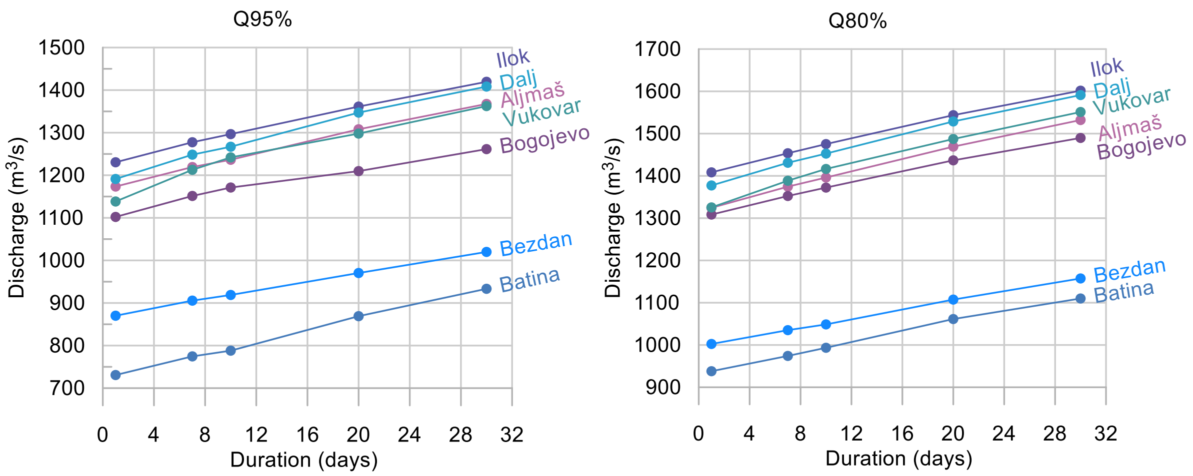


Figure 20: Relationship between low flows with 95% probability of exceedance and duration for the stations along the SRB-CRO Danube sector (results for 1994-2023)

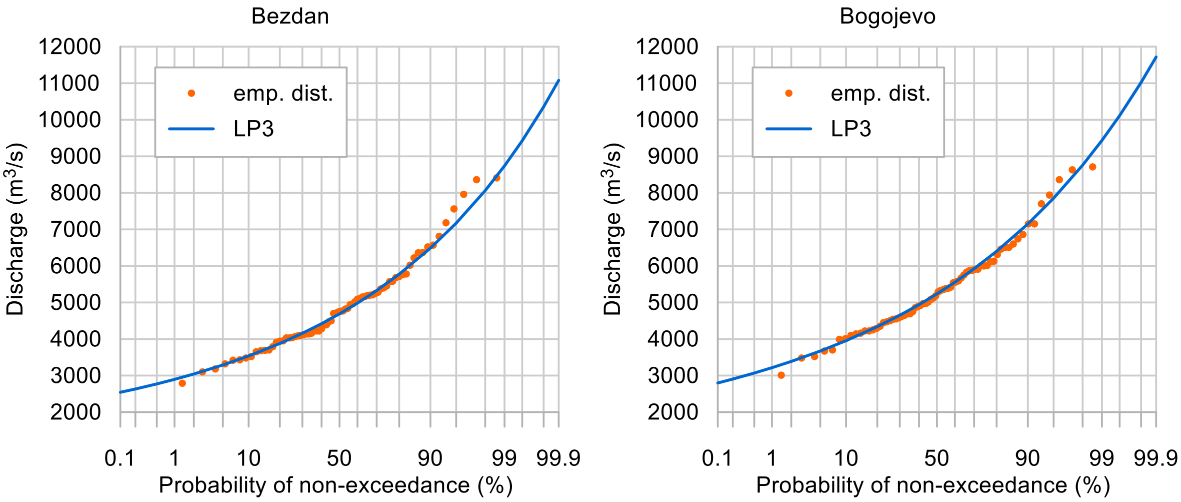
Having the above in mind, it can be concluded that the frequency analysis of short records, combined with inconsistencies in rating curves, cannot provide reliable information for the low flow analysis. Therefore, the results are shown here only for the long-term period at Bezdan and Bogojevo (Table 11).

Table 11: Comparison of characteristic discharges assessed from flow duration curves, before and after the adjustment with the transfer function

Duration (days)	Probability of exceedance				
	99%	98%	95%	90%	80%
	Low flows at Bezdan (m^3/s)				
1	728	762	816	869	938
7	751	785	841	894	965
10	760	795	851	905	977
20	789	825	884	941	1017
30	814	853	915	975	1055
	Low flows at Bogojevo (m^3/s)				
1	965	1014	1090	1162	1254
7	1003	1050	1126	1196	1287
10	1016	1063	1138	1209	1300
20	1041	1092	1172	1247	1345
30	1080	1133	1216	1294	1395

5. Flood Flows

Flood flows are characterized through the frequency analysis of annual maximum flows. Discharge records at Bezdan and Bogojevo from 1952-2023 are used to estimate floods for a range of probabilities. The observed data are fitted with the log-Pearson type III distribution, which was selected as the best fit for both stations (Figure 21). The flood quantiles are also shown in Table 12.



Note: dots: empirical distribution, lines: log-Pearson type III distribution fit

Figure 21: Frequency analysis of annual maximum discharges for 1952-2023

Table 12: Flood flows at Bezdan and Bogojevo from flood frequency analysis

Return period (years)	Probability of exceedance	Bezdan (m^3/s)	Bogojevo (m^3/s)
2	50%	4,689	5,235
5	20%	5,775	6,401
10	10%	6,488	7,148
20	5%	7,171	7,853
50	2%	8,062	8,758
100	1%	8,739	9,435
200	0.5%	9,425	10,114
500	0.2%	10,355	11,021
1000	0.1%	11,078	11,718

6. Navigable Water Levels

Low and high navigable water levels (LNWL and HNWL, respectively), as critical indicators for inland navigation, represent reference water levels at which the full functionality of the waterway is available for navigation (Muilerman et al., 2018). The Danube Commission (2013, 2015a) has defined LNWL as the water level having duration of 94% in a year that is computed from data on the observed river discharges over a period of 30 years, excluding the periods with presence of ice. HNWL is defined as the water level with duration of 1%, based on the discharges observed during a period of 30 years, excluding the ice periods. Danube Glossary (Danube STREAM project, 2019) defines LNWL further by specifying that it represents the water level derived from the stage-discharge rating curve based on the discharge having 94% duration over the 30-year period, on days without ice (and similarly for HNWL).

With flow duration curves computed as described in section 3.4, with an adjustment that accounts for lengths of record shorter than 30 years during 1994-2023, it is possible to define LNWLs and HNWLs at hydrological stations by converting the characteristic discharges Q94% and Q1% (with duration 94% and 1%, respectively) into corresponding levels by means of the stage-discharge rating curves.

The stage-discharge curves for Croatian stations were obtained from DHMZ in a functional form of quadratic relationship between the water levels and discharges. According to DHMZ, the functional rating curves are valid from 2019 to 2024. Stage-discharge curves for Serbian stations were not delivered directly by RHMSS, but were obtained unofficially from "Plovput".

Reference LNWLs and HNWLs are obtained from the stage-discharge curves for the mean values of Q94% and Q1%, and the results are shown in Table 13 and in Figure 22. Slight differences present at twin stations are not unexpected having in mind the disagreement of stage-discharge relationships for these stations. However, the reference levels resulting from the hydrological analysis should further be validated by hydrodynamic simulations, leading to the final adoption of the low and high navigable water level.

Table 13: Water levels corresponding to the discharges of duration of 94% and 1% at hydrological stations along the Serbian-Croatian common stretch of the Danube River

Station	Chainage (km)	Duration 94%		Duration 1%	
		Water level (m)	Stage (cm)	Water level (m)	Stage (cm)
Bezdan	1425.59	80.63	-1	86.12	548
Batina	1424.60	80.62	17	85.96	551
Aljmaš	1380.25	78.58	50	83.79	571
Bogojevo	1367.25	77.73	27	83.01	555
Dalj	1353.70	77.43	223	82.23	703
Vukovar	1333.40	76.68	49	81.14	495
Ilok	1298.70	74.68	71	79.15	518
Bačka Palanka	1298.56	74.87	90	79.23	526

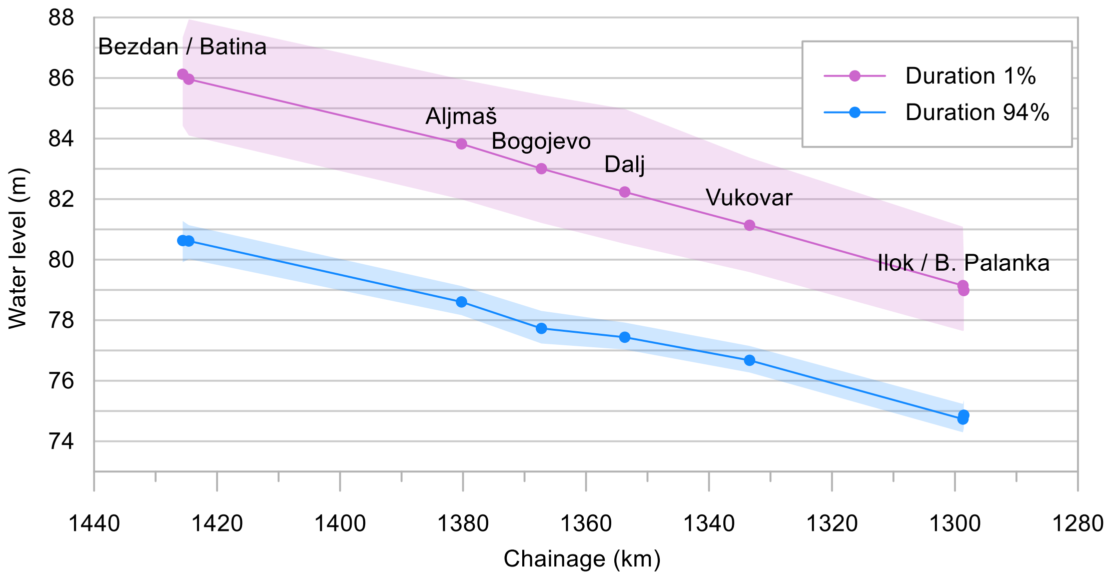


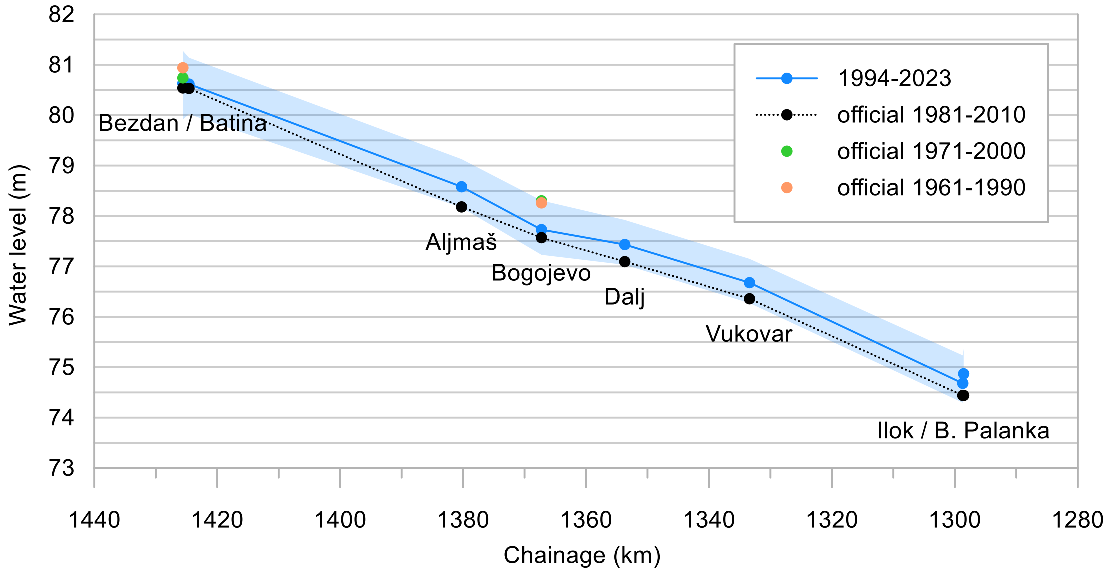
Figure 22: Water levels corresponding to discharges of 1% and 94% duration at hydrological stations along the Serbian-Croatian common stretch of the Danube River, with 90% confidence intervals (shaded areas)

Comparison of the reference water levels from this study with the official levels reported to the Danube Commission for the previous 30-year periods is given in Table 14. The official levels for 1961-1990, 1971-2000 and 1981-2010 are retrieved from the publications of the Danube Commission (1995, 2007, 2015b). For 1961-1990 and 1971-2000 the levels are available only for Serbian stations. The levels were not reported for the period 1991-2020, neither for Serbian nor for Croatian stations. All reference levels are also shown in Figure 23 and Figure 24. The comparison shows that the LNWLs in this study are higher than the corresponding levels for 1981-2010, but still lower than in earlier periods 1971-2000 and 1961-1990. On the other hand, reference HNWLs for 1994-2023 are lower than in previous calculations. The differences are less pronounced at Bezdan and Batina then at the stations downstream of the Drava confluence.

Table 14: Comparison of the results of this study with the official high and low navigable water levels reported to the Danube Commission

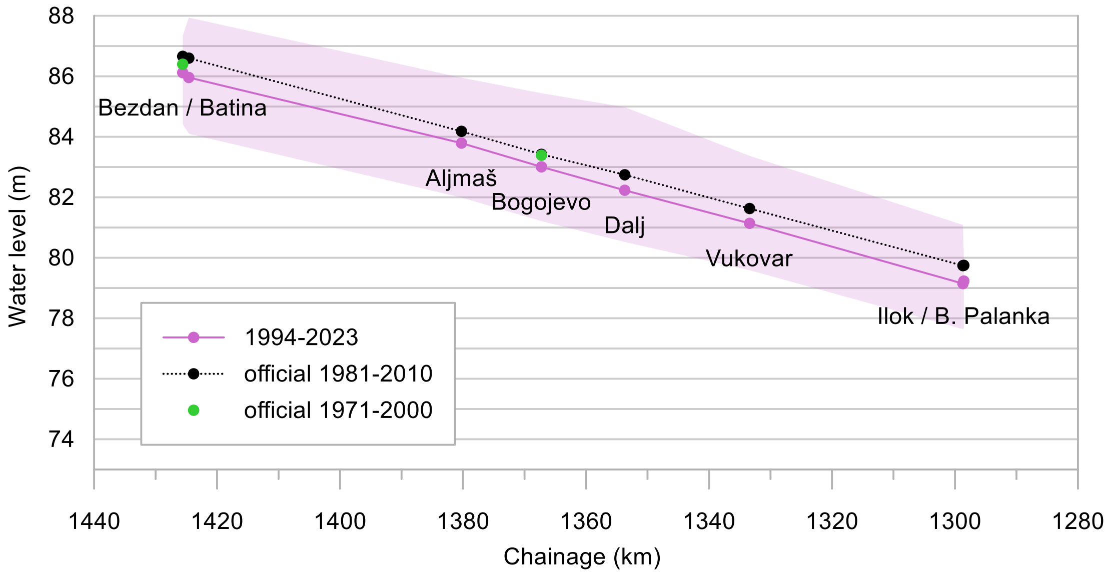
Station	Chainage (km)	Gauge zero (m)	Period	LNWL			HNWL		
				Q (m^3/s)	H (cm)	Z (m)	Q (m^3/s)	H (cm)	Z (m)
Bezdan	1425.59	80.64	1961-1990	1150	30	80.94	–	–	–
			1971-2000	1140	10	80.74	5048	576	86.40
			1981-2010	1180	-10	80.54	5280	602	86.66
			1994-2023	1344	-1	80.63	4920	548	86.12
Batina	1424.60	80.45	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1180	8	80.53	5280	615	86.60
			1994-2023	1349	17	80.62	4940	551	85.96
Aljmaš	1380.25	78.08	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1435	10	78.18	5850	610	84.18
			1994-2023	1707	50	78.58	5395	571	83.79
Bogojevo	1367.25	77.46	1961-1990	1530	80	78.26	–	–	–
			1971-2000	1480	84	78.30	5720	593	83.39
			1981-2010	1435	11	77.57	5850	596	83.42
			1994-2023	1707	27	77.73	5395	555	83.01
Dalj	1353.70	75.20	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1435	189	77.09	5850	754	82.74
			1994-2023	1768	223	77.43	5395	703	82.23
Vukovar	1333.40	76.19	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1435	17	76.36	5850	544	81.63
			1994-2023	1769	49	76.68	5395	495	81.14
Ilok / Ilok most	1298.70	73.97	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1435	47	74.44	5850	577	79.74
			1994-2023	1778	71	74.68	5449	518	79.15
Bačka Palanka	1298.56	73.97	1961-1990	–	–	–	–	–	–
			1971-2000	–	–	–	–	–	–
			1981-2010	1435	47	74.44	5850	578	79.75
			1994-2023	1778	90	74.87	5449	526	79.23

Note: Q is reference discharge, H is stage, and Z is water level



Note: shaded area represents 90% confidence interval for 1994-2023

Figure 23: Comparison of LNWLs from previous official calculations



Note: shaded area represents 90% confidence interval for 1994-2023

Figure 24: Comparison of HNWLs from previous official calculations

The main cause of different reference water levels are different reference discharges. Low flows Q94% at hydrological stations are greater in this study than the previous calculation by 14-24%, and the high flows Q1% are lower by 6-8% than in the previous calculation.

The shift in low flows from 1981-2010 to 1994-2023 can also be seen by comparing the distributions of daily discharges in these two periods at Bezdan and Bogojevo, presented in Figure 25. This figure shows that the distribution changed from one period to another. The change is especially visible in the domain of low flows. Discharges below 1500 m^3/s at Bezdan, and below 2000 m^3/s at Bogojevo, are much less frequent in the latter period then during 1981-2010. At the same time, about-average discharges (discharges between 1500 and 3000 m^3/s at Bezdan, and between 2000 and 3500 m^3/s at Bogojevo) are more frequent during 1994-2023. This explains the shift in Q94% from 1180 to 1344 m^3/s at Bezdan, and from 1435 to 1707 m^3/s at Bogojevo.

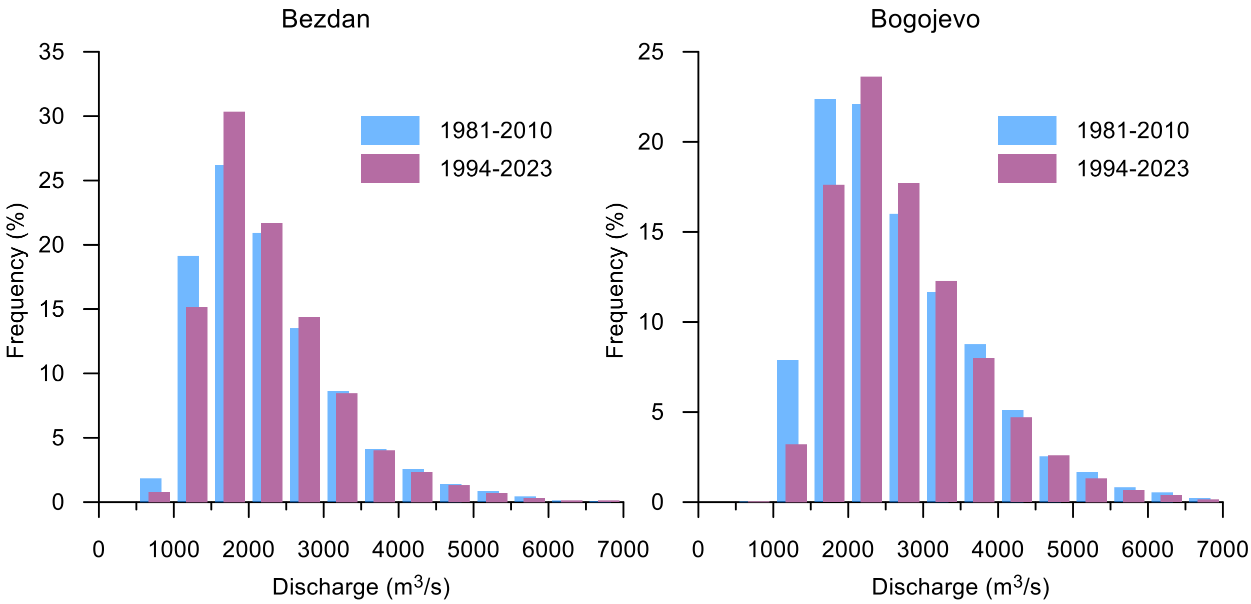


Figure 25: Comparison of distributions of daily discharges from two 30-year periods

This observation-based evidence on the increase of low flows at this stretch of the Danube does not support projected low flow trends anticipated by the climate models for the middle Danube basin in the update of the Danube Study by ICPDR (LMU, 2018). Conclusions from this study indicated that low flow conditions would be expected to increase in duration and intensity, with a reduction of low flows by 25-50% by mid 21st century. On the other hand, more recent projections (Probst and Mauser, 2023) show an expected increase in low flows in the near future (2031-2060) under two extreme climate change scenarios RCP 2.6 (very optimistic scenario) and RCP 8.5 (very pessimistic scenario). In the work of Probst and Mauser (2023; Fig. 14), climate simulations for Bezdan indicate an upward shift in the low-flow domain of flow duration curves in the future, compared to the historical 1971-2000 period. This means that a given discharge value would be exceeded in the future in more days in a year, or that a higher discharge would correspond to a given duration.

To conclude, although there is a certain reservation about the accuracy of the measurements and stage-discharge rating curves on the common Serbian-Croatian stretch of the Danube, the observations are clearly showing increased low flows in the last 30 years. This increase may be attributed to climate change as the observations support the most recent findings from Probst and Mauser (2023). However, this increase may also originate from the water management practices in the regulated upstream sections of the Danube and its tributaries, but this statement cannot be made without collecting further information on such practices.

7. Conclusions and Recommendations

Based on the available hydrological data at 8 hydrological stations, this hydrological study delivers information on hydrological regime of the Danube River along the common SRB-HRV stretch from the Hungarian border to Backa Palanka. All aspects of water regime are covered (mean, low and flood flows).

Analysis of the consistency of data across the stations (and especially at twin Serbian/Croatian stations) has shown that the data are generally consistent, but that there are occasional significant discrepancies that weaken the confidence in the results of the analysis. Consequently, there is a strong need for coordination and cooperation of hydrometeorological services of Serbia and Croatia that would lead to harmonization in terms of measurements, data collection and data processing.

The analysis has also shown that it is not possible to treat data from hydrological stations with shorter records (Croatian stations and Bačka Palanka) equally as the stations with longer records within the selected 30-year period. It is therefore recommended that similar future studies involving the assessment of reference water levels should be based on records from stations with complete records over 30 years. Eventually, Croatian stations would reach 30 years of records in 2030, when the new assessment can be performed.

The reference discharges Q94% and Q1% needed for the estimation of reference water levels (low and high navigable water levels) are estimated from duration analysis of observed discharges, with a necessary adjustment to compensate for the shortness of the records and lack of information on ice phenomena at some stations. Converting these discharges to water levels using the most recent stage-discharge rating curves resulted in different reference levels than those calculated previously for the 1981-2010 period. This difference is due to the less frequent occurrence of low flows in this stretch of the Danube. The results for the reference water levels obtained in this hydrological study will be further used and validated in hydrodynamic simulations that would lead to final adoption of the reference levels.

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Annex 1 – Table of ENRs Derived from the Hydraulic Model

The following table contains ENRs along the SRB-HRV joint stretch of the Danube River, derived from the developed hydraulic model, given in m.a.s.l., with reference to the Trieste zero.

rkm	ENR (m.a.s.l.)
1300.000	74.837
1300.100	74.841
1300.200	74.845
1300.300	74.850
1300.400	74.854
1300.500	74.859
1300.600	74.864
1300.700	74.868
1300.800	74.874
1300.900	74.880
1301.000	74.887
1301.100	74.893
1301.200	74.900
1301.300	74.907
1301.400	74.913
1301.500	74.920
1301.600	74.925
1301.700	74.931
1301.800	74.936
1301.900	74.940
1302.000	74.946
1302.100	74.951
1302.200	74.956
1302.300	74.961
1302.400	74.967
1302.500	74.972
1302.600	74.977
1302.700	74.982
1302.800	74.987
1302.900	74.991
1303.000	74.996
1303.100	75.000
1303.200	75.004
1303.300	75.008
1303.400	75.012

1303.500	75.016
1303.600	75.021
1303.700	75.026
1303.800	75.030
1303.900	75.035
1304.000	75.040
1304.100	75.043
1304.200	75.048
1304.300	75.053
1304.400	75.058
1304.500	75.064
1304.600	75.069
1304.700	75.074
1304.800	75.079
1304.900	75.084
1305.000	75.089
1305.100	75.095
1305.200	75.103
1305.300	75.111
1305.400	75.121
1305.500	75.132
1305.600	75.143
1305.700	75.154
1305.800	75.164
1305.900	75.173
1306.000	75.180
1306.100	75.188
1306.200	75.201
1306.300	75.207
1306.400	75.212
1306.500	75.216
1306.600	75.220
1306.700	75.223
1306.800	75.227
1306.900	75.229
1307.000	75.232
1307.100	75.235
1307.200	75.238
1307.300	75.241

1307.400	75.244
1307.500	75.247
1307.600	75.251
1307.700	75.255
1307.800	75.259
1307.900	75.263
1308.000	75.268
1308.100	75.274
1308.200	75.284
1308.300	75.294
1308.400	75.304
1308.500	75.320
1308.600	75.339
1308.700	75.356
1308.800	75.377
1308.900	75.392
1309.000	75.402
1309.100	75.411
1309.200	75.419
1309.300	75.426
1309.400	75.437
1309.500	75.446
1309.600	75.458
1309.700	75.469
1309.800	75.478
1309.900	75.485
1310.000	75.494
1310.100	75.499
1310.200	75.503
1310.300	75.507
1310.400	75.511
1310.500	75.522
1310.600	75.536
1310.700	75.546
1310.800	75.555
1310.900	75.564
1311.000	75.571
1311.100	75.578
1311.200	75.584

1311.300	75.589
1311.400	75.593
1311.500	75.598
1311.600	75.601
1311.700	75.604
1311.800	75.607
1311.900	75.609
1312.000	75.612
1312.100	75.615
1312.200	75.618
1312.300	75.621
1312.400	75.624
1312.500	75.628
1312.600	75.633
1312.700	75.636
1312.800	75.640
1312.900	75.645
1313.000	75.650
1313.100	75.654
1313.200	75.659
1313.300	75.666
1313.400	75.673
1313.500	75.679
1313.600	75.685
1313.700	75.692
1313.800	75.699
1313.900	75.706
1314.000	75.713
1314.100	75.721
1314.200	75.729
1314.300	75.737
1314.400	75.745
1314.500	75.752
1314.600	75.759
1314.700	75.766
1314.800	75.772
1314.900	75.779
1315.000	75.785
1315.100	75.790

1315.200	75.795
1315.300	75.801
1315.400	75.806
1315.500	75.813
1315.600	75.819
1315.700	75.826
1315.800	75.833
1315.900	75.839
1316.000	75.845
1316.100	75.852
1316.200	75.859
1316.300	75.866
1316.400	75.873
1316.500	75.881
1316.600	75.887
1316.700	75.893
1316.800	75.899
1316.900	75.905
1317.000	75.912
1317.100	75.918
1317.200	75.924
1317.300	75.931
1317.400	75.937
1317.500	75.944
1317.600	75.953
1317.700	75.960
1317.800	75.968
1317.900	75.977
1318.000	75.986
1318.100	75.996
1318.200	76.004
1318.300	76.012
1318.400	76.019
1318.500	76.025
1318.600	76.031
1318.700	76.035
1318.800	76.039
1318.900	76.043
1319.000	76.046

1319.100	76.048
1319.200	76.050
1319.300	76.052
1319.400	76.055
1319.500	76.057
1319.600	76.059
1319.700	76.061
1319.800	76.063
1319.900	76.065
1320.000	76.068
1320.100	76.070
1320.200	76.073
1320.300	76.075
1320.400	76.078
1320.500	76.081
1320.600	76.084
1320.700	76.087
1320.800	76.090
1320.900	76.093
1321.000	76.096
1321.100	76.099
1321.200	76.103
1321.300	76.106
1321.400	76.110
1321.500	76.113
1321.600	76.118
1321.700	76.122
1321.800	76.126
1321.900	76.130
1322.000	76.133
1322.100	76.138
1322.200	76.141
1322.300	76.144
1322.400	76.147
1322.500	76.150
1322.600	76.154
1322.700	76.158
1322.800	76.164
1322.900	76.168

1323.000	76.172
1323.100	76.176
1323.200	76.180
1323.300	76.184
1323.400	76.189
1323.500	76.193
1323.600	76.197
1323.700	76.201
1323.800	76.205
1323.900	76.209
1324.000	76.213
1324.100	76.217
1324.200	76.219
1324.300	76.222
1324.400	76.224
1324.500	76.227
1324.600	76.229
1324.700	76.231
1324.800	76.234
1324.900	76.237
1325.000	76.240
1325.100	76.243
1325.200	76.246
1325.300	76.249
1325.400	76.252
1325.500	76.255
1325.600	76.258
1325.700	76.261
1325.800	76.264
1325.900	76.266
1326.000	76.269
1326.100	76.272
1326.200	76.274
1326.300	76.276
1326.400	76.279
1326.500	76.281
1326.600	76.284
1326.700	76.286
1326.800	76.289

1326.900	76.292
1327.000	76.294
1327.100	76.297
1327.200	76.301
1327.300	76.304
1327.400	76.308
1327.500	76.312
1327.600	76.317
1327.700	76.322
1327.800	76.327
1327.900	76.334
1328.000	76.342
1328.100	76.350
1328.200	76.360
1328.300	76.370
1328.400	76.379
1328.500	76.388
1328.600	76.395
1328.700	76.403
1328.800	76.410
1328.900	76.417
1329.000	76.424
1329.100	76.431
1329.200	76.437
1329.300	76.443
1329.400	76.448
1329.500	76.452
1329.600	76.455
1329.700	76.458
1329.800	76.461
1329.900	76.464
1330.000	76.466
1330.100	76.468
1330.200	76.470
1330.300	76.472
1330.400	76.474
1330.500	76.475
1330.600	76.477
1330.700	76.479

1330.800	76.481
1330.900	76.483
1331.000	76.484
1331.100	76.486
1331.200	76.488
1331.300	76.490
1331.400	76.492
1331.500	76.494
1331.600	76.496
1331.700	76.499
1331.800	76.502
1331.900	76.505
1332.000	76.509
1332.100	76.513
1332.200	76.518
1332.300	76.523
1332.400	76.528
1332.500	76.533
1332.600	76.538
1332.700	76.544
1332.800	76.548
1332.900	76.553
1333.000	76.558
1333.100	76.563
1333.200	76.568
1333.300	76.572
1333.400	76.576
1333.500	76.579
1333.600	76.583
1333.700	76.587
1333.800	76.590
1333.900	76.594
1334.000	76.599
1334.100	76.603
1334.200	76.608
1334.300	76.614
1334.400	76.620
1334.500	76.626
1334.600	76.632

1334.700	76.639
1334.800	76.645
1334.900	76.652
1335.000	76.658
1335.100	76.664
1335.200	76.670
1335.300	76.676
1335.400	76.682
1335.500	76.687
1335.600	76.693
1335.700	76.698
1335.800	76.703
1335.900	76.708
1336.000	76.713
1336.100	76.717
1336.200	76.721
1336.300	76.725
1336.400	76.728
1336.500	76.731
1336.600	76.734
1336.700	76.738
1336.800	76.740
1336.900	76.743
1337.000	76.746
1337.100	76.749
1337.200	76.752
1337.300	76.755
1337.400	76.758
1337.500	76.761
1337.600	76.764
1337.700	76.767
1337.800	76.770
1337.900	76.772
1338.000	76.775
1338.100	76.778
1338.200	76.781
1338.300	76.783
1338.400	76.786
1338.500	76.788

1338.600	76.790
1338.700	76.792
1338.800	76.794
1338.900	76.796
1339.000	76.798
1339.100	76.799
1339.200	76.802
1339.300	76.804
1339.400	76.806
1339.500	76.809
1339.600	76.812
1339.700	76.815
1339.800	76.818
1339.900	76.822
1340.000	76.826
1340.100	76.831
1340.200	76.835
1340.300	76.840
1340.400	76.846
1340.500	76.852
1340.600	76.857
1340.700	76.862
1340.800	76.867
1340.900	76.871
1341.000	76.874
1341.100	76.876
1341.200	76.878
1341.300	76.880
1341.400	76.882
1341.500	76.884
1341.600	76.885
1341.700	76.887
1341.800	76.889
1341.900	76.890
1342.000	76.892
1342.100	76.894
1342.200	76.896
1342.300	76.897
1342.400	76.899

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1342.600	76.902
1342.700	76.905
1342.800	76.907
1342.900	76.910
1343.000	76.913
1343.100	76.916
1343.200	76.920
1343.300	76.924
1343.400	76.927
1343.500	76.930
1343.600	76.933
1343.700	76.936
1343.800	76.939
1343.900	76.942
1344.000	76.945
1344.100	76.948
1344.200	76.951
1344.300	76.955
1344.400	76.958
1344.500	76.960
1344.600	76.963
1344.700	76.966
1344.800	76.968
1344.900	76.971
1345.000	76.973
1345.100	76.975
1345.200	76.978
1345.300	76.981
1345.400	76.984
1345.500	76.986
1345.600	76.989
1345.700	76.992
1345.800	76.997
1345.900	77.001
1346.000	77.006
1346.100	77.011
1346.200	77.016
1346.300	77.021

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1346.500	77.031
1346.600	77.036
1346.700	77.040
1346.800	77.044
1346.900	77.048
1347.000	77.052
1347.100	77.055
1347.200	77.057
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1347.400	77.062
1347.500	77.064
1347.600	77.066
1347.700	77.069
1347.800	77.071
1347.900	77.074
1348.000	77.076
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1348.400	77.084
1348.500	77.085
1348.600	77.086
1348.700	77.087
1348.800	77.089
1348.900	77.093
1349.000	77.097
1349.100	77.101
1349.200	77.106
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1349.400	77.115
1349.500	77.119
1349.600	77.123
1349.700	77.127
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1349.900	77.134
1350.000	77.139
1350.100	77.143
1350.200	77.147

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1350.400	77.156
1350.500	77.160
1350.600	77.165
1350.700	77.168
1350.800	77.173
1350.900	77.176
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1351.400	77.191
1351.500	77.193
1351.600	77.195
1351.700	77.197
1351.800	77.198
1351.900	77.200
1352.000	77.202
1352.100	77.204
1352.200	77.208
1352.300	77.212
1352.400	77.216
1352.500	77.220
1352.600	77.224
1352.700	77.228
1352.800	77.232
1352.900	77.237
1353.000	77.243
1353.100	77.247
1353.200	77.253
1353.300	77.258
1353.400	77.264
1353.500	77.270
1353.600	77.276
1353.700	77.283
1353.800	77.291
1353.900	77.298
1354.000	77.305
1354.100	77.312

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1354.300	77.324
1354.400	77.330
1354.500	77.336
1354.600	77.341
1354.700	77.345
1354.800	77.349
1354.900	77.352
1355.000	77.354
1355.100	77.356
1355.200	77.358
1355.300	77.359
1355.400	77.360
1355.500	77.361
1355.600	77.362
1355.700	77.364
1355.800	77.365
1355.900	77.366
1356.000	77.367
1356.100	77.369
1356.200	77.371
1356.300	77.374
1356.400	77.376
1356.500	77.379
1356.600	77.381
1356.700	77.383
1356.800	77.385
1356.900	77.387
1357.000	77.390
1357.100	77.393
1357.200	77.396
1357.300	77.401
1357.400	77.406
1357.500	77.411
1357.600	77.416
1357.700	77.421
1357.800	77.426
1357.900	77.431
1358.000	77.436

1358.100	77.442
1358.200	77.448
1358.300	77.455
1358.400	77.462
1358.500	77.469
1358.600	77.475
1358.700	77.481
1358.800	77.488
1358.900	77.494
1359.000	77.500
1359.100	77.505
1359.200	77.511
1359.300	77.516
1359.400	77.521
1359.500	77.527
1359.600	77.532
1359.700	77.538
1359.800	77.544
1359.900	77.551
1360.000	77.558
1360.100	77.565
1360.200	77.572
1360.300	77.579
1360.400	77.585
1360.500	77.590
1360.600	77.595
1360.700	77.600
1360.800	77.604
1360.900	77.609
1361.000	77.613
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1361.200	77.619
1361.300	77.623
1361.400	77.626
1361.500	77.629
1361.600	77.633
1361.700	77.636
1361.800	77.639
1361.900	77.642

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1362.400	77.662
1362.500	77.667
1362.600	77.675
1362.700	77.685
1362.800	77.695
1362.900	77.705
1363.000	77.711
1363.100	77.718
1363.200	77.724
1363.300	77.729
1363.400	77.733
1363.500	77.738
1363.600	77.742
1363.700	77.745
1363.800	77.749
1363.900	77.752
1364.000	77.754
1364.100	77.757
1364.200	77.760
1364.300	77.762
1364.400	77.765
1364.500	77.767
1364.600	77.770
1364.700	77.772
1364.800	77.774
1364.900	77.776
1365.000	77.779
1365.100	77.781
1365.200	77.784
1365.300	77.788
1365.400	77.793
1365.500	77.797
1365.600	77.802
1365.700	77.806
1365.800	77.811

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1366.000	77.821
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1366.400	77.842
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1366.600	77.852
1366.700	77.858
1366.800	77.863
1366.900	77.869
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1367.100	77.880
1367.200	77.886
1367.300	77.892
1367.400	77.898
1367.500	77.905
1367.600	77.911
1367.700	77.916
1367.800	77.921
1367.900	77.926
1368.000	77.931
1368.100	77.942
1368.200	77.954
1368.300	77.962
1368.400	77.971
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1369.000	78.031
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1369.400	78.050
1369.500	78.054
1369.600	78.059
1369.700	78.065

1369.800	78.071
1369.900	78.077
1370.000	78.082
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1370.200	78.091
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1370.400	78.099
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1370.600	78.106
1370.700	78.110
1370.800	78.115
1370.900	78.119
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1371.100	78.125
1371.200	78.128
1371.300	78.133
1371.400	78.137
1371.500	78.140
1371.600	78.143
1371.700	78.146
1371.800	78.149
1371.900	78.152
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1372.200	78.165
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1372.600	78.184
1372.700	78.189
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1372.900	78.199
1373.000	78.204
1373.100	78.209
1373.200	78.215
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1373.400	78.227
1373.500	78.232
1373.600	78.236

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1374.400	78.258
1374.500	78.260
1374.600	78.262
1374.700	78.264
1374.800	78.265
1374.900	78.266
1375.000	78.268
1375.100	78.270
1375.200	78.272
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1375.400	78.275
1375.500	78.278
1375.600	78.282
1375.700	78.287
1375.800	78.293
1375.900	78.301
1376.000	78.309
1376.100	78.316
1376.200	78.321
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1376.400	78.333
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1376.600	78.345
1376.700	78.351
1376.800	78.358
1376.900	78.367
1377.000	78.374
1377.100	78.382
1377.200	78.391
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1377.400	78.408
1377.500	78.417

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1377.700	78.434
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1378.200	78.469
1378.300	78.474
1378.400	78.478
1378.500	78.482
1378.600	78.486
1378.700	78.490
1378.800	78.493
1378.900	78.497
1379.000	78.500
1379.100	78.503
1379.200	78.506
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1379.500	78.516
1379.600	78.520
1379.700	78.523
1379.800	78.528
1379.900	78.534
1380.000	78.539
1380.100	78.543
1380.200	78.548
1380.300	78.553
1380.400	78.559
1380.500	78.564
1380.600	78.570
1380.700	78.575
1380.800	78.580
1380.900	78.585
1381.000	78.589
1381.100	78.593
1381.200	78.598
1381.300	78.602
1381.400	78.607

1381.500	78.612
1381.600	78.617
1381.700	78.622
1381.800	78.626
1381.900	78.630
1382.000	78.634
1382.100	78.638
1382.200	78.641
1382.300	78.644
1382.400	78.647
1382.500	78.650
1382.600	78.652
1382.700	78.655
1382.800	78.659
1382.900	78.662
1383.000	78.666
1383.100	78.669
1383.200	78.672
1383.300	78.674
1383.400	78.677
1383.500	78.679
1383.600	78.682
1383.700	78.685
1383.800	78.687
1383.900	78.691
1384.000	78.694
1384.100	78.698
1384.200	78.701
1384.300	78.704
1384.400	78.707
1384.500	78.710
1384.600	78.713
1384.700	78.715
1384.800	78.718
1384.900	78.721
1385.000	78.723
1385.100	78.726
1385.200	78.728
1385.300	78.730

1385.400	78.732
1385.500	78.736
1385.600	78.739
1385.700	78.742
1385.800	78.745
1385.900	78.748
1386.000	78.752
1386.100	78.755
1386.200	78.758
1386.300	78.761
1386.400	78.764
1386.500	78.766
1386.600	78.769
1386.700	78.772
1386.800	78.775
1386.900	78.778
1387.000	78.781
1387.100	78.784
1387.200	78.787
1387.300	78.790
1387.400	78.792
1387.500	78.795
1387.600	78.797
1387.700	78.800
1387.800	78.803
1387.900	78.805
1388.000	78.808
1388.100	78.811
1388.200	78.814
1388.300	78.817
1388.400	78.820
1388.500	78.824
1388.600	78.828
1388.700	78.831
1388.800	78.836
1388.900	78.840
1389.000	78.844
1389.100	78.847
1389.200	78.851

1389.300	78.855
1389.400	78.859
1389.500	78.863
1389.600	78.868
1389.700	78.872
1389.800	78.875
1389.900	78.879
1390.000	78.882
1390.100	78.885
1390.200	78.888
1390.300	78.891
1390.400	78.894
1390.500	78.898
1390.600	78.900
1390.700	78.902
1390.800	78.904
1390.900	78.906
1391.000	78.907
1391.100	78.909
1391.200	78.911
1391.300	78.912
1391.400	78.914
1391.500	78.916
1391.600	78.917
1391.700	78.918
1391.800	78.920
1391.900	78.922
1392.000	78.926
1392.100	78.930
1392.200	78.934
1392.300	78.939
1392.400	78.943
1392.500	78.947
1392.600	78.949
1392.700	78.951
1392.800	78.953
1392.900	78.958
1393.000	78.962
1393.100	78.968

1393.200	78.973
1393.300	78.978
1393.400	78.984
1393.500	78.990
1393.600	78.995
1393.700	79.000
1393.800	79.005
1393.900	79.008
1394.000	79.010
1394.100	79.012
1394.200	79.016
1394.300	79.025
1394.400	79.035
1394.500	79.042
1394.600	79.047
1394.700	79.052
1394.800	79.057
1394.900	79.062
1395.000	79.067
1395.100	79.071
1395.200	79.075
1395.300	79.079
1395.400	79.082
1395.500	79.085
1395.600	79.087
1395.700	79.089
1395.800	79.090
1395.900	79.093
1396.000	79.095
1396.100	79.097
1396.200	79.100
1396.300	79.102
1396.400	79.105
1396.500	79.108
1396.600	79.110
1396.700	79.112
1396.800	79.114
1396.900	79.116
1397.000	79.118

1397.100	79.120
1397.200	79.122
1397.300	79.124
1397.400	79.126
1397.500	79.129
1397.600	79.132
1397.700	79.136
1397.800	79.141
1397.900	79.145
1398.000	79.150
1398.100	79.155
1398.200	79.161
1398.300	79.167
1398.400	79.173
1398.500	79.179
1398.600	79.184
1398.700	79.190
1398.800	79.198
1398.900	79.207
1399.000	79.215
1399.100	79.223
1399.200	79.230
1399.300	79.238
1399.400	79.245
1399.500	79.252
1399.600	79.258
1399.700	79.263
1399.800	79.268
1399.900	79.272
1400.000	79.277
1400.100	79.280
1400.200	79.283
1400.300	79.285
1400.400	79.287
1400.500	79.288
1400.600	79.288
1400.700	79.289
1400.800	79.291
1400.900	79.293

1401.000	79.295
1401.100	79.298
1401.200	79.300
1401.300	79.303
1401.400	79.305
1401.500	79.307
1401.600	79.310
1401.700	79.314
1401.800	79.319
1401.900	79.323
1402.000	79.327
1402.100	79.332
1402.200	79.338
1402.300	79.346
1402.400	79.354
1402.500	79.364
1402.600	79.372
1402.700	79.380
1402.800	79.388
1402.900	79.397
1403.000	79.405
1403.100	79.413
1403.200	79.422
1403.300	79.429
1403.400	79.437
1403.500	79.444
1403.600	79.450
1403.700	79.456
1403.800	79.463
1403.900	79.470
1404.000	79.477
1404.100	79.485
1404.200	79.494
1404.300	79.502
1404.400	79.510
1404.500	79.517
1404.600	79.523
1404.700	79.530
1404.800	79.536

1404.900	79.541
1405.000	79.549
1405.100	79.557
1405.200	79.566
1405.300	79.576
1405.400	79.586
1405.500	79.597
1405.600	79.605
1405.700	79.613
1405.800	79.620
1405.900	79.627
1406.000	79.633
1406.100	79.640
1406.200	79.645
1406.300	79.650
1406.400	79.655
1406.500	79.660
1406.600	79.665
1406.700	79.669
1406.800	79.673
1406.900	79.677
1407.000	79.681
1407.100	79.685
1407.200	79.690
1407.300	79.693
1407.400	79.697
1407.500	79.701
1407.600	79.704
1407.700	79.708
1407.800	79.711
1407.900	79.715
1408.000	79.720
1408.100	79.726
1408.200	79.731
1408.300	79.737
1408.400	79.742
1408.500	79.747
1408.600	79.753
1408.700	79.759

1408.800	79.764
1408.900	79.770
1409.000	79.776
1409.100	79.782
1409.200	79.789
1409.300	79.796
1409.400	79.804
1409.500	79.811
1409.600	79.818
1409.700	79.824
1409.800	79.829
1409.900	79.836
1410.000	79.843
1410.100	79.851
1410.200	79.859
1410.300	79.865
1410.400	79.871
1410.500	79.877
1410.600	79.883
1410.700	79.888
1410.800	79.893
1410.900	79.898
1411.000	79.903
1411.100	79.907
1411.200	79.912
1411.300	79.916
1411.400	79.920
1411.500	79.925
1411.600	79.931
1411.700	79.936
1411.800	79.941
1411.900	79.947
1412.000	79.952
1412.100	79.957
1412.200	79.961
1412.300	79.965
1412.400	79.968
1412.500	79.972
1412.600	79.976

1412.700	79.979
1412.800	79.983
1412.900	79.985
1413.000	79.988
1413.100	79.990
1413.200	79.993
1413.300	79.997
1413.400	80.001
1413.500	80.004
1413.600	80.009
1413.700	80.014
1413.800	80.019
1413.900	80.024
1414.000	80.030
1414.100	80.035
1414.200	80.041
1414.300	80.047
1414.400	80.054
1414.500	80.061
1414.600	80.066
1414.700	80.071
1414.800	80.075
1414.900	80.079
1415.000	80.082
1415.100	80.085
1415.200	80.087
1415.300	80.090
1415.400	80.092
1415.500	80.094
1415.600	80.096
1415.700	80.099
1415.800	80.102
1415.900	80.105
1416.000	80.108
1416.100	80.112
1416.200	80.115
1416.300	80.118
1416.400	80.122
1416.500	80.125

1416.600	80.129
1416.700	80.133
1416.800	80.138
1416.900	80.142
1417.000	80.147
1417.100	80.152
1417.200	80.156
1417.300	80.161
1417.400	80.166
1417.500	80.170
1417.600	80.173
1417.700	80.176
1417.800	80.179
1417.900	80.182
1418.000	80.184
1418.100	80.187
1418.200	80.189
1418.300	80.192
1418.400	80.195
1418.500	80.198
1418.600	80.200
1418.700	80.204
1418.800	80.209
1418.900	80.213
1419.000	80.219
1419.100	80.224
1419.200	80.229
1419.300	80.232
1419.400	80.235
1419.500	80.239
1419.600	80.244
1419.700	80.250
1419.800	80.256
1419.900	80.261
1420.000	80.266
1420.100	80.271
1420.200	80.277
1420.300	80.283
1420.400	80.289

1420.500	80.295
1420.600	80.300
1420.700	80.306
1420.800	80.311
1420.900	80.316
1421.000	80.322
1421.100	80.327
1421.200	80.332
1421.300	80.337
1421.400	80.343
1421.500	80.348
1421.600	80.355
1421.700	80.361
1421.800	80.369
1421.900	80.375
1422.000	80.382
1422.100	80.387
1422.200	80.394
1422.300	80.399
1422.400	80.405
1422.500	80.411
1422.600	80.416
1422.700	80.422
1422.800	80.428
1422.900	80.434
1423.000	80.440
1423.100	80.445
1423.200	80.450
1423.300	80.456
1423.400	80.461
1423.500	80.468
1423.600	80.475
1423.700	80.482
1423.800	80.488
1423.900	80.493
1424.000	80.499
1424.100	80.506
1424.200	80.512
1424.300	80.519

1424.400	80.525
1424.500	80.531
1424.600	80.536
1424.700	80.542
1424.800	80.550
1424.900	80.557
1425.000	80.564
1425.100	80.570
1425.200	80.575
1425.300	80.580
1425.400	80.584
1425.500	80.589
1425.600	80.594
1425.700	80.600
1425.800	80.604
1425.900	80.609
1426.000	80.613
1426.100	80.616
1426.200	80.620
1426.300	80.623
1426.400	80.626
1426.500	80.629
1426.600	80.632
1426.700	80.634
1426.800	80.637
1426.900	80.639
1427.000	80.643
1427.100	80.647
1427.200	80.650
1427.300	80.653
1427.400	80.657
1427.500	80.661
1427.600	80.665
1427.700	80.670
1427.800	80.674
1427.900	80.677
1428.000	80.679
1428.100	80.682
1428.200	80.684

1428.300	80.686
1428.400	80.688
1428.500	80.691
1428.600	80.693
1428.700	80.697
1428.800	80.701
1428.900	80.705
1429.000	80.710
1429.100	80.716
1429.200	80.723
1429.300	80.731
1429.400	80.737
1429.500	80.741
1429.600	80.745
1429.700	80.749
1429.800	80.753
1429.900	80.758
1430.000	80.763
1430.100	80.771
1430.200	80.780
1430.300	80.789
1430.400	80.797
1430.500	80.804
1430.600	80.811
1430.700	80.817
1430.800	80.823
1430.900	80.829
1431.000	80.836
1431.100	80.841
1431.200	80.846
1431.300	80.851
1431.400	80.854
1431.500	80.857
1431.600	80.861
1431.700	80.863
1431.800	80.867
1431.900	80.870
1432.000	80.875
1432.100	80.879

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1432.300	80.888
1432.400	80.893
1432.500	80.898
1432.600	80.902
1432.700	80.907
1432.800	80.911
1432.900	80.915
1433.000	80.919
1433.100	80.924
1433.200	80.927
1433.300	80.931
1433.400	80.937
1433.500	80.942
1433.600	80.947
1433.700	80.952
1433.800	80.958
1433.900	80.963
1434.000	80.969