3 NINE GEO-MORPHOLOGICAL DANUBE REACHES

3.1 Introduction

The Danube River is the second largest stream in Europe spanning between its source and its mouth in the Black Sea a total of 2,857 km and covering an overall catchment area of 817,000 km². A broad spectrum of variation is found along the Danube's longitudinal, lateral and vertical stretch. Chemical parameters as well as aquatic Danubian organisms adapt and change dynamically in a close interaction with its connected environment. In river basins in general, geo-morphological landscape features strongly impact the rivers' abiotic and biotic condition by setting the basic framework for their genesis influencing such parameters as discharge, slope, depth or sediment transport. Based on this general frame, the key hydraulic and morphological features of a river develop over space and time, forming riverine habitats characterised by specific chemical and biological parameters.

3.2 Definition Procedure

For the purpose of the Joint Danube Survey data evaluation, the entire course of the Danube was divided into nine so-called geo-morphological Reaches. This sectioning was largely based on the geo-morphological features of the Danube Basin landscape, but the impact of anthropogenic action such as damming or significant emission inputs were also considered. However, the division of the longitudinal Danube stretch into these nine Reaches should enable the evaluation of possible interactions or correlation of basic geo-morphological and anthropogenic impact features with in-stream measured chemical and ecological characteristics. Consequently, the presentation of biological results in particular was done with reference to the nine defined Danube Reaches.

According to literature, several different authors have divided the Danube Basin into separate units based on specific criteria. On a rough catchment scale, Lászlóffy (1967) sectioned the Danube River into four general units (Upper, Middle, Lower Danube and the Danube Delta) based on geo-morphological and hydrological features. Within Lászlóffy's division, the upper Danube covers a length of 900 river km strongly influenced by the discharges of the Isar, the Inn, the Traun and the Enns tributaries. The Middle Danube section starts where the Danube enters the Carpatian Basin and stretches over 925 longitudinal river km. The major tributaries influencing the hydrology of the Danube within this section include the Drava, the Tisza, the Sava and the Velika Morava rivers. The Lower Danube section stretches over 885 river kilometres from the point where the Danube breaks through the Carpatian Mountains and passes through the Walachian Lowlands. Its major tributaries in that section include the Siret and the Prut rivers. The last section is represented by the arms of the Danube Delta.

Lászlóffy (1967) revised the above described sectioning of the Danube by integrating into it the "slope" parameter, which resulted in six defined Danube sections. It should be noted that neither the Iron Gate Dam nor the Gabcikovo hydroelectric power plant existed at the time this sectioning was made. Therefore, the former cataracts, which characterised the flow of the Danube River as it breaks through the Carpatian and Balkan Mountains, forms a characteristic section of its own.

As a result of regional co-operation between the Danube countries, the Danube Basin was in 1986 divided into the following three major sections shown in the hydrological monograph of the Danube and its Basin.

- The Upper Danube section from the source in Germany to the "Porta Hungarica" eastwards of Vienna. "Porta Hungarica" connects the eastern foothills of the Alps with the small Carpatian Mountains below the Morava confluence.
- The Middle Danube section stretches from "Porta Hungarica" to the point where the River breaks through the southern Carpatians and the Balkan Mountains before the Iron Gate hydroelectrical power plant.
- The Lower Danube section is defined by the Romanian and Bulgarian lowlands includ--ing the catchments of the Prut and Siret rivers and their surrounding mountains.

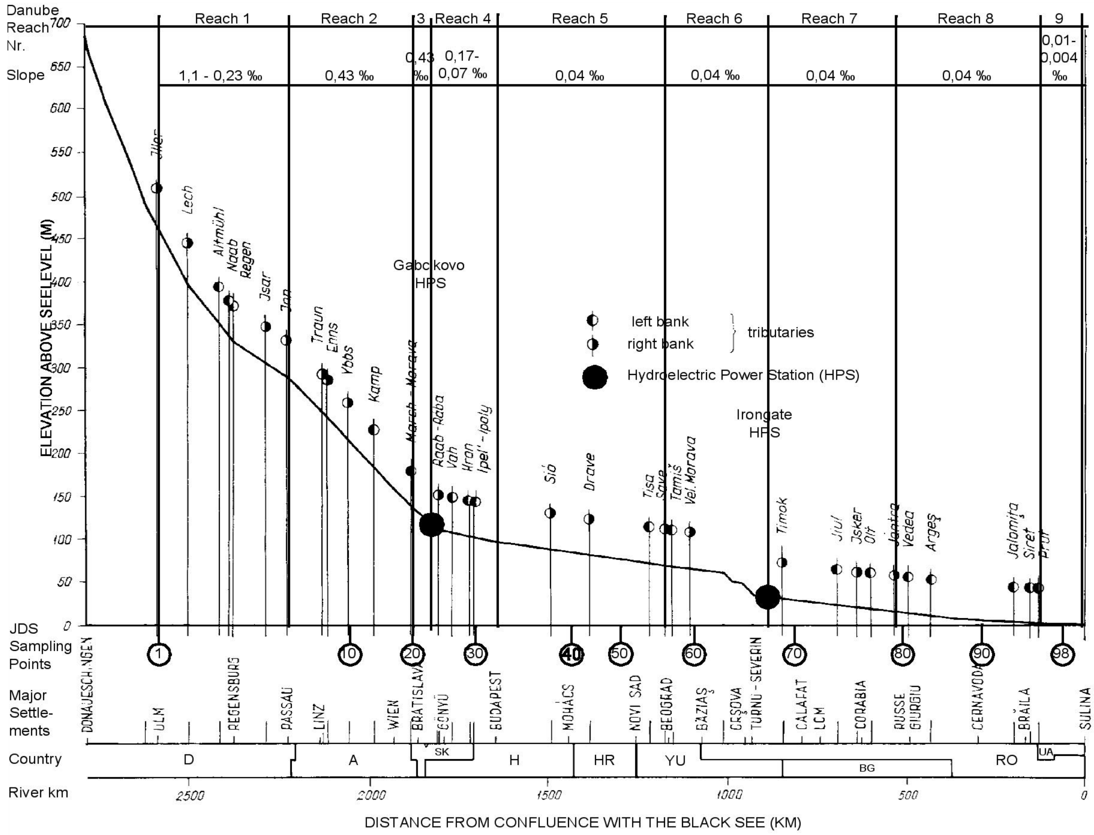


FIGURE GEO-1: Schematic longitudinal profile of the Danube River including the nine JDS Danube Reaches, major tributaries, major settlements, large hydroelectric power plants, Danube countries and a scale for JDS sampling points. Modified after Lászlóffy (1967).

In defining the geo-morphological Reaches of the Danube for the purpose of JDS, the above-described knowledge was used as a sound starting point. Emphasis was placed on geo-morphological elements including geology, topography, hydrology, slope or regional landscape characteristics. However, given the specific objectives of JDS, the criteria used in the previous divisions of the Danube were this time supplemented by aspects of major anthropogenic impacts on the Danube River, ultimately leading to the division of the River into the nine Reaches.

In terms of anthropogenic impacts, emphasis was placed on those that influence both the abiotic (pyhsical and chemical parameters) and the biotic (aquatic biota) condition of the Danube River. Such criteria include big impoundments affecting abiotic parameters (e.g. flow, morphology, sediment transport) and biological development (e.g. interruption of river continuum, change of habitat conditions). Hence, the Reaches of the Danube River impacted by the big impoundments (Gabcikovo and Iron Gate reservoir) are defined as individual Reaches of anthropogenic impact starting at the head of the impoundment and ending at the dam construction. Additionally, emissions from point sources of pollution (big cities, e.g., Budapest and Belgrade) were used for setting Reach borders. Figure GEO-1 illustrates a modification of the schematic longitudinal Danube Reach as defined by Lászlóffy in 1967, including the nine geo-morphological Reaches defined for the purpose of JDS considering current anthropogenic impacts on the Danube River.

3.3 Description of the Danube Reaches

Based on the above-mentioned considerations of the Danube Basin's geo-morphology and significant anthropogenic impacts on the river, Table GEO-1 provides information on the nine defined geo-morphological Reaches delineating the longitudinal extent of each of these Reaches, their assigned number and river kilometre. Further, Figure GEO-2 illustrates the nine geo-morphological Danube Reaches in the form of a map providing an overview of the borders, the number of JDS sampling points and river kilometres of each Reach.

TABLE GEO-1: Danube Reaches based on geo-morphology and anthropogenic impact

Reach Nr.	Longitudinal stretch according to JDS points	River km
1	Neu Ulm (JDS 1) – Confluence with River Inn (JDS 5)	2581 – 2225
2	the Inn River (JDS 5) – Confluence with the Morava River (JDS 16)	2225 – 1880
3	the Morava River (JDS 16) – Gabcikovo Dam (river km 1816)	1880 – 1816
4	Gabcikovo Dam – Budapest end of side arm (JDS 35)	1816 – 1659
5	Budapest (JDS 35) – Confluence with the Sava River (JDS 55)	1659 – 1202
6	the Sava River / Belgrade (JDS 55) – Iron Gate Dam	1202 – 943
7	Iron Gate Dam – Confluence with the Jantra River (JDS 81)	943 – 537
8	the Jantra River (JDS 81) – Reni (JDS 95)	537 – 132
9	Reni (JDS 35) – Black Sea / Danube Delta arms (JDS 96 - 98)	132 – 12

Under the Joint Danube Survey, sampling was performed between Neu Ulm and the last three sampling sites in the Danube Delta. This left outside the sampling programme the upper section of the River defined by its source at the confluence of the Brigach and the Breg rivers and the point where it breaks through the Swabian Alb mountain range. Within this upper section, the Danube has a low discharge and even loses water by infiltration into its surrounding environment at Immendingen. The section that follows (Danube Reach 1) provides a significant discharge input from several tributaries and changes the Danube's appearance.

What follows is a description of the nine JDS Danube Reaches with their geo-morphological and anthropogenic impact characteristics.

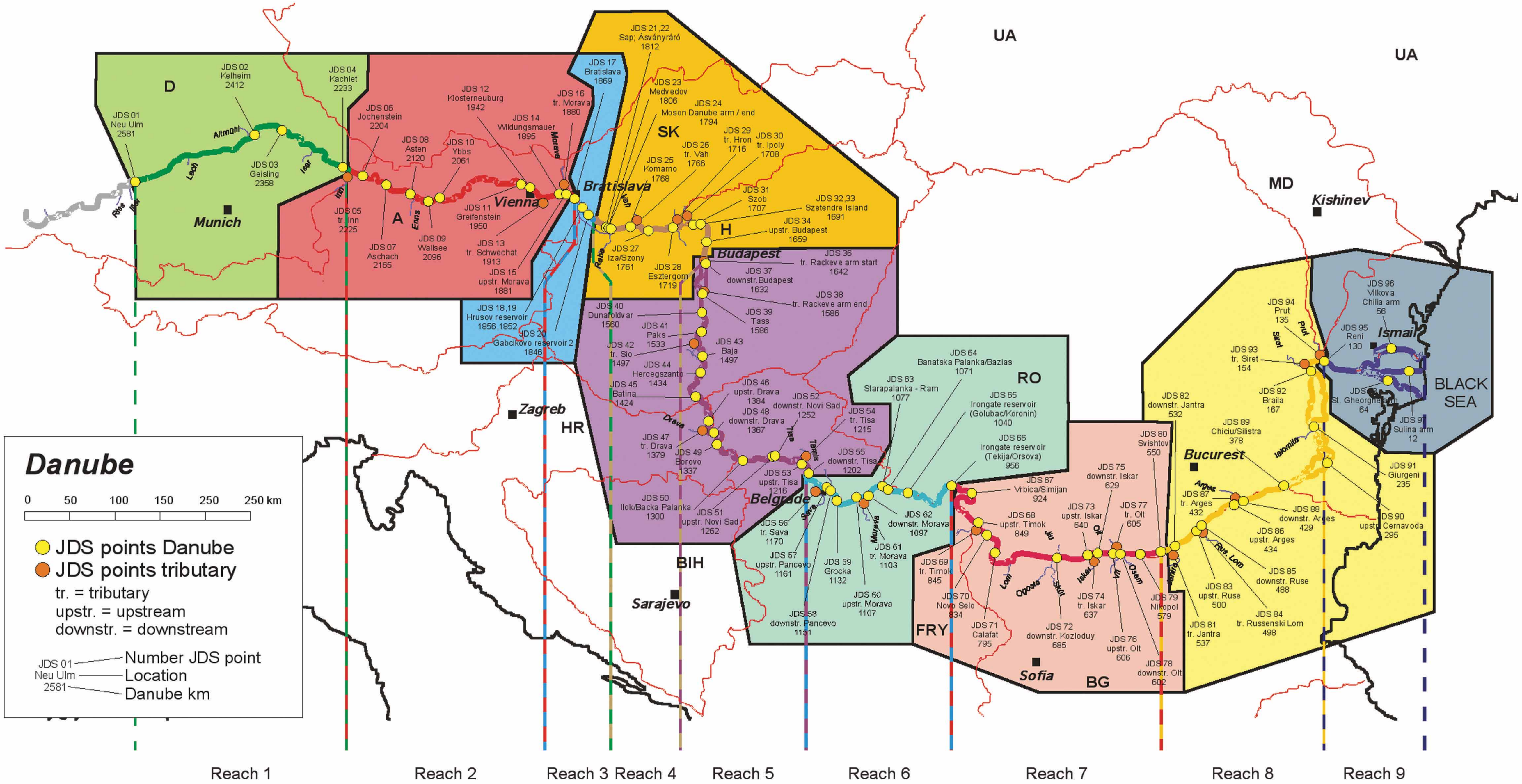
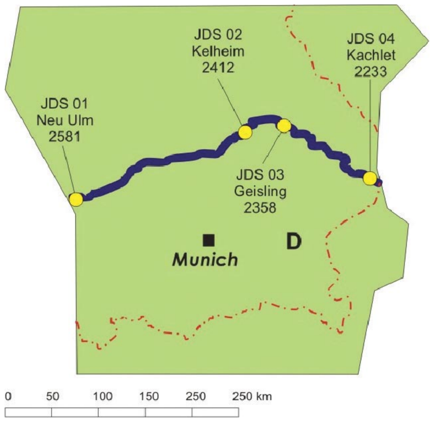


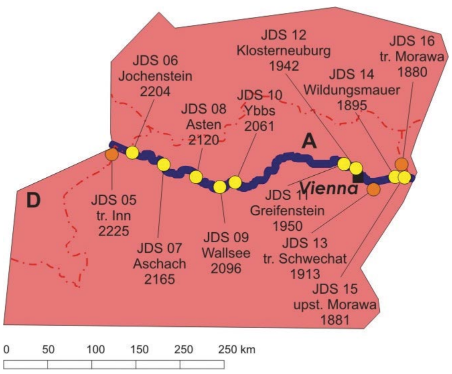
FIGURE GEO-2: Geo-morphological Reaches of the entire Danube stretch covered by JDS with JDS sampling point name, number and its assigned river kilometre.

GEO-MORPHOLOGICAL REACH 1



Danube Reach 1 stretches over 356 river km between Neu Ulm (JDS1) and the Danube's confluence with the Inn River. Four JDS sampling points were situated within this Reach. The Danube defines the southern border of the low mountain range of the Swabian Alb while the stream itself is bordered by the southern stretches of the Bavarian alpine foothills. Within this Reach, the Danube receives important hydrological discharge input from the Iller, the Lech and the Isar tributaries. Due to its alpine hydrological regime, the Iller River contributes to the Danube substantial amount of sediment and water changing it into a larger stream (Danube Hydrological Monography, 1986). Although the Danube's continuum is interrupted by hydroelectric power plants, it still remains a typical stream of the rhitron (upland section of a river) within this Reach. The slope of this Danube Reach decreases from 1,1 ‰ (Neu Ulm) to 0,23 ‰ (Danube Hydrological Monograph, 1986) at the confluence with the Inn River (KWD, 1996). The Inn River defines the border with the Danube Reach 2. The Inn River discharges into the Danube with a mean annual runoff of 727 m^3/s (Hydrographischer Dienst Österreich, 1996) and therefore strongly influences the Danube in its further flow regime and resulting conditions (chemical/biological).

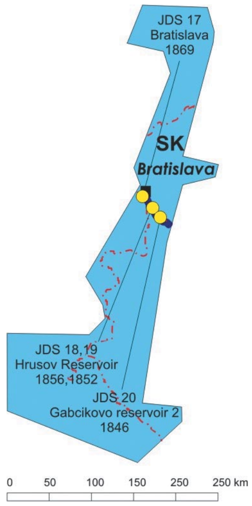
GEO-MORPHOLOGICAL REACH 2



Danube Reach 2 (345 river km) is situated between the confluence of the Inn River and the "Porta Hungarica" at the confluence of the Morava River 22 JDS sampling points were placed within this Reach. As mentioned above, the Inn River influences the further condition of the Danube with a mean discharge of 737 m^3/s, changing its temperature, suspended matter load and transparency values. Again, this river stretch is characterised by continuum interruptions due to hydroelectric power plants. Nevertheless, high flow velocities and reduced visibility caused by the glacial influence of the Inn River were recorded during JDS. Important discharging tributaries include the Traun and the Enns rivers. The mean slope of 0,43 ‰ (Danube Hydrological Monograph, 1986) changes only downstream beyond Bratislava. Overall, same as Reach 1, this Danube Reach represents a typical alpine stream. In terms of geo-morphology, the Danube passes the canyon Reach of the Strudengau and Nibelungengau and flows on through the narrow valley of the Wachau. After passing the basin of Vienna, the Danube is characterised by alluvial forests on both river banks until the end of this Reach at the confluence with the Morava River.

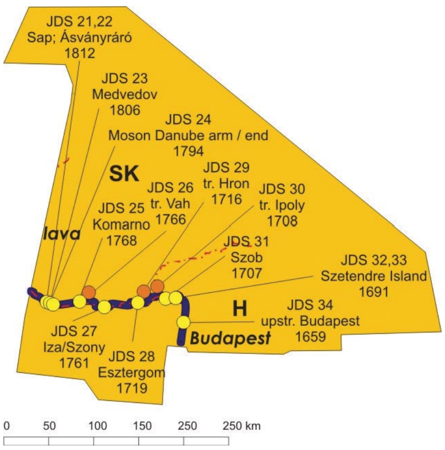
GEO-MORPHOLOGICAL REACH 3

Three JDS sampling sites were located along the 64-km-long Reach 3 of the Danube. This Reach was defined based on the anthropogenic impact caused by the construction of the dam



for the Gabcikovo hydroelectric power plant. Reach 3 starts at the root of the dam's headwater and ends at the dam itself. Gabcikovo reservoir is characterised by typical features of a dammed river section. Within reservoirs, abiotic and biological characteristics of running waters turn to stagnant lake systems. Flow velocities are reduced by a broadened width profile causing a further change in the process of sedimentation (accumulation of fine sediments). This increased sedimentation of fine suspended sediment results in higher transparency values. This shift of abiotic parameters further affects and changes the riverine biological composition (e.g. macrozoobenthos, macrophytes, phytoplankton, zooplankton etc.) as habitat structures within reservoirs are poor and limited. In terms of geo-morphology, in Reach 3 the Danube leaves the alpine foothills behind and breaks through the small Carpatian mountain range. The mean slope within this Reach is 0,43 ‰.

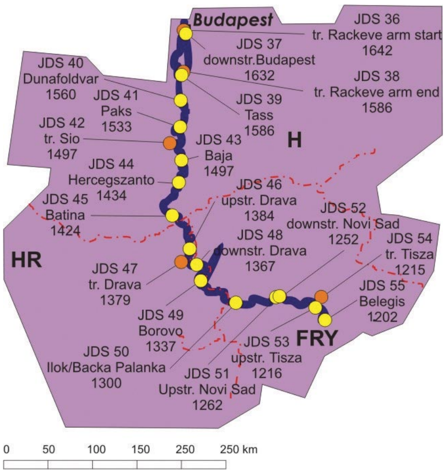
GEO-MORPHOLOGICAL REACH 4



Reach 4 covers 157 river km between the Gabcikovo Dam and JDS sampling site 35 (upstream of Budapest). Within this Reach (between Gabcikovo Dam and the confluence with the Vah River) the Danube starts to develop from an alpine (rhithron) to a lowland (potamon) river. This shift is associated with changing abiotic, chemical and biological conditions of the River. Morphologically significant and characteristic for such a region is the formation of islands that are the result of sedimentation of the bed load transported from the upper parts of the river with higher drag forces. There are a few islands within this Reach, e.g. at Szetendre. The change from an alpine to a lowland river is also reflected in the decreasing slope values. While the Danube's slope amounts to around 0,43 ‰ before Bratislava, a decreased slope of 0,07 ‰ (Danube Hydrological Monograph, 1986) is recorded at Budapest. Additionally, the Danube's horizontal profile widens within this Reach. After the confluence with the Vah Rive and after Komarno, the Danube River cuts through the Hungarian Highlands before flowing through the large Hungarian lowlands after Budapest. Its major tributaries include the Rába, the Vah, the Hron and the Ipoly rivers. On the one hand the border of Danube Reach 4 is set before Budapest because of the geo-morphological situation described above. At the same time, however, the anthropogenic impact caused by significant wastewater emissions from Budapest was also considered.

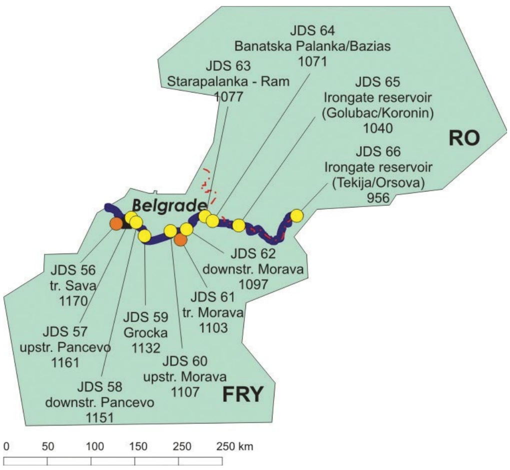
GEO-MORPHOLOGICAL REACH 5

Reach 5 covers 457 river km starting at Budapest and ending before the confluence with the Sava River at Belgrade. 36 JDS sampling points were placed along this stretch. In this Reach, the emissions of untreated wastewaters of the city of Budapest strongly impact the River's chemistry and biology. The lowland character of the Danube becomes very distinct. In terms of morphology, the horizontal Danube profile widens significantly in this section and its slope



further decreases to 0,04 ‰ (Danube Hydrological Monograph, 1986). With increasing distance from the beginning of Reach 5, artificial bank constructions decrease and the Danube assumes the appearance of a free-flowing river. Due to its lowland character, the composition of the river banks turns more frequently to sand and finer sediments resulting in more gentle bank slopes. Alluvial forests characterise the bordering landscape. Reported transparency values are in the medium range and a full range of flow velocities was registered. Major tributaries include the alpine Drava River and the lowland Tisza River both contributing considerable hydrological discharges.

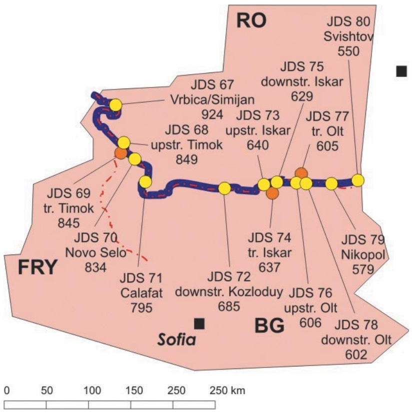
GEO-MORPHOLOGICAL REACH 6



Reach 6 extends between the confluence of the Sava River and the Iron Gate Dam (259 river km, 20 JDS sampling points). This Reach is defined by both distinct geo-morphological features and anthropogenic impacts. Anthropogenic impacts are the result of significant emissions of untreated wastewater in the Belgrade area and the impact of the Iron Gate Dam. The headwaters of the Iron Gate Dam impact the flow behaviour of the Danube up to Belgrade and cause the characteristic shift from a riverine to a stagnant lake system (see Reach 3). Flow velocities are low and continue to decrease as the River approaches the Dam. Aquatic communities adapt to these reservoir conditions and might therefore differ slightly from those in the upper Reaches. The Danube is connected with its neighbouring terrestrial environment by alluvial forests. Typical for a lowland river and for dammed river sections, the river banks are dominated by fine substrates except along the canyon Reach of the Iron Gate. In terms of geo-morphology, the Danube breaks through the Carpatian and Balkan Mountains passing narrow canyons sometimes widening into broader reservoirs. Before the Iron Gate Dam was constructed, this Reach used to be marked by very turbulent flows and cataracts. After the construction, the horizontal profile of the Danube was significantly widened. While the mean slope within this Reach is 0,04 ‰, slope values within the canyon Reach increase up to 0,25 ‰ (see Fig. GEO-1.) Concerning hydrological discharge input, the Sava and the Velika Morava rivers contribute significantly.

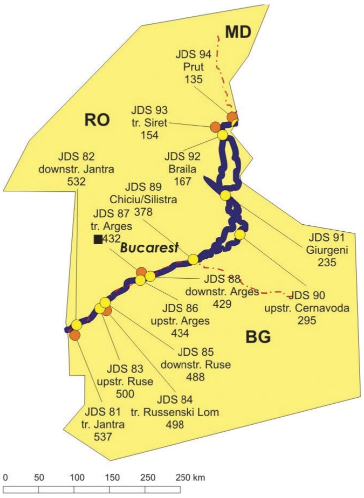
GEO-MORPHOLOGICAL REACH 7

Reach 7 (406 river km, 25 JDS sampling points) stretches between the Iron Gate Dam and the confluence with the Jantra River in Bulgaria The Danube flows through the Walachian lowlands and passes along the foothills of the middle Balkan Mountains. The geo-morphological landscape is dominated by aeolian sediments and loess. In this Reach, the right river bank of the Danube (Bulgaria) shows a characteristic landscape feature. After a narrow stretch of gen-



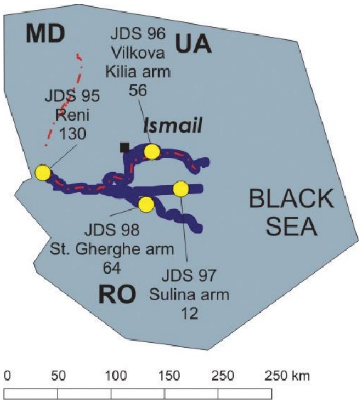
tle river banks, steep sediment walls (up to 150m) rise up to the neighbouring terrestrial environment. Alluvial forests are better developed on the left Danube bank (Romania). Mean slope values within this Reach amount to 0,04 ‰ (Danube Hydrological Monograph, 1986) and do not vary much until the Danube Delta. Downstream of the Iron Gate impoundment there are no more dams to interrupt the free flow of the Danube. Therefore, from that point on the Danube is a predominantly free-flowing stream with connected alluvial forests. In Reach 7, higher flow velocities were recorded and significantly high transparency values (up to 280 cm) were measured over a Danube stretch of about 380 km (starting after the Iron Gate Dam) during JDS. Reach 7 is marked by the discharge of he Olt and the Iskar rivers.

GEO-MORPHOLOGICAL REACH 8



Reach 8 covers 405 river km from the Jantra to the Reni rivers. 23 JDS sampling points were placed along this section of the Danube. As mentioned above, the mean slope within this free-flowing Danube section stands at 0,04 ‰. Landscape geo-morphology is characterised by features similar to those found in Reach 7 with some noticeable distinct features. The Danube splits twice into two arms generating large islands between them. These alluvial islands include Balta Ialomitei and Balta Brailei. Reaching the end of this stretch, where the Dobrujan foothills merge into the Bessarabian Plateau, the Danube receives significant discharge inputs from the Prut and the Siret rivers. Concerning abiotic parameters, decreasing transparency values were measured due to a higher load of suspended sediments.

GEO-MORPHOLOGICAL REACH 9



Reach 9 represents the 120-river-km section of the Danube Delta where four JDS sampling sites were located. The Danube Delta consists of three major arms (Kilia, Sulina, and St. Gheorghe) with connected wetlands between them. With its wetlands and estuaries the Danube Delta provides unique habitats for a variety of biological communities. Another significant feature of the Delta is the chemical interaction of the main stream with these connected wetlands. Nutrient dynamics (retention and input processes) play an important role. Slope values range between 0,4 ‰ and 0,001 ‰. The Danube Delta receives discharge input from the Prut and the Siret rivers (see Reach 8).

3.4 Summary

The division of the Danube River into nine geo-morphological reaches described in this chapter takes into consideration significant anthropogenic impacts on the River. Geo-morphological landscape features strongly impact the chemical and biological condition of running waters. By setting a basic framework marked by specific parameters (e.g. discharge, slope, depth, width or sediment transport), geo-morphology plays a crucial role in the development of hydraulic and morphological elements. These elements further determine the variety and quality of riverine habitats for aquatic organisms and plants. The Danube River integrates into its catchment a range of diverse morphological patterns and reflects this variation in a broad spectrum of chemical and ecological variation from its source to its confluence with the Black Sea.

The division of the Danube into nine Reaches provides a clear picture of the most important geo-morphological characteristics of the River. At the same time, significant anthropogenic impact points out major changes in the River's morphology and the quality of its water. The impact of damming (Gabcikovo Dam, Iron Gate Dam) and significant emissions of untreated wastewater into the Danube at Budapest and Belgrade were taken into account in defining the borders of the nine Reaches.

The charcteristics of the nine geo-morphological Reaches as defined for the purposes of JDS can roughly be summarized as follows:

Reach 1: *Neu Ulm - confluence with the Inn River (river km 2581-2255)*
Alpine (rhithron) river character, anthropogenic impact by hydroelectric power plants.

Reach 2: *The Inn River - Confluence with the Morava River (river km 2225-1880)*
Alpine (rhithron) river character, anthropogenic impact by hydroelectric power plants.

Reach 3: *The Morava River – Gabcikovo Dam (river km 1880-1816)*
Anthropogenic impact by the construction of Gabcikovo Dam.

Reach 4: *Gabcikovo Dam – Budapest (upstream, river km 1816-1659)*
Starting development from alpine (rhitron) to lowland (potamon) river, the Danube passes the Hungarian Highlands.

Reach 5: *Budapest (upstream) – confluence with the Sava River (river km 1659-1202)*
Lowland river; the Danube passes the Hungarian Lowlands; anthropogenic impact by significant emissions of untreated wastewater at Budapest.

Reach 6: *The Sava River/Belgrade – Iron Gate Dam (river km 1202-943)*
Lowland river; the Danube breaks through the Carpatian and the Balkan Mountains; anthropogenic impact by damming effects of Iron Gate hydroelectric power plant and significant emission input of untreated wastewaters at Belgrade.

Reach 7: *Iron Gate Dam – confluence with the Jantra River (river km 943-537)*
Lowland river; the Danube flows through the Walachian Lowlands (Aeolian sediments and loess); steep sediment walls (up to 150 m) characterise the Bulgarian river bank.

Reach 8: *The Jantra River – Reni (river km 537-132)*
Lowland river; alluvian islands between two Danube arms.

Reach 9: *Reni – Black Sea / Danube Delta arms (river km 132 – 12)*
The Danube splits into three Delta arms; characteristic wetland and estuary ecosystem; slopes decrease to 0,01 ‰.

Defined in this way, i.e. based on both geo-morphological and anthropogenic aspects, the nine Danube reaches should enable a better understanding of the chemical and ecological results obtained during the Survey.

3.5 References

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