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Risk Assessment Related to the Sediment Regime of the Danube

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Project Introduction

Sediments are a natural part of aquatic systems. During the past centuries, humans have strongly altered the Danube River. Riverbed straightening, hydropower dams and dikes have led to significant changes in the sediment load. This sediment imbalance contributes to flood risks, reduces navigation possibilities and hydropower production. It also leads to the loss of biodiversity within the Danube Basin.

The Danube near Hainburg, Austria. (Philipp Gmeiner/ IWA-BOKU)

To tackle these challenges, 14 project partners and 14 strategic partners came together in the DanubeSediment project. The partnership included numerous sectoral agencies, higher education institutions, hydropower companies, international organisations and nongovernmental organisations from nine Danube countries.

Closing knowledge gaps: In a first step, the project team collected sediment transport data in the Danube River and its main tributaries. This data provided the foundation for a Danube-wide sediment balance that analysed the sinks, sources and redistribution of sediment within the Danube - from the Black Forest to the Black Sea. In order to understand the impacts and risks of sediment deficit and erosion, the project partners analysed the key drivers and pressures causing sediment discontinuity.

Strengthening governance: One main project output is the Danube Sediment Management Guidance (DSMG). It contains recommendations for reducing the impact of a disturbed sediment balance, e.g. on the ecological status and on flood risk along the river. By feeding into the Danube River Management Plan (DRBMP) and the Danube Flood Risk Management Plan (DFRMP), issued by the International Commission for the Protection of the Danube River (ICPDR), the project directly contributes to transnational water management and flood risk prevention.

International Training Workshops supported the transfer of knowledge to key target groups throughout the Danube River Basin, for example hydropower, navigation, flood risk management and river basin management, which includes ecology. The project addressed these target groups individually in its second main project output: The Sediment Manual for Stakeholders. The document provides background information and concrete examples for implementing good practice measures in each field.

DanubeSediment was co-funded by the European Union ERDF and IPA funds in the frame of the Danube Transnational Programme. Further information on the project, news on events and project results are available here: www.interreg-danube.eu/danubesediment.

Project Reports

The DanubeSediment project was structured into six work packages. The main project publications are listed below. You will find all eleven reports on our website: www.interreg-danube.eu/approved-projects/danubesediment/outputs.

1) Sediment Monitoring in the Danube River
2) Analysis of Sediment Data Collected along the Danube
3) Handbook on Good Practices in Sediment Monitoring
4) Data Analyses for the Sediment Balance and Long-term Morphological Development of the Danube
5) Assessment of the Sediment Balance of the Danube
6) Long-term Morphological Development of the Danube in Relation to the Sediment Balance
7) Interactions of Key Drivers and Pressures on the Morphodynamics of the Danube
8) Risk Assessment Related to the Sediment Regime of the Danube
9) Sediment Management Measures for the Danube
10) Danube Sediment Management Guidance
11) Sediment Manual for Stakeholders

Risk Assessment Related to the Sediment Regime of the Danube

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Introduction

Sediments play an important role in maintaining fluvial environments such as channel systems, floodplains, wetlands and estuaries, an equilibrium between erosion and deposition usually occurring along a river course. Human economic activities such as navigation, hydropower, and extractive industry led to significant changes of natural sediments balance and transport along many rivers in Europe. The Danube, as the second longest river in Europe, is subject to changes in terms of hydrological and ecological aspects over large stretches.

This report addresses the issues related to the environmental risks associated with the hydromorphological (including sediments) and biological alterations of the Danube River. The overall guidance documents on the assessment of hydromorphological features in rivers and of water quality are: the CEN Guidance "Water quality – Guidance standards" (EN14614:2004 (CEN 2004) and CEN "Water quality – Guidance standard on determining the degree of modification of river hydromorphology" EN 15843:2010 (CEN 2010).

'River condition assessment' aims to measure both "pressure" and "response" variables (hydromorphological and biological quality indicators). This provides the means to develop a clear understanding of the pressure – response (i.e. cause – effect) relationships that regulate observed changes in system conditions. This in turn allows a better identification of the impacts that a pressure has as well as an assessment of the risk to both hydromorphology and biology (Rinaldi et al., 2013).

The risk methodology proposed within the project brings up a flexible conceptual model that aims to integrate the significant hydromorphological drivers and pressures on the sediment continuity and sediment balance, considering the spatial and temporal changes of suspended sediment load and bedload transport.

1 Methodology of risk assessment related to sediment regime

1.1 General overview

The current methods for hydromorphological risk assessment are briefly presented below. A focus is put on highlighting their strengths and limitation, stressing the need for developing a more comprehensive methodology.

An increasing discrepancy between the surplus and deficit of sediment is observed in the Danube Basin, e.g. reservoir sedimentation and deficit of sediment, leading to riverbed erosion and coastal erosion in the Danube Delta. This imbalance contributes to flood risk, reduces navigation possibilities, reduces hydropower production, deteriorates the ecological conditions of the Danube River and alters the ground water level.

According to the Danube Basin Analysis 2013 (JDS3), the key driving forces causing continuity interruption are hydropower generation (45%), flood protection (18%) and water supply (13%)[1]. In many cases, barriers are not linked to a single purpose due to their multifunctional characteristics, e.g. hydropower use and navigation or hydropower use and flood protection. The project report on "Interactions of Key Drivers and Pressures on the Sediment Balance of the Danube" contains more details.

The actual status of the hydromorphology in the Danube River Basin and the sediment regime parameters show a heavily disturbed system at various scales. The combined effects of different drivers, such as hydropower, navigation and flood protection, are responsible for the alterations in the sediment regime, e.g. a lack of bed load and suspended load in the remaining free-flowing sections.

River channel and watercourse activities, such as channel deepening, channel widening, channel regrading and channel realignment, alter the physical characteristics of the water body and therefore change the velocity and variability of flows. They impact the sediment regime, for example by transferring sediment through a straightened system and reducing diversity or increasing sedimentation in over-widened or deepened sections (EEA, 2010).

Chains of **hydropower plants** in the Danube itself and along many tributaries (approximately 700 large dams)[2] interrupt the natural transport of sediments. Hydropower acts on the natural hydrological regime, especially due to the river dams, weirs, and water storage.

[1] https://www.icpdr.org/main/dba-2013
[2] https://www.icpdr.org/main/activities-projects/danube-basin-analysis-report-2004

Navigation is a traditional activity on the Danube River. At present, the Danube is navigable from Kelheim (river kilometre (rkm) 2411) to the Delta, so the Danube serves as an international waterway (Via Donau, 2004). These 2411 km are equivalent to 87 % of the Danube's length. 78 harbours are located on the navigable Danube. Therefore, navigation is of multilateral importance (ICPDR, 2005).

Navigation, through dredging for channel deepening, ship locks, groynes and river regulation (i.e. the modification of the river bank), alters the physical characteristics of the water body and therefore has the potential to change the sediment regime. For example, changes in flow velocity can increase sediment transport in a straightened area of the river or increase sedimentation in over-widened to deepened sections.

The Danube River Basin has been the site of many disastrous floods in the past. In the last two decades, severe floods have been registered in 2002, 2006, 2010, 2013 and 2014. The massive floods in 2002 and 2006 were caused by high amounts of precipitation over a short period. In contrast, 2010 was a year with scattered rainfall throughout the whole year and throughout most of the Danube River Basin. This led to a high number of damaging flood events on the local level. Structural, traditional engineering measures like dams, dykes and draining systems play a significant role in **flood protection**. At the same time, they contribute to the alteration of the sediment regime on a significant stretch of the Danube River and its tributaries.

Degradation of the riverbed caused by changes in substrate composition can lead to severe ecological problems. When lateral erosion is limited due to the stabilisation of the navigation channel, the natural sediment exchange with the floodplain is no longer balanced. Dredging the channel bed usually destroys, or at least disrupts, the environmental features, creating a more uniform, less stable and less diverse environment.

The above-mentioned pressures all affect the flow regime through changes in the seasonal flow, daily flow (hydro-peaking) and water level fluctuations. In addition, river stretches may dry up and the water levels of lakes and reservoirs may be heavily impacted. Alterations of the flow regime directly act on aquatic ecosystems, e.g. through modification of physical habitat, erosion, sediment supply rates and sediment transport. Barriers, such as dams and weirs, have an effect on the natural sediment transport, resulting in retention of sediment upstream of dams and loss of sediment downstream of dams, which changes the suspended sediment balance. River dams also cause a deepening of the downstream riverbed. In order to compensate the deficit of sediments, the river gathers material from the river bottom. Along certain stretches, this can cause the river to "dig into" the landscape more extensively.

Hydromorphological pressures that have a significant impact are the following:

- disruption of longitudinal continuity for aquatic organisms and sediment transport, the alteration of river morphology and habitats;
- the disconnection of adjacent wetlands, floodplains;
- impoundments, water abstractions or diversions and hydropeaking.

These significant hydromorphological pressures can induce a high degree of changes in flow dynamics, sediment continuity and river morphology. Hence, the alteration of sediment transport is a direct effect of the hydromorphological pressures.

1.2 Review of hydromorphological quality assessment methodologies

Hydromorphological river assessment has significantly expanded over the last years, triggered especially by the development of river management policies. In European countries, this process has been accelerated by the implementation of the EU Water Framework Directive (WFD; European Commission, 2000), which recognizes hydromorphology as an important component in supporting the assessment and integrated management of river ecosystems.

Several tools have been developed in Europe and worldwide to assess hydromorphology. Methods for physical habitat assessment are the most common approach for this assessment (Belletti et al., 2015). They generally consist of surveying, characterization and classification of physical habitat elements, mainly focusing on in-stream features. Among them are the River Habitat Survey (Raven et al., 1997) and several derived methods (e.g. the national German method; LAWA, 2000).

Although physical habitat assessments often collect data on features (e.g. shading, organic matter, refuge areas) that can be helpful in establishing links between river hydromorphology and biota, they are affected by a series of limitations (Belletti et al., 2015). In a review, Rinaldi et al. (2013) present five broad categories of hydromorphological assessment methods: (1) Physical habitat assessment; (2) Riparian habitat assessment; (3) Morphological assessment; (4) Hydrological regime alteration assessment; (5) Longitudinal fish continuity assessment. Although a clear separation between different categories does not exist, this distinction enables the main characteristics and scope of each method to be clearly presented. According to the EU Water Framework Directive (WFD), the assessment of river hydromorphology requires the consideration of any modifications to flow regime, river morphology, and lateral channel mobility.

1.2.1 Morphological assessment

Morphological assessment methods take into account physical processes at appropriate spatial and temporal scales. The main limitation is linked to the complexity in assessing and understanding physical processes; indeed, these methods need to be applied by specialists and the assessment is often limited by data availability (e.g. historical photo and maps, GIS data etc.).

Examples of morphological assessment methods are the River Styles Framework (Brierley and Fryirs, 2005) and the Morphological Quality Index (MQI, Rinaldi et al., 2013, Golfieri et al., 2018) and HYMET (Klösch and Habersack).

However, some of the previous strengths can, to some extent, also imply a series of limitations, including:

- assessing the correct functioning of processes (requires the collection of measurements at different times) and
- process rates (e.g. bank erosion or deposition) and/or
- quantitative modelling or analyses of changes in the process regime (e.g. alterations in sediment transport);
- definition of a reference state for morphological conditions.

The focus of these methods is generally on fluvial systems and processes at wider spatial and temporal scales compared to the physical habitat assessment.

1.2.2 Assessment of hydrological regime

Methods for the assessment of hydrological regime alterations make use of indicators derived by quantitative, statistical or physically-based models, e.g., indicators of Hydrologic Alteration (IHA) proposed by Richter et al. (1996) and Poff et al. (2003) that imply the use of existing large data sets and long-time series. However, several factors can impede the assessment process:

- the difficulty of defining a reference hydrological regime state (pre-impact conditions);
- a lack of sufficient or proper quantitative data to evaluate the effects of a given pressure and thus;
- the type of impacts and causes of alteration, which can be a more feasible assessment method and sometimes;
- the lack of indicators for assessment of different types of hydrological alteration (e.g., hydrological alterations due to hydropower impacts).

1.2.3 River continuity assessment

Methods for longitudinal continuity assessment mainly consist of the assessment of barrier passability at the single barrier scale, rather than on the effective assessment of longitudinal river continuity at the catchment scale. This limitation could be surpassed by analysing for example the cumulative effect of barriers for a large range of fish communities and environmental conditions. For this, standardized protocols or structured methods should be further developed in the future.

1.3 Relationship between hydromorphological and biological quality elements

The hydromorphological quality elements (HQE) are, within the meaning of the WFD, "supporting elements" for communities of aquatic organisms. When values are assigned that imply a "good ecological status", these HQE must be able to sustain the biological quality elements. It is deemed that alterations of HQE may cause the decline of species biodiversity, a reduced species abundance, altered population composition and the hindrance of species migration, e.g. decline of naturally reproducing fish populations, in particular sturgeon species for the Danube River. However, several studies reported a lack of response or a weak response of biota to hydromorphological changes (e.g. Lepori et al., 2005; Jähnig et al., 2009; Haase et al., 2013; Hering et al., 2006; Friberg et al., 2009; Marzin et al., 2012; Dahm et al., 2013). In contrast, other studies found a significant positive effect on richness and abundance of benthic invertebrates fauna[3], aquatic macrophytes and fish (Miller et al., 2010; Schmutz et al., 2014; Ecke et al., 2016).

The relation of hydromorphological alterations with the biological components is hard to assess within an area under influence of both natural and anthropogenic factors. However, many studies highlighted the specific response of biological elements to specific hydromorphological changes. For example, the variation of benthic macroinvertebrate taxa richness and density of invertebrates' indicators with decreased stream flow was shown by numerous authors (Wright and Symes 1999; Cortes et al. 2002; McIntosh et al. 2002; Wood and Armitage, 2004). In recent years, a series of freshwater indices have been developed that combine biotic, abiotic, multi-taxa and multi-trophic level indicators. Among the most reliable ones are those developed by UKTAG (The UK Technical Advisory Group on the Water Framework Directive) in relation with benthic macroinvertebrates, such as: The Lotic invertebrate Index for Flow Evaluation [LIFE] and Proportion of Sediment-sensitive Invertebrates [PSI]. Armitage (2006), found that changes occurring within the physical habitat

[3] The term „Benthic invertebrates fauna" is equivalent to „benthic macroinvertebrates" and „macrozoobenthos" or „MZB".

downstream of a reservoir resulted in a dynamically fragile macroinvertebrate community, which became vulnerable to invasive species. Plachter and Reich (1998) found that exposed riverine sediment communities (ERSC) to be very sensitive indicators of prolonged high flooding events. ERSC communities are formed of specialized invertebrates (particularly beetles and spiders) that live in the terrestrial-aquatic interface and depend on the disturbance regime of seasonal water level changes.

Sediment regimes are crucial to aquatic and riparian ecosystems in many ways. Some species prefer a particular type of substrate along their stages of development (Angradi, 1999, Miyake & Nakano, 2002; Gilmore, 2002; Buss et al., 2004; Gonçalves & Menezes, 2011). For example, the fine sediments and organic matter create a very unstable and easily erodible habitat for aquatic invertebrates (Allan and Castillo, 2007; Jones et al. 2011). Pan et al. (2012) showed that the gravel substrate creates more stable microhabitats that allow the development of a greater number of species of invertebrates. Therefore, the large particles substrate is a high-quality habitat for benthic macroinvertebrates in contrast to substrates composed of small sand particles (Duan et al., 2009). In case of fish fauna, salmonids can be sensitive to excess of fine sediment and they require gravels substrate for spawning (Riebe et al. 2014).

The predators are strongly dependent on suspended sediment and turbidity, which can alter the visibility necessary for feeding activity (Newcombe and MacDonald 1991). The linkages between riparian plants and sediments in terms of sediment retention have been widely described in the scientific literature (Daniels and Gilliam, 1996; Dosskey et al., 2010; McKergow et al., 2003; Yuan et al., 2009).

The mutual relationship of submerged and floating aquatic plants with the flow regime and low flow effects was shown by Hatton-Ellis, Greive and Newman, 2003. So-called Diatoms comprise microscopic algae that are abundant within the periphyton. These algae grow on surfaces in rivers and streams, and contribute to the phytoplankton in larger rivers. These diatoms have been used for a long time as good indicators of the ecological status as they can respond to factors such as increased nutrients, temperature, light, flow etc. However, a strong relationship was found between the periphytic communities, taxonomic and structural changes during succession (life cycle) and fluctuations/disturbance level of river flow. Thus, in not-disturbed rivers, thick biofilms can be found containing loosely attached diatom species and long filaments visible to the naked eye. On contrary, in biofilms that become exposed, aerophilous taxa, e.g. *Diadesmis* or *Luticola*, frequently increase (Kelly et al. 1998). Many species of fish are suitable indicators of hydromorphological conditions of riverine habitats. The preferences for specific habitat conditions of some species during their life stages are well documented, for example for brown trout (*Salmo trutta* L), grayling (*Thymallus thymallus* L.), river lamprey (*Lampetra fluviatilis* L.), European eel (*Anguilla anguilla* L.) and bullhead (*Cottus gobio* L.) (Maitland, 1980; Potter, 1980; Riley and Pawson, 2010).

In Table 1, more examples of biotic elements (benthic macroinvertebrates, phytobenthos, macrophytes and fish) and some indices and metrics are given, which are used for the ecological quality assessment in relation with the hydromorphological alterations in the framework of ICPDR 2015 and XGIG Large River Intercalibration Exercise 2012 (Schöll et. al, 2012).

Table 1: Biological elements and metrics highly correlated with the hydromorphological parameters

Biological elements	
Phytobenthos	
In the framework of the JDS3, **18 diatom indices available** within the OMNIDIA ver. 5.3 (Lecointe et al 1993, 1999) were tested against different environmental indicators, including hydromorphological ones. In addition, the proportion of species belonging to three ecological guilds (low profile, high profile and motile) adopted from Passy (2007) and Berthon et al. (2011) and two life forms (planktonic, benthic) were included in the assessment of Danube water quality under the same project. The structural parameters (taxonomic composition) of the non-diatom community: cyanobacteria (*Cyanophyta*), green algae (*Chlorophyta*) and red algae (*Rhodophyta*), showed significant section specificity along the Danube. A comprehensive presentation of the indicator species is given in the JDS3 report (Makovinská et al., 2014). Distribution of non-diatom taxa in the Danube was significantly correlated with river kilometres and suspended solids, explaining 21% of the total variance in the non-diatoms data. The diatoms distribution showed a clear differentiation of Danube sections, mainly as a result of longitudinal gradient of suspended solids, positively correlated with proportion of centric diatoms in the samples. Below are the most representative indices widely used around Europe for ecological status assessment in rivers (Kelly et al. 2014) and successfully applied during an intercalibration exercise by Kelly et al. 2009. These best correlated with the hydromorphological parameters,	
Indices/Metrics	Significant correlations (p>0.001 (**) and p>0.05 (*) between biological and hydromorphological parameters based on literature data (+/+) – positive correlation; (+/- and -/+) - negative correlation.
GENRE (Generic Diatom Index (Rumeau & Coste 1988, Coste & Ayphassorho 1991)	Velocity (+/+**), Q (-/+*); Slope (+/+**)
TID Trophic Index Diatom (Rott et al. 1999)	Velocity (+/+*); Slope (+/+**)
High-profile guilds	Slope +/+**, Velocity +/+*; granulometry (+/+)
Low profile	Velocity (+/+*); Suspended solids (+/+*)
Motile	Velocity (-/+**); Suspended solids (-/+*)
Planktonic	Suspended solids (+/+**)
Benthic	Suspended solids (-/+**)
Benthic macroinvertebrates	
Several metrics have been developed and tested by the European countries to assess the general degradation for the rivers. However, there is no commonly agreed metrics for the assessment of large rivers. As for example, different metrics are used by the European countries to assess the hydromorphological changes. In Austria, Ofenböck et al. 2005 proposed *Number of EPT taxa, Proportion of EPT taxa, Lithal-profundal preferring taxa (Large Alpine rivers),* in Germany is used *Potamon-Typie-Index* (Schöll et al. 2005), in Hungary, the *ASPT, Number of EPTCBO taxa* (Várbíró et al., 2011), in Slovakia - *Rhithron-Type Index, Index of biocoenotic region, Proportion of akal-lithal-psammal preferring taxa, BMWP* (Šporka et al. 2009), in Romania - *Proportion of rhithral/potamal preferring taxa.*	

During the Common Intercalibration exercise, several metrics have been tested against natural variables (e.g. catchment size, discharge, altitude, water temperature) and pressure-variables (e.g. annual averages of physico-chemical parameters; degree of channelization, riparian habitat alteration, water abstraction; navigation activity). Below highly correlated metrics with abiotic parameters are shown. The Slovak method for large rivers applied for the JDS 3 MHS-data managed to detect the morphological high degraded sites (channelized or impounded, with rip-rap dominating at the shore zones) in the Upper Danube section indicating a moderate status, while sites with less morphological impact, providing adequate gravel banks, indicate generally good status. In the Lower Danube section, the method was not fully applicable due to lack of reference conditions.	
Indices/Metrics	Significant correlations (p>0.001 (**) and p>0.05 (*) with the hydromorphological parameters based on literature
% Rhithral-preferring taxa	Catchment area (significantly negatively correlated (-/+); discharge (significantly positive correlated (+/+); water temperature (-/+)
% Active filter feeders	Catchment area (+/+); discharge (-/+); water temperature (+/+)
Ratio of rhithral to potamal-preferring taxa of samples at free-flowing sites	Catchment area (-/+); water temperature (-/+)
Macrophytes	
Natural macrophytes distribution can be changed by anthropogenic influence, mainly by hydrological or morphological changes in the river (Gecheva, 2013). The metric *Relative Plant Mass (RPM)* (Kohler and Janauer, 1995; Pall and Janauer, 1995) describes the quantitative relationship of individual plants and how they relate to each other with respect to dominance, as based on the total plant mass in a surveyed river section. It was tested against different environmental parameters, including the hydrological and hydromorphological ones. Different life forms (hydrophytes, helophytes, amphiphytes) or groups (bryophytes, macroalgae, angiosperms etc.) of macrophytes respond differently to environmental parameters as has been indicated by many authors. The most significant abiotic parameters correlated with the macrophytes have been proved to be the substrate (submerged and emerged), the shading, turbidity, slope of the substrate and water current classes. This enabled differentiation of several Danube sections.	
Indices/Metric	Relationship with the environmental parameters
Relative Plant Mass (RPM) of mosses (bryophytes)	**+/+** with turbidity, shading and high-water velocity and hard substrate (technolithal, megalithal) (Upper section)
Relative Plant Mass (RPM) of Rooted water plants and macroalgae	+/+ with light availability, high transparency and low turbidity water, low shading and soft substrates (pelal, microlithal). -/+ high water velocity
Relative Plant Mass (RPM) of floating taxa	+/+ with still and slow flowing water, presence of side arms or upstream reservoirs, soft substrates (pelal, microlithal)
Bank vegetation (bryophytes, rural plants)	+/+ artificial substrate (technolithal) and natural large stones +/- shading effect of riparian vegetation
Fish fauna	
The FIA and the EFI based on the Danufishbase at the Institute for Water Ecology, Fisheries and Lake Research in Austria and the German FiBs (fish-based assessment approach) were used to assess the impact of alterations of hydromorphological parameters such as impoundments, since these have been proved the most consistent assessment methodology for the Upper Danube section. For the	

Middle Danube section, the FIS (Fish index of Slovakia) was used. However, these indices have a limited application and their use for the entire Danube course is not recommended. The Application of these indices requires knowledge about the reference conditions. The assessment includes parameters like abundance and biomass, species guilds, and age structure. The proportion of allochthonous species to the total number of species along the entire Danube course recorded an increasing trend, a significant difference being seen between the sites upstream and downstream of the Iron Gate Dam (JDS 3 final report).
According to the main results of ICPDR, 2015, in the upper course of the Danube the fish fauna mainly reflects hydromorphological alterations and damming as most important human impacts, but also the lack of connectivity along the whole river stretch; FIA and FIS indices revealed the impoverishment of aquatic habitats due to the use of waterpower. Instead, the lower course of the Danube is mostly influenced by professional and recreational fishery and poaching.

1.4 Proposed methodology for risk assessment

The proposed methodology is developed on three stages:

1. Risk identification is the process of finding, recognizing and describing risks. It is a screening exercise and serves as a preliminary step for the subsequent risk analysis stage – Step 1, Step 4;
2. Risk analysis is the process to comprehend the nature of risk and to determine the level of risk – Step 2, Step 5;
3. Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable – Step 3, Step 6.

Risk criteria are the terms of reference against which the significance of a risk is evaluated.

The risk methodology proposed within the project brings up a flexible conceptual model that aims to integrate the significant hydromorphological drivers, pressures on the sediment continuity and the sediment balance (considering the pressure's characteristics on hydromorphological quality elements assessment). Thereby, it includes relevant spatial and temporal hydromorphological data and data on suspended sediment load and bedload transport as well as grain composition for both sediment transport modes. As result, the changes in the sediment transport over an extended period of time from 1956 to 2016 and the space along the entire Danube) could be assessed.

The methodology proposed for the risk assessment related to the Danube sediment regime will consider the DPSIR scheme (Figure 1) adopted by the European Environment Agency, based on the pressure-state-response (PSR) model that was developed in the 1970s by the Canadian statistician Anthony Field. Pressures are direct results of the drivers in form of environmental stress, leading to altered states of the environmental compartments like air, water and soil.

The effects are impacts on ecosystems or human health and functions, eventually leading to responses, which are defined as human measures like research and information, regulations and adjustments. The Elements of DPSIR represent in fact the key elements of the Pressure and Impact analysis, which finally will underpin the risk assessment. In this phase, the state of hydromorphological and biological quality elements and various impacts and risks associated with the alteration of their state will be analysed.

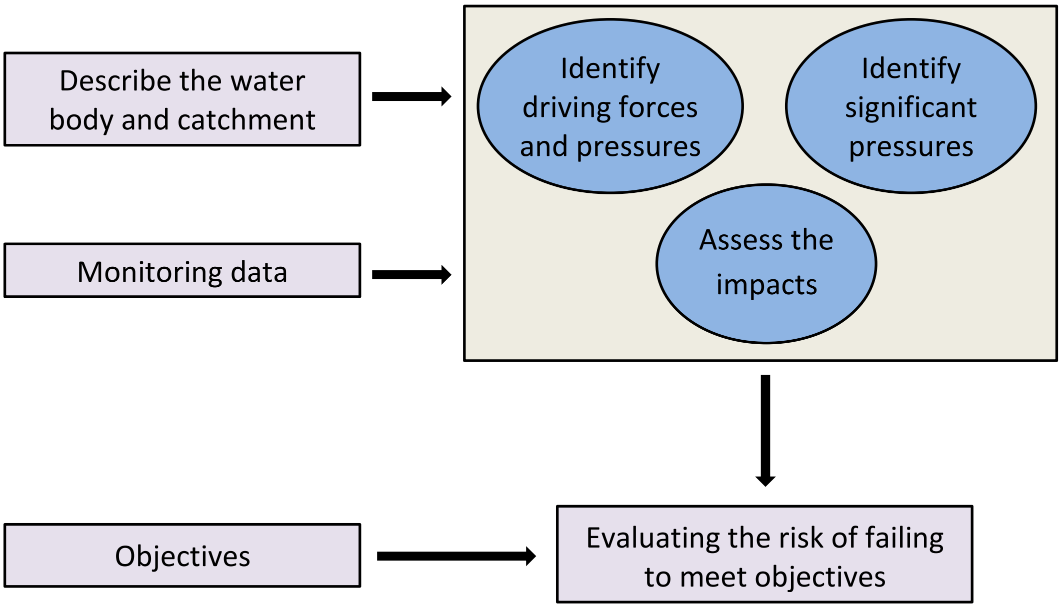

Figure 1: Key elements in the analysis of pressures and impacts (source: CIS Guidance Document no 3, Analysis of Pressures and Impacts, processed)

According to the findings of the report on "Interactions of Key Drivers and Pressures on the Sediment Balance of the Danube", the key drivers responsible for the alteration of the sediment regime in the entire Danube River and all major selected tributaries, are (in terms of river stretch impacted): flood protection (99%), hydropower (89%), water supply (53%), dredging (not for navigation) (49%), navigation (40%), and agriculture (39%).

In terms of anthropogenic pressures on the sediment regime, the report shows that hydromorphological alterations at the Danube Basin-wide scale are evident and are generated by the following: longitudinal continuity interruption (dams, weirs, sluices, groins, dredging), lateral continuity interruption (dykes, regularization works in river) and fairway navigation.

The methodology applied in this report incorporates the requirements of the WFD, the EU Strategy for the Danube Region and of other relevant European environmental documents (e.g. CEN "Water quality – Guidance standard on determining the degree of modification of river hydromorphology" EN 15843:2010 (CEN 2010)), by considering the already developed hydromorphological and biological elements and associated parameters.

In the context of the present project, parameters like suspended sediment (SS) load and bedload transport as well as the grain composition of the riverbed were analysed. These could be easily related to and considered as suitable surrogates of the parameters recommended by the WFD (Table 2).

Moreover, based on the historical data on mean annual SS load values and longitudinal variation of the long-term bedload transport, from the period before and after construction of the hydropower plants, the **changes of hydrological regime due to artificial in-channel structures within the sections (impoundments) parameter** were assessed.

Relevant data concerning the Danube's river channel width changes from reference conditions are published in the report "Long term-morphological development of the Danube in relation to the sediment balance". The report thoroughly analysed the erosion or deposition character, based on deviation from near to natural conditions for section types.

Although the parameters analysed are far from exhaustive for the variety of hydromorphological alterations, they are compliant with the main objective of this project, which aims at analysing the alteration of the sediment balance in the Danube. Considering the parameters analysed in the JDS3 expedition (ICPDR, 2015) to understand the relationship of abiotic elements and pressures, including the hydromorphological ones on the biotic element, our project recommends adding further sediment-related hydromorphological elements, which we included in the current methodology (see "sediments" in Table 2).

As discussed in the chapter above, literature shows that not only the hydromorphological changes which occurred along the Danube have dramatically modified its natural watercourse, but also its ecological functions.

In short, the of risk assessment presented in this report took the following steps: we analyse the hydromorphological status of one of the analysed river sections (called "pilot sites" in the frame of this project) in order to determine the high or good ecological class. If the status of the HQE is at risk, the biological status should be assessed. This includes the biological quality elements (BQE) macrozoobenthos, phytobenthos and fish.

Therefore, the risk analysis begins with a status assessment of the hydromorphological quality elements (HQE) (Figure 2). If the status is moderate, poor or bad, this may have a potential negative impact and an increased risk on the biota, habitats, and ecosystems. In these cases, the status of the biological quality should be evaluated. If the status of BQE falls within the moderate, poor or bad class, this means there could be a risk of failing to achieve the WFD targets by 2021.

According to the WFD classification, an environmental risk related to the impact of the altered hydromorphology on the biological elements should be considered for the section and action taken, e.g. by implementing measures to improve the sediment balance of the river.

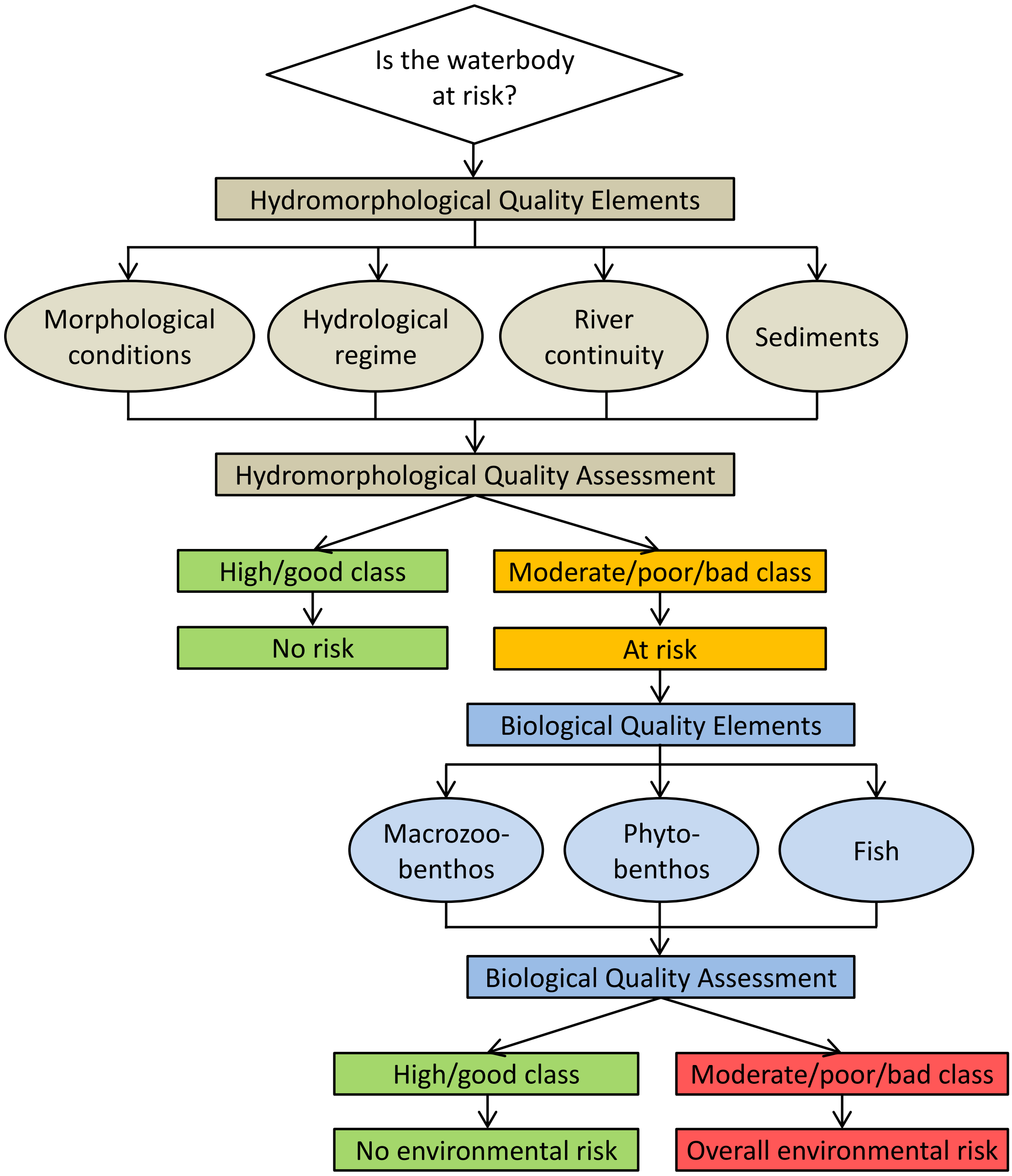

Figure 2: The steps of hydromorphological and ecological risk assessment

1.5 The risk assessment steps

1.5.1 Step 1: Identification of hydromorphological elements

The process consists in selecting the elements and parameters which are most affected by the identified hydromorphological pressures. These elements and parameters are in compliance with Guidelines (CEN, 2010) and other relevant documents like the WFD, which define the river watercourse and changes (Table 2, Annex 1).

The morphological assessment method is designed to be relatively simple and not excessively time consuming. The following aspects are considered for the assessment of the morphological quality of river sections:

1) **Morphological conditions** of channel, banks and floodplains, including channel pattern, cross section configuration bed substrate, etc.;
2) **Hydrological regime** of the river including changes in flow conditions;
3) **Continuity of river** processes, including longitudinal and lateral continuity;
4) **Sediment** including channel and its main parameters relevant for sediment regime (sediment continuity, increase/decrease suspended sediment concentration load, erosion rate).

These aspects are analysed taking into account the natural as well as the artificial components (e.g. natural river processes and forms vs. artificial channel structures and adjustments). Parameters of geomorphic natural functionality evaluate whether or not the processes and related forms responsible for the correct functioning of the river are prevented or altered by artificial elements or by channel adjustments. These processes include, among others, the continuity of sediment, bank erosion, periodic inundation of the floodplain, morphological diversity in planform and cross section, the mobility of bed sediment, etc.

Table 2: Selected hydromorphological quality elements (HQE) according to the scheme for WFD 3-digit continuous survey (CEN, 2010); for the complete list of HQE selected in the project, see the Annex 1 and Table 12 Overall Risk assessment

	CEN, 2010 Parameters	Analogy with the Parameters analysed in the project	WFD parameters covered
Morphology	Planform (based on deviation from near to natural conditions for section types)	- change of the morphological type - shortening of the river channel (meandering index, sinuosity) - changes in lateral connectivity (anabranching index) - river width changes	"Channel patterns"
	Substrates (Natural substrate mix or character altered) (based on deviation from near to natural conditions for section types)	changes in the bed sediment calibre	"Substrate conditions"
	Erosion/deposition character (based on deviation from near to natural conditions for section types)	Erosion/deposition volume changes	"River depth and width variation"
	Land cover in riparian zone (top of banks and adjacent narrow strip) (% of bank length)		"Structure of the riparian zone"
Hydrology	Changes of flow conditions due to artificial in-channel structures within the sections (impoundments, density of groins and reflectors)	Long-term water discharge and SS load changes[4]	"Quantity and dynamics of water flow"
River continuity	Section-based and local impacts of sluices and weirs on river continuity regarding biological and sediment continuity	Presence of dams, sluices and weirs	"The continuity of the river is not disturbed by anthropogenic activities, undisturbed migration of aquatic organisms and undisturbed sediment transport"

[4] The sediment load changes are analyzed separately (see Table 12).

1.5.2 Step 2: Hydromorphological quality assessment

For each parameter chosen, a reference state or a slight deviation from it has been assigned with class I, for which the scores characteristic of group indicators is maximal (Schwarz et al., 2014).

For the other scenarios (class II – V), the score is smaller based on the severity of anthropogenic pressures. Regarding the approach towards establishing the reference conditions, it was considered that the reference state is represented by the natural hydrologic regime and the natural riverbed morphology (Schwarz et al., 2014). The overall CEN assessment is based on individual parameters for channel, banks and floodplain and allows an assessment into five classes based on arithmetic mean values for each parameter group and the overall assessment (Table 3). For channel, the parameter of "impacts of artificial in-channel structures" was assessed only in 1, 3 and 5 (Schwarz et al., 2014) (Annex no. 3).

As a response of an erosion or sedimentation trend, changes in the river morphodynamics could become significant. The understanding of river morphodynamics is important in the process of mitigating the erosion and sedimentation effects, such as bank erosion, river planform changes, overflows, silting up of reservoirs, etc.

Therefore, in the **DanubeSediment** project, the Danube channel's morphology has been comprehensively assessed by collecting and assessing different morphological data, e.g. bathymetric changes in the river channel, longitudinal profile, dredging, feeding and disposal of the sediments, sediment size variations. Having in view that this risk assessment seeks to analyse the impact of an altered sediment balance, the project extended the set of **relevant sediment-related parameters** already assessed by JDS3. These relevant parameters are: **sediment continuity, increase/decrease of suspended sediment concentration load, erosion rate depending on data availability in pilot sites).** They were assessed depending on data availability in pilot sites. We derived the morphological data from a former project report, followed by assigning a score value for quality assessment of each parameter.

Scores have been assessed based on expert judgment, having in view the range of class limits for JDS3 hydromorphological assessment.

Table 3: Assessment class boundaries (Source: JDS3 Report)

Avg. Score	HQ WFD Classes	
1.0 to 1.4	Class 1	"Near-natural"
1.5 to 2.4	Class 2	"Slightly modified"
2.5 to 3.4	Class 3	"Moderately modified"
3.5 to 4.4	Class 4	"Extensively modified"
4.5 to 5.0	Class 5	"Severely modified"

1.5.3 Step 3: Hydromorphological risk evaluation based on the results of hydromorphological quality assessment

It will be considered that there is a hydromorphological risk (HR) if the quality assessment of hydromorphological elements falls within the classes 3, 4 or 5.

1.5.4 Step 4: Selection of biological quality elements

This step is designed to guide the decision maker through the analysis as straightforward as possible. Depending on the results from step 3, a stepwise decision process will be employed in order to further decide on the necessity of initiation of the biological quality assessment (Figure 2).

This process, based on the selected biological parameters, should provide a quick analysis of the main biological elements that could be influenced by changing hydromorphological parameters. To achieve this, a review of diversity and of ecological preferences was performed, including benthic macroinvertebrates, phytobenthos and fish species within each Danube section based on the JDS3 report (ICPDR, 2015; Makovinská et al., 2014; Graf et al., 2014; Stanković et al., 2014). The data obtained during JDS3 expeditions took into consideration the most sound biological methodological sampling protocols according to the AQEM Consortium, 2002 (Multi-Habitat-Sampling), along with other standard sampling methodologies, e.g., deep Water Sampling, DWS: cross-sectional survey by dredging in the deep-water area; kick and sweep sampling, K&S: sampling with a hand net at the shore region. This way most of the Danube's habitats are covered and all samples are analysed by specialists.

1.5.5 Step 5: Biological quality assessment

Based on biological elements selected in the previous step, the following assessment approach has been performed:

- A quantitative assessment of the macrozoobenthos and phytobenthos elements characteristic for each Danube's sector was undertaken with the help of the parameters „*Number of benthic indicator species presence*", the "*Ratio of dominant phytobenthos classes*", respectively. These are calculated (expert judgement) for each ecological class (Tables 7, 8, 9).

- In case of the fish element, the FIA, EFI and FIS (Bammer *et al.*, 2014) tested within the JDS3 can be used, with precaution related to their feasibility for different water typologies (details in the Table 1). References for the ecological status based on the parameters: *Composition, Density, Abundance, Age structure* for the fish element for each Danube's sector are also given in Bammer *et al.*, 2014.

1) Ecological assessment based on benthic macroinvertebrates

The benthic macroinvertebrates species, whose presence or abundance is considered to be good indicators for ecological conditions in each Danube section, are presented in the tables 4, 5 and 6. These could be used to decide if a specific habitat is in good ecological status based on the presence of as many as possible of the characteristic/indicator species for different habitats. In order to have a reference for the presence of taxa typical for different habitats, the impoundment sites have been excluded from the analysis.

Table 4: Benthic macroinvertebrates indicator species for the **Upper Danube** habitats types (Source: JDS3 Report)

Upper Danube section: Significant (p≤0.05) indicator taxa per substrate type; impounded sites excluded				
Taxagroup	Genus	Species	Neozoon	Substrate type
Oligochaeta	Tubificidae	Gen.sp.		Microlithal
Gastropoda	Ancylus	fluviatilis		
Odonata	Platycnemis	pennipes		Xylal
Diptera	Cricotopus (I.)	dobrogicus/sylvestris-Gr.		
Diptera	Orthocladiini	CP		
Bivalvia	Pisidium	sp.		Pelal to akal
Bivalvia	Corbicula	sp.	yes	
Diptera	Chironomini	Gen.sp.		
Oligochaeta	Potamothrix	moldaviensis		
Diptera	Procladius (H.)	choreus		
Diptera	Chironomus (C.)	nudiventris		
Diptera	Tanytarsus	ejuncidus		
Diptera	Cryptochironomus	sp.		
Oligochaeta	Psammoryctides	barbatus		
Diptera	Harnischia	sp.		
Amphipoda	Chelicorophium	curvispinum	yes	Rip-rap
Amphipoda	Corophium	sp.	yes	
Bivalvia	Dreissena	polymorpha	yes	
Diptera	Cricotopus (C.)	sp.		
Amphipoda	Dikerogammarus	villosus	yes	

Table 5: Benthic macroinvertebrates indicator species for the **Middle Danube** habitats (Source: JDS3 Report)

Middle Danube section: Significant (p≤0.05) indicator taxa per substrate type; impounded sites excluded (MP=Macrophytes; R/D=Roots/Debris)				
Taxa group	Genus	Species	Neozoon	Substrate type
Diptera	Procladius (H.)	sp.		MP
Diptera	Cryptochironomus	sp.		
Diptera	Cladopelma	sp.		
Diptera	Cryptochironomus	obreptans/supplicans		
Diptera	Tanypus	punctipennis		
Mysida	Limnomysis	benedeni	yes	R/D
Gastropoda	Ferrissia	sp.		
Ephemeroptera	Caenis	sp.		
Gastropoda	Physella	sp.	yes	
Oligochaeta	Dero	digitata		
Oligochaeta	Specaria	josinae		
Bivalvia	Pseudanodonta	complanata complanata		
Diptera	Polypedilum	(P.) nubeculosum		
Diptera	Ceratopogonidae	Gen. sp.		
Oligochaeta	Ophidonais	serpentina		
Oligochaeta	Stylaria	lacustris		
Bivalvia	Sinanodonta	woodiana	yes	
Oligochaeta	Propappus	volki		
Isopoda	Asellus	aquaticus		
Odonata	Libellulidae	Gen. sp.		
Odonata	Orthetrum	cancellatum		
Heteroptera	Corixidae	Gen. sp.		
Heteroptera	Ilyocoris	cimicoides		
Coleoptera	Hydrophilidae	Gen. sp.		
Diptera	Endochironomus	tendens		
Diptera	Polypedilum (U.)	convictum		
Diptera	Cricotopus (I.)	dobrogicus/sylvestris-Gr.		MP
Diptera	Cricotopus (I.)	dobrogicus cf.		
Diptera	Cricotopus	sp.		
Diptera	Parachironomus	arcuatus-Gr.		
Odonata	Coenagrionidae Gen.	sp. juv.		
Diptera	Nanocladius	dichromus/distinctus		
Diptera	Chironomini Gen.	sp.		
Diptera	Microchironomus	tener		
Diptera	Dicrotendipes	cf.nervosus		
Gastropoda	Radix	ovata/peregra		
Diptera	Procladius (H.)	sp.		
Diptera	Cryptochironomus	sp.		
Diptera	Cladopelma	sp.		
Diptera	Cryptochironomus	obreptans/supplicans		
Diptera	Tanypus	punctipennis		

Table 6: Benthic macroinvertebrates indicator species for the **Lower Danube** habitats (Source: JDS3 Report)

Lower Danube section: Significant (p≤0.05) indicator taxa per substrate type; impounded sites excluded				
Taxagroup	Genus	Species	Neozoon	Substrate type
Diptera	Cricotopus (I.)	cf. dobrogicus		Macrophytes
Ephemeroptera	Cloeon	dipterum		
Diptera	Cricotopus	sp.		
Diptera	Tanypus	punctipennis		
Odonata	Coenagrionidae Gen.	sp. juv.		
Diptera	Procladius (H.)	sp.		
Diptera	Rheotanytarsus	sp.		Roots/Debris
Gastropoda	Esperiana	daudebartii acicularis		Microlithal
Gastropoda	Viviparus	viviparus		
Gastropoda	Theodoxus	fluviatilis	*	Meso-/ macrolithal
Diptera	Xenochironomus	xenolabis		
Heteroptera	Micronecta	sp.		Xylal
Amphipoda	Chelicorophium	curvispinum	*	
Amphipoda	Pontogammarus	sarsi	*	
Oligochaeta	Specaria	josinae		
Amphipoda	Pontogammarus	robustoides	*	
Mysida	Paramysis	sp.		
Amphipoda	Pontogammaridae	Gen.sp.	*	

The tables 4, 5 and 6 can be used to make a comparison of the benthic community structure in natural habitats with the structure of the observed benthic macroinvertebrates community.

Table 7 contains a qualitative description of the 5 quality classes (High, Good, Moderate, Poor, Bad) based on benthic macroinvertebrates assessment according to the WFD and the SR EN ISO 8689-1, 2. This could serve for a rapid diagnostic on the ecological quality of a habitat based on benthic macroinvertebrates (Table 7).

Table 7: Classification of the ecological status quality of **benthic macroinvertebrates** in five classes (SR EN ISO 8689-1, 2)

Scale	Quality classes for benthic macroinvertebrates	Observations
I	High	The observed community corresponds totally or nearly totally to conditions in which there are no anthropogenic stress factors, or they are considered insignificant (community undisturbed).
II	Good	There are small changes in the observed community compared to the reference community.
III	Moderate	The composition of the observed community differs moderately from the reference community. The main taxonomic groups of the reference community are absent.

IV	Poor	The composition of the observed community differs significantly from the reference community. Many taxonomic groups of the reference community are absent.
V	Bad	The observed community is heavily affected compared to the reference community. Only taxonomic groups capable of living in highly disturbed conditions are present.

For a quantitative assessment based on the biological elements selected, in accordance with the results of JDS3 report, the ecological classes were defined.

The quality classes for the benthic macroinvertebrates (Table 8) have been set based on the expert judgement, being assumed that the number of species from high to bad class decreases gradually. The number of species of benthic macroinvertebrates for each sector was retrieved from the assessment performed within the JDS3 expedition (Graf et al., 2014).

Table 8: Classification of the ecological status quality of **benthic macroinvertebrates** for the Upper, Middle and Lower Danube Section (expert judgement Based on JDS 3 Report)

Scale	Quality classes for benthic macroinvertebrates	No. of Indicator taxa		
		Upper Danube	Middle Danube	Lower Danube
I	High	>16	>21	>16
II	Good	11 -15	11 - 20	11- 15
III	Moderate	6 -10	6 - 10	6 - 10
IV	Poor	3- 5	3- 5	3 -5
V	Bad	<3	< 3	< 3

2) Ecological assessment based on phytobenthos

Benthic algae (periphyton or phytobenthos) are the most successful primary producers in aquatic habitats. They are widely considered to be the main source of energy for higher trophic levels in many, if not most, unshaded temperate region streams (e.g. Minshall, 1978, Lamberti, 1996).

Phytobenthos is identified as Biological Quality Element under the European Water Framework Directive (2000/60/EC), and as such need to be monitored to identify anthropogenic influences on aquatic ecosystems.

A quantitative assessment based on phytobenthos characteristic for each Danube's section can be done by using the "Ratio of dominant phytobenthos classes", calculated (expert judgement) for each ecological class (based on JDS 3 Report, see table 9).

According to the main results of JDS3 analysis of phytobenthos, the algal biomass generally increases in the lower Danube, being significantly influenced by phosphates and suspended solids. The indices based on the diatoms analysis revealed a gradually and significantly decrease downstream reflecting the increase of general degradation of aquatic environment and natural longitudinal changes.

Table 9: Classification of the ecological status quality of **phytobenthos** in five classes for Danube River (expert judgement based on JDS 3 Report)

Scale	Quality classes	Group Indicator
I	High	Dominate Diatoms
II	Good	Diatoms/Green algae > 1
III	Moderate	Green algae /Cyanobacteria > 1
IV	Poor	Cyanobacteria /Green algae >1
V	Bad	Dominate Cyanobacteria

3) Ecological assessment based on Fish

In total, 102 species of freshwater fish inhabit the Danube along its entire course, covering various ecological and functional guilds (Schiemer & Waidbacher, 1992, Schiemer, 2003, Eros *et al.*, 2005). Fish populations are a good indicator for human pressures and for hydromorphological alterations, which are the main cause for declining fish stocks in the Upper Danube (e.g. Spindler, 1997). Various studies (e.g. Wiesner et al., 2007) have shown, that the loss of connectivity due to the use of hydropower and the resulting deterioration of habitat quality can be seen as the main reason for ecological deficits of the fish fauna (e.g., migratory sturgeon species) in the Upper Danube. On the contrary, bad water quality and the exploitation of fish stocks, both by legal fishery and poaching, are the most considerable causes in the middle and lower course (Schmall & Friedrich, 2014).

In case of fish element, the FIA, EFI and FIS (Bammer *et al.*, 2014) tested within the JDS3 can be used, with precaution related to their feasibility for different water typologies (Table 10). Results of ecological assessment at several sites along the Danube are presented in detail in Bammer *et al*., 2014. References for the ecological status for the fish element for each Danube section are given in Bammer *et al.*, 2014 based on the parameters: *Composition, Density, Abundance, Age structure*.

Table 10: Classification of the ecological status quality of **fish** in five classes for Danube River (expert judgement based on the available data or literature (Bammer et al., 2014))

BQ Class	Quality Assessment Score
High	1
Good	2
Moderate	3
Poor	4
Bad	5

Overall ecological quality classes

For the integration of the risk assessment of all three biological elements, the principle of WFD, “one out - all out”, will be applied. Depending on the availability and accuracy of the data from other pilot sites analysed in the project, **it is possible also to mediate** the results of the three biological elements, obtaining a score according to Table 11.

By averaging the combinations of all five possible ranks (column 2) resulted from quality assessment of each of the three biological elements (combination of 5 by 3), 25 final ecological score values resulted (column 3). Based on these scores, ecological quality classes have been established based on expert judgement (Table 11).

Table 11: Overall ecological quality classes

BQ WFD Classes	Assessment rank	Average Score
High	1	1 – 1.33
Good	2	1.34 – 2
Moderate	3	2.1 – 3.33
Poor	4	3.34 – 4
Bad	5	4.1 – 5

In case of the approach based on average, for instance, if the results of quality assessment of benthic macroinvertebrates element is High, the score is 1 (according to table 8) and the ECOQ of Phytobenthos is Moderate, the score is 3 (according to table 9), and the ECOQ of Fish is Poor, the score is 4 (according to table 10). By averaging the assessment scores, the final ecological score is 2.66, which fall into the Moderate ecological quality class (Table 11).

1.5.6 Step 6: Risk evaluation based on the results of hydromorphological and biological quality assessment

A decrease in the sediment supply reduces the river braids, opens the river roosting habitat and reduces sediment deposition in the floodplains and riparian heterogeneity. On the other hand, elevated levels of sediment, which are not within the natural seasonal fluctuations, may be harmful to aquatic species and habitats. A reduction in water flow alters the depth, width, velocity, and reduces solid flow rates. This can interrupt the migration routes of species, which may lead to habitat fragmentation, loss or conversion and to altered population composition, decline of species biodiversity and abundance and to a decrease in the capacity for self-recovery (Statzner & Higler, 1986; Armitage & Petts, 1992).

In order to improve flood protection and to reduce and minimize flood risks, flood protection measures have been built within the Danube River Basin. In some cases, the flood defence measures could lead to alterations of the ecological status and of the sediment regime or transport by interrupting the lateral continuity.

The **approach** to determine if a **risk** is **significant or not,** is based on the results of the hydromorphological and ecological quality assessment.

Thus, whereas an alteration of hydromorphological and ecological quality has been identified (**moderate, poor, bad classes**), the risks are considered **significant**, otherwise these risks are **not significant**.

The significant hydromorphological and ecological risks are analysed in table 12. However, in the case that a relationship between the hydromorphological and biological quality is not evident as result of the quality assessment, no further risk assessment will be done, e.g. either high/good hydromorphological quality vs. moderate/poor/bad ecological status or other way round.

If one of the biological elements falls in “Moderate”, “Poor” or “Bad” quality class and the specialist decides that this is the result of other causes and not hydromorphological alterations, then the specialist may decide whether or not he considers the biological element in the final assessment of risk (as was illustrated in Figure 2).

Table 12: Overall Risk assessment

HQ Parameters/elements			Related background and source (to be seen for details)	Values/ descriptions	HQ assessment	Ecological quality assessment	Impacts and Significant risks
Morpho-logy	Channel	Planform (based on deviation from near to natural conditions for section types)	*"JDS3 Extended Report on: Hydromorphology"* and Annex *"JDS3HYMO_CONT_ASS080714"*, accessed on: http://www.danubesurvey.org/jds3/results	1 = 0 % to 5 % of reach length with changed planform. 2 = > 5 % to 15 % of reach length with changed planform. 3 = > 15 % to 35 % of reach length with changed planform. 4 = > 35 % to 75 % of reach length with changed planform. 5 = > 75 % of reach length with changed planform.	Moderate/ Poor/ Bad hydro-morpho-logical status	Moderate/ Poor/ Bad ecological status of FBK, MZB, Fish	Slope increases - increase of flow velocity and stream power - erosion of channel bed and banks. Reduced diversity of habitat types Fish mortality, aquatic insect population decreases, changes of FBK structure and concentration. Risk to not achieve significant reductions of flood risk events by 2021. Risk of failing to achieve the good hydromorphological and ecological/potential state. Habitat loss for fish reproduction and feeding. Changing of biota structure and ecosystem functions. Risk of failing to halt the deterioration in the status of all species and habitats by 2020. Risk of failing to secure viable populations of Danube sturgeon species and other indigenous fish species by 2020.
		Substrates (Natural substrate mix or character altered) (based on deviation from near to natural conditions for section types)		1 = Near-natural mix 3 = Natural mix/character slightly to moderately altered 5 = Natural mix/character greatly altered			

							Alteration of bed loads and water quality (increase of turbidity/ suspended solids). Risk of failing to achieve the good hydromorphological and ecological/potential state. Habitat loss for biota reproduction and feeding Sediments transport alteration. Risk of failing to achieve the Danube's Strategy target: to increase cargo transport on the River by 20%. Risk of failing to achieve the good hydromorphological and ecological/potential state.
	Banks	Extent of reach affected by artificial bank material (% of bank length)	*JDS3 Extended Report on: Hydromorphology*" and Annex "*JDS3HYMO_CONT_ASS080714*", accessed on: http://www.danubesurvey.org/jds3/results	1 = Banks affected by 0 % to 5 % hard, artificial materials. 2 = > 5 % to 15% 3 = > 15% to 35% 4 = > 35% to 75% 5 = > 75 %	Moderate/ Poor/ Bad hydro-morpho-logical status	Moderate/ Poor/ Bad ecological status of FBK, MZB, Fish	
		Land cover in riparian zone (top of banks and adjacent narrow strip) (% of bank length)		1 = 0 % to 5 % non-natural land cover in riparian zone. 2 = > 5 % to 15 % ~. 3 = > 15 % to 35 % ~. 4 = > 35 % to 75 % ~. 5 = > 75 % ~.			

	Flood-plain	"Degree of lateral connectivity of river and floodplain (Extent of floodplain not allowed to flood regularly due to engineering - based on hydromorpho-logical surveys – such as: *dykes, channel straightening and shortening as regulation works*). Is over-bank flooding likely to occur (or likely to have occurred historically) naturally in the reach? (based on deviation from near to natural conditions for section types)"		Is over-bank flooding likely to occur (or likely to have occurred historically) naturally in the reach? Yes/No. If No – N/A. If Yes, score: "1 = 0 % to 5 % reach affected by dykes or other measures impeding flooding of floodplain" 2 = > 5 % to 15 % as above. 3 = > 15 % to 35 % as above. 4 = > 35 % to 75 % as above. 5 = > 75 % as above.			

Hydro-logy	Channel	Changes of flow conditions due to artificial in-channel structures within the reach (impoundments, density of groynes and reflectors)	*JDS3 Extended Report on: Hydromorphology*" and Annex "*JDS3HYMO_CONT_ASS080714*", accessed on: http://www.danubesurvey.org/jds3/results	1 = Flow character not or only slightly affected by structures 3 = Flow character moderately altered 5 = Flow character extensively altered	Moderate/ Poor/ Bad hydro-morpho-logical status	Moderate/ Poor/ Bad ecological status of FBK, MZB, Fish	Increasing sediment transport or sedimentation - Risk of failing to achieve the good hydromorphological and ecological/potential state. Risk to not achieve the national targets based on the Europe 2030 climate and energy targets Risk to not achieve the waterway infrastructure management by 2020.
River conti-nuity	Channel	Reach-based and local impacts of sluices and weirs on river continuity with regard to **biological and sediment transport**		1 = No structures, or if present no (or very minor effect) on migration or sediment transport. 3 = Structures present, having only minor or moderate effects on migratory biota and sediment transport. 5 = Structures that are general barriers to all species and sediment.			Risk of failing to secure viable populations of Danube sturgeon species and other indigenous fish species by 2020. Risk of failing to achieve the good hydro-morphological and ecological/potential state.
Sediment	Channel	Erosion/ deposition character (based on deviation from near to natural		1 = Erosion/deposition features reflect near-natural conditions. 3 = Erosion/deposition features reflect moderate departure from near-natural			Slope increases - increase in flow velocity and stream power - erosion of the channel bed and banks Reduced diversity of habitat types Habitat loss for fish reproduction and feeding Alteration of bed

		conditions for section types)		conditions (10 % to 50 % of the features expected are absent). 5 = Erosion/deposition features reflect great departure from near-natural conditions (≥ 50 % of the features expected are absent).			loads and water quality (increase of turbidity/ suspended solids). Risk of failing to achieve the good hydromorphological and implicitly ecological/potential status.
		Erosion rate (bed erosion)	WP4 results comparing transversal profiles (depending on data availability in pilot sites)	1 = very low erosion (0%) 2 = low erosion (0-15%) 3 = moderate erosion (15-30%) 4 = strong erosion (30-60%) 5 = very strong erosion (>60%)			Decreasing the bed resistance, increasing energy slope and bed shear stress Reduced diversity of habitat types Habitat loss for fish reproduction and feeding. Risk of failing to achieve the good hydromorphological and implicitly ecological/potential status.
		Longitudinal continuity of sediment transport affected by artificial structures	Results from WP5 pressure assessment, completed by internal knowledge/information about the pressures characteristics	1 = no structures or structure has no effect on sediment transport 2 = no effect on suspended sediment; only frequency of bedload is affected 3 = partially permeable for bedload; suspended sediments only frequency affected 4 = impermeable for bedload; suspended	Moderate/ Poor/ Bad hydro-morpho-logical status	Moderate/ Poor/ Bad ecological status of FBK, MZB, Fish	Changes of the natural river dynamics, river morphology as well as riverbed incision due to the interruption of sediment transport. Risk of failing to achieve the good hydromorphological and implicitly ecological/potential status.

				sediments can partially pass through 5 = general barrier for all sediments			
		Suspended sediment concentration / load (**decrease**)	Results from WP3 (data collection) and WP4 (sediment balance processing)	1 = very low alterations (0 - 10%) 2 = low alterations (10 - 20%) 3 = moderate alterations (20 - 35%) 4 = strong alterations (35 - 50%) 5 = very strong alterations (>50%)			The quantity of the eroded, deposited and transported sediment is directly related to the size of the available sediments The substrate provides the support in terms of physical habitat description of fish, macrozoobenthos and macrophytes and directly supports the assessment of the biological quality elements (BQE) under the WFD requirements.
		Suspended sediment concentration / load (**increase**)		1 = very low alterations (0 - 20%) 2 = low alterations (20 - 50%) 3 = moderate alterations (50 - 75%) 4 = strong alterations (75 - 100%) 5 = very strong alterations (>100%)			

2 Results of the risk analysis performed in Upper, Middle and Lower Danube

Considering several of the sediment key aspects approach in the frame of main activities till this stage of the project, respectively on Upper, Middle and Lower Danube River scale (drivers, pressures, sediment balance, but also taken into account the proposal structure of recommendations) the present report developed follows the same approach.

The involved project partners provided the description of the pilot sites according to Annex 1. They also provided the short reports after applying the risk methodology presented in Chapter 1, following the template from Annex 2.

The results of the application of the risk methodology in the frame of each pilot site (Figure 3) are summarised following every step (the algorithm scheme is presented in Annex 3).

Figure 3: Pilot sites selected for applying the risk methodology in Upper, Middle and Lower Danube

2.1 Results of the risk analysis performed in the Upper Danube pilot sites

The methodological steps were applied in two pilot sites in the Upper Danube. The German stretch is a representative 50 km long reach from rkm 2415 to 2365 and the Austrian stretch ranges from downstream of the HPP Freudenau at rkm 1921 to the Slovakian border at rkm 1880 (map and description are included in Annexes 4 and 5).

➢ Regarding the identification of hydromorphological elements:

In the Upper Danube, the identification of the hydromorphological elements in the selected pilot sites shows the following characteristics: the alteration of the morphology in the planform varies from 35 – 75 % in pilot site in Germany to 15-35 % in the Austrian pilot site. The alteration of the substrate indicates moderate to greater changes; banks affected by hard artificial material varies from 15 to 75 %; land cover is in generally moderately altered and the degree of lateral connectivity of river and floodplain is variable in the pilot site in Austria and severely changed in the pilot site in Germany. The changes in flow conditions are similar in both pilot sites.

➢ Assessment of hydromorphological quality elements:

The approach to assess the hydromorphological quality elements was performed by the partners in different ways in the two pilot sites. Therefore, a comparative analysis is difficult to perform. The following paragraphs illustrate this difference.

German pilot site: The risk assessment methodology applied resulted in an overall score for the hydromorphological quality elements, which consist of the following: morphology, hydrology, river continuity and sediments. The assessment of the individual parameters of each element had the following results:

- Morphology:
  - Planform: 35 % to 75 % of reach length changed;
  - Substrates: Natural mix/character greatly altered;
  - Reach-based and local impacts of sluices and weirs on ability of biota and sediment continuity: Structures present, but having only minor or moderate effects;
  - Extent of reach affected by artificial bank material: Banks affected by > 35 % to 75 % hard artificial materials;
  - Land cover in riparian zone: 35 % to 75 % non-natural land cover;
  - Degree of lateral connectivity of river and floodplain: 35 % to 75 % of reach affected by floodbanks or other measures impeding flooding of floodplain.

- Hydrology: Changes of flow conditions due to artificial in-channel structures within the reach: Flow character moderately altered;
- River continuity: Structures present, but having only minor or moderate effects on migratory biota and sediment transport.
- Sediment:
  - Erosion rate: strong erosion (30-60%);
  - Longitudinal continuity of sediment transport affected by artificial structures (Sediment continuity): partially permeable for bedload; suspended sediments only frequency affected;
  - Suspended sediment concentration / load: no data;
  - Erosion/deposition character: great departure from near-natural conditions (≥ 50 % of the features expected are absent).

According to defined HQ WFD class, the German pilot section received a total score of 3 (between 2.5 and 3.4), meaning the stretch was moderately changed from natural conditions. Therefore, further risk assessment is necessary to evaluate the impact of this risk on biology.

Austrian pilot site: The assessment of the hydromorphological quality elements, based on JDS3 results, includes the category sediment continuity (Erosion rate (bed erosion), Longitudinal continuity of sediment transport affected by artificial structures (Sediment continuity), Suspended sediment concentration / load (decrease), Erosion/deposition character (based on deviation from near to natural conditions for section types)), according to the results from the technical work packages of the project. For this pilot site, three assessment scenarios have been performed having in view different approaches related to river continuity, longitudinal continuity of sediment transport and gravel feeding, as follows:

- First assessment: The score for longitudinal continuity of the sediment transport was increased due to gravel feeding downstream of HPP Freudenau;
- Second assessment: The parameter river continuity was not considered and the score for longitudinal continuity of sediment transport was increased due to gravel feeding downstream of HPP Freudenau. In JDS3 for the parameter river continuity it is only assessed if structures are present in this 10 km segment that have an effect on migration or on sediment transport and also the degree of the effect. But downstream effects of these structures are not considered. The parameter river continuity in its present form is not suited to identify the alteration of the sediment regime in terms of continuity in the pilot reach, therefore it was not used;
- Third assessment: River continuity and the gravel feeding downstream of the HPP Freudenau were not considered.

- Evaluation of the hydromorphological risk based on the results of the hydromorphological quality assessment:

Having in view the particularities presented in the previous step, the risk assessment results are presented separately for each pilot site, as follows:

German pilot site: Considering the HQ WFD class in the frame of the hydromorphological risk assessment, we can indicate for the pilot site a present risk. Therefore, further risk assessment is necessary to evaluate the impact of this risk on biology.

Austrian pilot site: For all three assessments scenarios mentioned above, there is a hydromorphological risk, as follows:

- first assessment scenario: the pilot site is moderately modified;
- second assessment scenario: the pilot site is moderately modified;
- third assessment scenario: the pilot site is moderately modified.

Based on the average score and extensively modified based on the worst average value. Even if three different scenarios were considered in Austria, the results of all assessment scenarios conclude that there is a hydromorphological risk. A similar result regarding the hydromorphological risk was obtained for the German pilot site only based on JDS3 data.

- Selection of biological quality elements and ecological quality assessment:

According to the methodology, three biological quality elements, which are relevant for sediments in all Danube sections, were assessed in the pilot sites: macroinvertebrates, phytobenthos and fish. Based on the BQE assessment, the quality class evaluated varies according to pilot site: moderate (DE) to good (AT) for macroinvertebrates; good (AT) to high (DE) for phytobenthos and moderate (AT) to good (DE) for fish.

The overall ecological score of these three biological quality elements was "good" for the German and "moderate" for the Austrian pilot site. However, when applying the "one out - all out"-principle of the WFD, both the German and Austrian assessment have one parameter scoring "moderate", therefore both pilot sites in the Upper Danube receive a moderate ecological quality score.

- Risk evaluation based on the results of the hydromorphological and ecological quality assessment:

In terms of the environmental risk due to the sediment regime, for German pilot site, the hydromorphological risk assessment estimates an extensively modified river stretch, but the ecological risk is not concluded as being present. In Austria, an alteration of the hydromorphological as well as of the ecological status has been identified, the risk related to sediment regime is considered significant.

2.2 Results of the risk analysis performed in Middle Danube pilot site

The Slovakian-Hungarian pilot site is located between rkm 1790-1768 between Gönyű and Komárom, map and description are included in Annex 6.

➢ Regarding the identification of hydromorphological elements:

According to JDS3, this section can be described with the following characteristics:

- Morphology:
  - Planform: 15 % to 35 % of reach length with changed planform;
  - Substrates: natural mix/character slightly to moderately altered;
  - Erosion/deposition features reflect moderate departure from near-natural conditions (10 % to 50 % of the features expected are absent);
  - Extent of reach affected by artificial bank material: Banks affected by > 35 % to 75 % hard artificial materials;
  - Land cover in riparian zone: 15 % to 35 % non-natural land cover;
  - Land cover beyond the riparian: 15 % to 35 % non-natural land cover;
  - Degree of lateral connectivity of river and floodplain: 15 % to 35 % reach affected by floodbanks or other measures impede flooding of floodplain;
  - Degree of lateral movement of river channel: 35 % to 75 % reach constrained.
- Hydrology: flow character is moderately altered due to artificial in-channel structures within the reach (impoundments, density of groynes and reflectors);
- River continuity: no structures, or if present they have no effect (or very minor effect) on migration or on sediment transport.

Due to the character of the pilot site, the sediment analysis performed within the DanubeSediment project shows that there is no erosion along this section (not considering long term development), there are no structures that have effect on sediment transport and very low alterations of suspended sediment concentration/load occur.

➢ Assessment of the hydromorphological quality elements:

The overall score for the hydromorphological quality elements is 2.09 and falls within class 2 (slightly modified from natural conditions).

➢ Evaluation of the hydromorphological risk based on the results of the hydromorphological quality assessment:

The hydromorphological risk assessment indicated a slightly modified river stretch at the HU-SK pilot site. According to the applied risk assessment methodology, no further biological quality assessment was needed.

2.3 Results of the risk analysis performed in Lower Danube pilot site

The Romanian pilot site is located between rkm 80.5 and 133, being the last section (53 km length) of the Danube River before the delta, where the Danube River is splitting in two (Chilia and Tulcea) and then in three branches (Chilia, Sulina and Sf. Gheorghe). The pilot area has been selected having in view the importance of sediment inputs in the frame of the morphodynamic processes of the Danube Delta (map and description are included in Annex 7).

- Regarding the identification of hydromorphological elements:

The JDS 3 results emphasize that regarding the morphology the Lower Danube provides moderated modified stretches, due to the limited lateral connectivity (floodplains). Regarding the continuity interruption in the Lower Danube, only the Iron Gate reach falls in extensively and severely modified, taking into consideration that sediment and hydrological changes were caused by the two Iron Gate dams (and also, various dams on the Lower section of major tributaries, Siret and Prut Rivers, confluences located closer to the Romanian pilot site). However, the Iron Gates are located about 900 km upstream of the Romanian pilot site.

Considering the hydromorphological pressures, the pilot area is mainly characterized by the flood protection regulation works: dykes located in major riverbed nearby localities, dykes for protecting different enclosures, especially agriculture ones and river bank protection structures. Drainage systems including pumping stations are present in the pilot area, discharging high waters back into Danube River after floods events. Dredging works for navigation should be considered (Tulcea harbour is located immediately downstream of the RO pilot site).

According to JDS3 results, the pilot site can be described with the following characteristics:

- Morphology:
  - planform: about 15 to 35% of the stretch length;
  - substrates: altered;
  - extent of reach affected by artificial bank material: range of 15%-35%;
  - land cover in riparian zone: 15 % to 35 % is non-natural land cover;
  - degree of lateral connectivity of river and floodplain: up to 75% considering all different 10 river km sectors assessed in JDS3.
- Hydrology: flow character is moderately altered mostly due to changes in river flow sections;
- Referring to sediment, erosion/deposition character reflects moderate departure from near-natural conditions (10 % to 50 % of the features expected are absent);

- Longitudinal continuity of the sediment is not altered due to the absence of transversal barriers (dams and weirs) along the pilot sector;
- Suspended sediment concentration registered a small alteration due to a small increase, according to data provided in the frame of the project;
- Data for erosion rate was not available.

➢ Assessment of the hydromorphological quality elements:

A score set up by the JDS3 results and GeoEcoMar "Monitoring Programmes" (the contracted partner for development and application of the methodology in RO pilot site) has been assigned to each parameter depending on the level of disturbance. The main hydromorphological element at risk due to hydromorphological works for regulation and dredging for navigation is the lateral connectivity of river and floodplain. The floodplain element is heavily and extensively affected, therefore a score of 4 has been assigned.

The morphological parameters score, including channel, banks and floodplain is 3.34. The overall score for the **hydromorphological quality is 2.5**. According to the defined HQ WFD class, the pilot section fell into class 3 meaning moderately modified from natural conditions.

➢ Evaluation of the hydromorphological risk based on the results of the hydromorphological quality assessment:

The morphological risk assessment estimates a moderately modified river stretch, the hydromorphological quality assessment score is moderately modified with 2.5 (according with JDS3 report assessment class boundaries). Further risk assessment was necessary to evaluate the impact of this risk on biological quality elements.

➢ Selection of biological quality elements and ecological quality assessment:

According to the categories of the biological risk assessment, MZB can be categorized as high-quality class. The green algae were the most abundant group in terms of species composition and abundance within the Lower Danube. Therefore, the results of the JDS3 assessment for phytobenthos classified this sector within the moderate ecological quality class. For fish biological element, the results based on JDS3 report data indicate a poor ecological quality class.

The application of WFD principle (one out - all out) for the ecological quality assessment leads to the fact that the overall quality class for this pilot site is poor.

➢ Risk evaluation based on the results of hydromorphological and ecological quality assessment:

Taking into account the results of quality assessment of hydromorphological and ecological elements the risk related to the sediment regime for the pilot site is significant.

3 Conclusions

3.1 Conclusions regarding the methodology

Based on the vast literature information, the European legislation, the findings of the ICPDR, 2015 and keeping the objectives of the project in mind, namely the assessment of hydromorphological risks in association with the biological elements, a straightforward methodology was proposed. This methodology was developed to be widely applied by the Danube riparian countries. It focuses mainly on the hydromorphological elements, its purpose being to assess the impact of alteration of sediments on hydromorphological quality elements and consequently on biological quality elements of all river components (i.e. channel, bank, and floodplain). Therefore, almost all parameters used during the HYMO JDS3 were considered. This approach is applied for the near to natural based assessment of the morphological, hydrological and continuity components required by Annex II and V of WFD. Beside the significant hydromorphological parameters assessed in JDS3, also a set of relevant sediment-related parameters (**sediment continuity, increase/decrease suspended sediment concentration load, erosion rate - depending on data availability in pilot sites**) was added.

Furthermore, our project methodology sought to choose undemanding biological parameters related to hydromorphological parameters in order to improve the environmental risk assessment (see beginning Step 5).

To resume, our methodology follows a stepwise process to decide if a specific river section is at risk of failing the good ecological status of the WFD. Depending on the results of the hydromorphological quality assessment, one should undertake a biological assessment or not.

The risk assessment at the moment includes one difficulty: the biological assessment is always a mirror of the existing situation plus some historic influence. Once the biology shows a negative condition it means that already a significant hydromorphological change took place leading to an existing deficit. The consequence is that when discovering an ecological problem, it might be too late to react because a change of the sediment regime and morphodynamics is much slower than the biological reaction. As a consequence, an understanding of the development of the sediment regime and the morphology must be developed in order to predict in time the probable morphological consequences.

3.2 Conclusions regarding the results of risk performed

- In the Upper Danube:

German pilot site: Several pressures like hydropower, navigation and flood protection have severely altered the German Danube, creating a river that has only a few near-natural stretches left. Sediments are trapped in reservoirs, causing erosion of the downstream riverbed due to a lack of sediment. Moreover, a chain of hydropower plants regulates the flow and corresponding reservoirs reduce natural flow variations. Therefore, a comprehensive flood protection system is needed for nearby cities and communities.

However, some processes such as riverbed erosion seem to have been reduced in recent decades, and sediment continuity for suspended load has been re-established. Moreover, new technologies and management schemes for hydropower plants might further improve the sediment continuity in this region. In addition, renaturation measures are implemented along the German Danube – where possible. It is clear that close to communities, natural flooding is not acceptable, but elsewhere, in order to create valuable habitats, flooding can be re-established to a certain extent (Stammel, 2012). In addition, alternative groynes can improve navigation and establish a stable channel to avoid non-natural dredging and feeding of sediments (Tritthart, 2014).

Despite the contradiction to the strongly modified morphological status of the pilot region, the biological quality assessment revealed a moderate class for this section. To improve the biological quality assessment class, we recommend improving the morphological quality. For example, by evaluating options for floodplain restoration and sediment management for bedload and to continue the ecological monitoring to track the development of the river and ensure a near natural life in the river.

Austrian pilot site: The results of the risk assessment show that the hydromorphological as well as the biological status in the pilot site at the Danube East of Vienna are moderate and thus there is a risk not to reach the objectives aimed by the WFD. It is clear that there is a causal chain from sediment transport to river morphology and ecology. Thus, the sediment regime is a prerequisite for river morphodynamics and habitat dynamics. Furthermore, there is no doubt that habitat quality directly influences the ecological status. Thus, the link between sediments and aquatic species is given by providing habitats, spawning places etc. Of course, there are other factors (e.g. water quality, water temperature, ship waves) influencing the biological status. Besides the risk of not achieving the good ecological status, an imbalanced sediment regime also puts other sectors such as navigation, flood protection and water supply at risk. So, for this pilot site, as both an alteration of hydromorphological as well as of the ecological status has been identified, the risk related to sediment regime is considered significant.

For the assessment of the sediment continuity, it is very important to consider, that the effect of a transversal structure (e.g. dam, weir) on the sediment regime is usually not only a local one, but also has an effect in the downstream and upstream direction.

Also, the thresholds used to score the sediment-related indicators were a first attempt and should be further refined / calibrated. The suggestion of the DanubeSediment project is to take the evaluated value for sediment continuity as threshold, which doesn't allow any parameter dependent on sediments (e.g. morphology) to have a better scoring. This approach ought to reflect that the sediment regime determines the overall hydromorphological and ecological class.

Intensified investigations are necessary to further develop this approach and it then should be tested on selected rivers in the Danube River Basin.

- In the Middle Danube:

The main drivers in relation with sediment balance were identified as navigation and flood protection. The most important pressures are groynes and bank protection work in the main channel and flood protection dykes in the floodplains.

The above implemented risk analysis indicated that the most relevant feature regarding the hydromorphological alterations at the Hungarian-Slovakian pilot site is the river bank, where bank protection works were constructed for stabilising the geometry of the main channel. The planform, the substrates, the land cover in riparian zone, lateral connectivity within the floodplain as well as the flow character are moderately modified. On the other hand, due to the fact that this is a free flowing section of the Danube without any significant barriers for the sediment transport, the continuity of the sediment is ensured. Overall, the risk assessment suggested a slightly modified reach of the Danube River in the pilot site, showing no hydromorphological risk and therefore no ecological risk needs to be assessed.

- In the Lower Danube:

The main drivers identified in this section are navigation and flood protection. As the significant pressures identified in pilot site, we mention flood protection dykes located on the Romanian side between rkm 100 to 133 and dykes for the protection of agricultural enclosures between rkm 80 and rkm 100.

Following the assessment, the main hydromorphological element at risk is the channel morphology. This is due to hydromorphological works of regulation and dredging for navigation, which causes a disruption of the sediment balance and the longitudinal transport. The same drivers also led to an impact on the lateral connectivity of river and floodplain, the quality of floodplain element being heavily and extensively affected.

The narrowing or enlargement of the channel as result of engineering works within the channel and floodplain may pose an increasing hydromorphological risk, because the bed and suspended sediment loads transported along the river in the pilot site changed.

According to the results of the hydromorphological quality assessment, the overall score was 2.5, meaning moderately modified.

In terms of individual biological quality elements, the ecological quality class in the pilot area was high according to macroinvertebrates, moderate according to phytobentos and poor according to fish. Based on the results, the overall ecological quality class is poor according to WFD, one out - all out principle. In relation with the hydromorphological pressures, the fish element suffered a decline of diversity, probably as result of regulations works and intense navigation.

Taking into account the results of the quality assessment of hydromorphological and ecological elements, the risk for the pilot site is significant.

List of Abbreviations

AT - Austria

AQEM - Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macroinvertebrates

BQEs - Biological quality elements

CEN - European Committee for Standardization

CIS - Common Implementation Strategy

DBA - Danube Basin Analysis

DE - Germany

DFRMP - Danube Flood Risk Management Plan

DPSIR - Driver, Pressure, Status, Impact, Response

DRB - Danube River Basin

DRBD - Danube River Basin District

DRBMP - Danube River Management Plan

DSMG - Danube Sediment Management Guidance

EFI - European fish index

EUSDR - European Union Strategy for the Danube Region

ECOQ - Ecological quality

FD - EU Floods Directive 2007/60/EC

FIA - Fish index Austria

FIS - Fish index Slovakia

FP EG - Flood Protection Experts Group

FRMP - Flood Risk Management Plan

HU - Hungary

HQ - Hydromorphological quality

HQE - Hydromorphological quality elements

ICPDR - International Commission for the Protection of the Danube River

JDS - Joint Danube Survey

MZB - Macrozoobenthos

NIRD GeoEcoMar - National Institute for Research and Development on Marine Geology and Geo-Ecology

PPs - Project Partners

QEs - Quality Elements

RBMP - River Basin Management Plan

rkm - river kilometre

RO – Romania

SS - suspended sediment

SK - Slovakia

WFD - EU Water Framework Directive 2000/60/EC

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Annexes

Annex 1: Template for Short Report including the results after applying the methodological steps in the pilot site

1. INTRODUCTION

Briefly, about location of the pilot site on rkm of the Danube River: ………… Country(ies) involved in appliance of the methodology: …………… PPs involved in appliance of the methodology: ……………. (total 300 characters)

2. RESULTS OF THE HYDROMORPHOLOGICAL ELEMENTS AND BIOLOGICAL QUALITY ELEMENTS SCORING

STEP 1. Identification of hydromorphological elements

Results of selecting the hydromorphological elements and parameters which are most affected by the identified hydromorphological pressures (according to Table 12 from chapter 1)

(Note: The parameter "erosion rate" included if data available in pilot site)

(2000 characters)

…………

STEP 2. Hydromorphological quality assessment

Results of the quality assessment of hydromorphological elements (according to Table 12 from chapter 1)

(2000 characters)

………..

STEP 3. Hydromorphological risk evaluation based on the results of hydromorphological quality assessment

Result of hydromorphological risk evaluation.

(If assessment of hydromorphological elements falls within the Class 3, 4 or 5, will be considered that there is a hydromorphological risk).

(1000 characters)

……………

STEP 4. Selection of biological quality elements and STEP 5. Ecological quality assessment

Results of selecting the biological quality elements (according to related steps described in chapter 1) and overall ecological quality status (according to Table 11 from chapter 1).

(2000 characters)

……………

STEP 6. Risk evaluation based on the results of hydromorphological and ecological quality assessment

Result of risk evaluation based on the results of hydromorphological and ecological quality assessment.

(2000 characters)

…………………

3. CONCLUSIONS:

(5000 characters) ………….

4. BIBLIOGRAPHY:

…………………..

Annex 2: Template for proposed Pilot Sites located in Upper, Middle and Lower Danube

- Name of the PP proposing the pilot site:

……

- Name of the pilot site (if any):

……

- The region/country/**river kms/ GIS information**, where the pilot site is located:

……

- **Reasons** for recommending this pilot site for the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) in **DanubeSediment** project:

……

- How the proposed pilot site will contribute to the achievement of the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) objective (data availability, diversity):

……

- Mention if your pilot site proposal it based on a study or measures arising from other projects (having similar risk assessment):

……

- If yes, please indicate the name of the study / projects:

……

- If available, insert here a map illustrating the location of the pilot site:

……

Annex 3: The risk methodology - overall scheme

STEP 1.Identification of hydromorphological elements					STEP 2. Hydromorphological quality assessment		
		HQ Parameters/elements	Source	Values/ descriptions	SCORE OF ELEMENT	AVG SCORE OF ELEMENT GROUP	TOTAL AVG. HYMO QUALITY SCORE
MORPHOLOGY	CHANNEL	**Planform (based on deviation from near to natural conditions for section types)**	"JDS3 Extended report on: Hydromorphology" and Annex "JDS3HYMO_CONT_ASS080714", accessed on: http://www.danubesurvey.org/jds3/results	**1** = 0 % to 5 % of reach length with changed planform.			
				2 = > 5 % to 15 % of reach length with changed planform.			
				3 = > 15 % to 35 % of reach length with changed planform.			
				4 = > 35 % to 75 % of reach length with changed planform.			
				5 = > 75 % of reach length with changed planform.			
		Substrates (Natural substrate mix or character altered) (based on deviation from near to natural conditions for section types)		**1** = Near-natural mix			
				3 = Natural mix/character slightly to moderately altered			
				5 = Natural mix/character greatly altered			
				CHANNEL AVERAGE SCORE			
	BANKS	**Extent of reach affected by artificial bank material (% of bank length)**	"JDS3 Extended report on: Hydromorphology" and Annex (…)	**1** = Banks affected by 0 % to 5 % hard, artificial materials.			
				2 = Banks affected by > 5 % to 15 % hard, artificial materials.			
				3 = Banks affected by > 15 % to 35 % hard, artificial materials.			
				4 = Banks affected by > 35 % to 75 % hard artificial materials.			
				5 = Banks affected by > 75 % hard artificial materials			
		Land cover in riparian zone (top of banks and adjacent narrow strip) (% of bank length)		**1** = 0 % to 5 % non-natural land cover in riparian zone.			
				2 = > 5 % to 15 % non-natural land cover in riparian zone.			
				3 = > 15 % to 35 % non-natural land cover in riparian zone.			
				4 = > 35 % to 75 % non-natural land cover in riparian zone.			
				5 = > 75 % non-natural land cover in riparian zone.			
				BANK AVERAGE SCORE			
	FLOODPLAIN	**"Degree of lateral connectivity of river and floodplain (Extent of floodplain not allowed to flood regularly due to engineering-based on hydromorphological surveys – such as: dykes, channel straightening and shortening as regulation works). Is over-bank flooding likely to occur (or likely to have occurred historically) naturally in the reach? (based on deviation from near to natural conditions for section types)"**	"JDS3 Extended report on: Hydromorphology" and Annex (…)	**1** = 0 % to 5 % reach affected by floodbanks or other measures impeding flooding of floodplain (e.g. channel and bank regrading).			
				2 = > 5 % to 15 % as above.			
				3 = > 15 % to 35 % as above.			
		Yes/No. If No – N/A. **If Yes, score:**		**4** = > 35 % to 75 % as above.			
				5 = > 75 % as above.			
				FLOODPLAIN AVERAGE SCORE			
				MORPHOLOGY AVERAGE SCORE			
HYDROLOGY	CHANNEL	Changes of flow conditions due to artificial in-channel structures within the reach (impoundments, density of groynes and reflectors)	"JDS3 Extended report on: Hydromorphology" and Annex (…)	**1** = Flow character not or only slightly affected by structures			
				3 = Flow character moderately altered			
				5 = Flow character extensively altered			
				HYDROLOGY AVERAGE SCORE			
RIVER CONTINUITY	CHANNEL	Reach-based and local impacts of sluices and weirs on river continuity with regard to biological and sediment transport	"JDS3 Extended report on: Hydromorphology" and Annex (…)	**1** = No structures, or if present they have no effect (or very minor effect) on migration or on sediment transport.			
				3 = Structures present, but having only minor or moderate effects on migratory biota and sediment transport.			
				5 = Structures that in general are barriers to all species and to sediment.			
				RIVER CONTINUITY AVERAGE SCORE			
SEDIMENT	CHANNEL	Erosion rate (bed erosion)	WP4 results comparing transversal profiles (depending on data availability in pilot sites)	1 = very low erosion (0%)			
				2 = low erosion (0-15%)			
				3 = moderate erosion (15-30%)			
				4 = strong erosion (30-60%)			
				5 = very strong erosion (>60%)			
		Longitudinal continuity of sediment transport affected by artificial structures (Sediment continuity)	Results from WP5 pressure assessment, completed by internal knowledge/information about the pressures characteristics	1 = no structures or structure has no effect on sediment transport			
				2 = no effect on suspended sediment; only frequency of bedload is affected			
				3 = partially permeable for bedload; suspended sediments only frequency affected			
				4 = impermeable for bedload; suspended sediments can partially pass through			
				5 = general barrier for all sediments			
		Suspended sediment concentration / load (decrease) (SSC_change = 1 – SSCpresent / SSCref)	Results from WP3 (data collection) and WP4 (sediment balance processing)	1 = very low alterations (0 - 10%)			
				2 = low alterations (10 - 20%)			
				3 = moderate alterations (20 - 35%)			
				4 = strong alterations (35 - 50%)			
				5 = very strong alterations (>50%)			
		Suspended sediment concentration / load (increase) (SSC_change = SSCpresent / SSCref - 1)	Results from WP3 (data collection) and WP4 (sediment balance processing	1 = very low alterations (0 - 20%)			
				2 = low alterations (20 - 50%)			
				3 = moderate alterations (50 - 75%)			
				4 = strong alterations (75 - 100%)			
				5 = very strong alterations (>100%)			
		Erosion/deposition character (based on deviation from near to natural conditions for section types)	"JDS3 Extended report on: Hydromorphology" and Annex (…)	**1** = Erosion/deposition features reflect near-natural conditions.			
				3 = Erosion/deposition features reflect moderate departure from near-natural conditions (10 % to 50 % of the features expected are absent).			
				5 = Erosion/deposition features reflect great departure from near-natural conditions (≥ 50 % of the features expected are absent).			

STEP 2. Hydromorphological quality			STEP 3. Hydromorphological risk evaluation		
HQ WFD Class			Hydromorphological risk assessment	Decision	Biological Quality Assessment
1.0 to 1.4	Class 1	"Near-natural"	Hydromorphological risk?	NO	not necessary
1.5 to 2.4	Class 2	"Slightly modified"			
2.5 to 3.4	Class 3	"Moderately modified"		YES	necessary
3.5 to 4.4	Class 4	"Extensively modified"			
4.5 to 5.0	Class 5	"Severely modified"			

STEP 4. Selection of biological quality elements							STEP 5. Ecological quality assessment			
Biological	Biologic							TOTAL AVG		
MZB	No. of taxa	Upper Danube	Middle Danube		Lower Danube	BQ Class	Score			
		16 - 20	21 - 52		16 - 18	High	1			
		11 -15	11 - 20		11- 15	Good	2			
		6 -10	6 - 10		6 - 10	Moderate	3			
		3- 5	3- 5		3 -5	Poor	4			
		<3	< 3		< 3	Bad	5			
					MZB Quality Assessment score					
Phyto-benthos (FBK)	Ratio of indi-cator class domi-nant species	All Danube course				BQ Class	Score		Score range	ECOQ class
		Dominate diatoms				High	1		1 – 1.33	High
		diatoms/green algae > 1				Good	2		1.34 - 2	Good
		green algae /cyanobacteria > 1				Moderate	3		2.1 – 3.33	Moderate
		cyanobacteria / green algae >1				Poor	4		3.34 - 4	Poor
		Dominate cyanobacteria				Bad	5		4.1 -5	Bad
					FBK Quality Assessment score					
Fish*	FIA	EFI	FIS	Abundance	Taxonomic Composition	BQ Class	Score			
						High	1			
						Good	2			
						Moderate	3			
						Poor	4			
						Bad	5			
					Fish Quality Assessment score					

Fish* parameters will be assessed based on the available data or litterature (Bammer *et al*., 2014)

Step 6. Risk evaluation		
Risk categories		Observation
Significant	Not significant	in case that a relationship between the hydromorphological and ecological quality is not evident as result of quality assessment (E.g., either high/good hydromorphological quality vs. moderate/poor/bad ecological status or other way round), no further risk assessment will be performed.
Hydromorphological and ecological status moderate/poor/bad	Hydromorphological and ecological status high/good	

To SEDIMENT - CHANNEL - Erosion rate (bed erosion):

0		-0,25
15	-0,25	-0,21
30	-0,21	-0,18
60	-0,18	-0,10
	-0,10	

cm/year

Remarks:

- Percentage of the high to poor classes is fixed.
- The maximum erosion rate sets the corresponding absolute values in cm/a.
- Erosion of -0.25 cm/a is tolerated: Capture measurement uncertainty and river dynar
- cm /year class boundaries (based on percentage of the rating)

$$Years = {}^{-(h_{alluvial} - h_{max-Flood})}/_{\Delta blc} + f_{erodibility}$$

$h_{alluvial}$ (m) – alluvial layer depth
$h_{max\text{-}flood}$ (m) – maximum erosion depth during a flood
Δblc – bed level change in cm/year
positive: sedimentation
negative: erosion
$f_{erodibility}$ – bonus / malus based on erodibility
high: -25 years
moderat: 0 years
low: +25 years

Annex 4: German Pilot Site proposed in Upper Danube

- Name of the PP proposing the pilot site:
  LFU and TUM
- Name of the pilot site (if any):

Kelheim (rkm 2415) to Geisling (rkm 2365)

- The region/country/**river kms/ GIS information**, where the pilot site is located:

Bavaria/Germany/rkm from 2415 to rkm 2365

Longitude (WGS 84, decimal) O 11.84761
Latitude (WGS 84, decimal) N 48.90599

- **Reasons** for recommending this pilot site for the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) in **DanubeSediment** project:

The section is typical for the German Danube, since it includes two run-of-river hydropower plants, the stretch is navigable and flood protection measures for nearby cities are also a significant pressure.

- How the proposed pilot site will contribute to the achievement of the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) objective (data availability, diversity):

The impact on (and therefore the risk for) sediment from the drivers mentioned above can be analysed in more detail since high quality data is available. A variety of data on morphology as well on biology was provided from regional authorities and institutes. Moreover, JDS3 sampling points are located within this section.

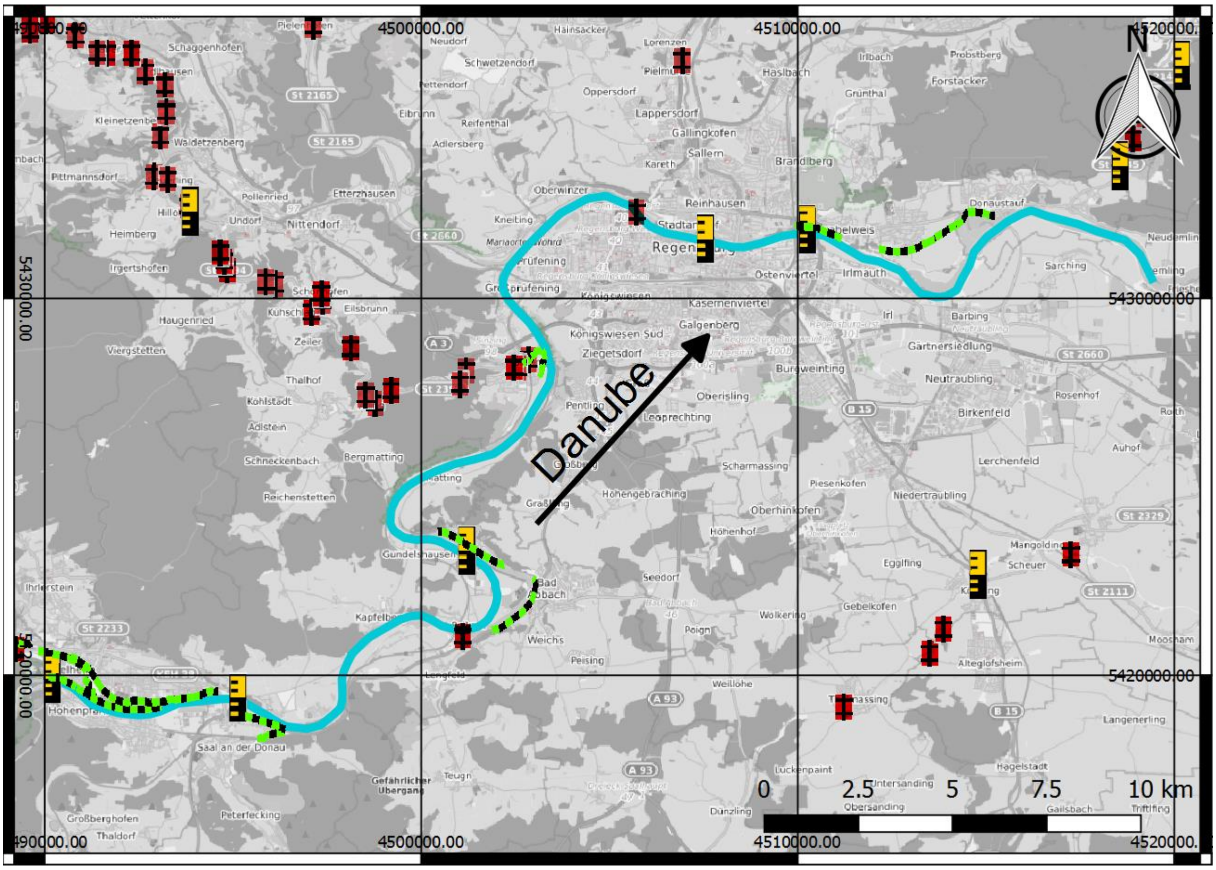
- Mention if your pilot site proposal it based on a study or measures arising from other projects (having similar risk assessment):

No.

- If yes, please indicate the name of the study / projects:

NA.

- If available, insert here a map illustrating the location of the pilot site:



Green: Flood protection dykes
Red: Weirs, Culverts, hydropower plants
Yellow: Gauging stations
Map is created using OpenSteetmap www.openstreetmap.org/copyright
Coordinate System: DHDN GK Z4: 31468

Annex 5: Austrian Pilot Site proposed in Upper Danube

- Name of the PP proposing the pilot site:
  BOKU – University of Natural Resources and Life Sciences, Vienna (ERDF PP1)
- Name of the pilot site (if any):

Danube East of Vienna

- The region/country/**river kms/ GIS information**, where the pilot site is located:

The pilot site is located downstream of the HPP Freudenau (river-km 1921) until the border to Slovakia (river-km 1880) in Lower Austria, Austria.

- **Reasons** for recommending this pilot site for the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) in **DanubeSediment** project:

The reach East of Vienna is one of the two remaining free flowing sections at the Austrian Danube and is located in the national park 'Donau-Auen'.

Boundary conditions:

- Negative sediment balance (no natural bedload input, modified suspended sediment);
- Riverbed erosion (1-2cm/year);
- Gravel feeding downstream of the HPP Freudenau;
- Ecological deficits in national park;
- Lowering of the groundwater table;
- Reduced hydrological connectivity between river and floodplains and reduced geomorphic processes;
- Concentration of erosive forces in the main channel and consequently a deepening of the riverbed;
- Loss of riverine inshore habitats;
- Isolation of backwaters;
- Bottleneck for navigation;
- Disturbance of the water body due to ship waves (might have an influence on habitat quality, biomass).

One important part is the gravel feeding downstream of the HPP Freudenau by the hydropower company VERBUND. In addition, several measures are implemented in the frame of the catalogue of measures for the reach East of Vienna with the general and equivalent development targets to stabilize the water levels of the surface and ground water, to maintain and improve the habitats in the Danube floodplains and to improve the waterway infrastructure for inland navigation. Those integrated measures consist of an integrated sediment management, the optimization of the river training, side channel reconnections, removal of bank protection and protection of critical scours. These measures tend to keep the sediments longer in the system, reduce the transport capacity in the main channel, to prevent a riverbed break-through and to improve the ecological situation.

- How the proposed pilot site will contribute to the achievement of the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) objective (data availability, diversity):

Viadonau is performing regular bathymetry measurements in this reach, which makes it possible to assess bed level changes and erosion rates. Especially in the downstream part of this reach between river km 1887.5 and river km 1884.5, many sediment measurements were performed. Here the only bedload monitoring station and the only suspended sediment monitoring station that takes the temporal and spatial variability of the suspended sediments into account are located. Additionally, bed material sampling was performed.

- Mention if your pilot site proposal it based on a study or measures arising from other projects (having similar risk assessment):

No

- If yes, please indicate the name of the study / projects:

NA

- If available, insert here a map illustrating the location of the pilot site:

No

Annex 6: Slovakian-Hungarian Pilot Site proposed in Middle Danube

- Name of the PP proposing the pilot site:

BME and VUVH

- Name of the pilot site (if any):

Gönyű-Komárom section

- The region/country/**river kms/ GIS information**, where the pilot site is located:

The Slovakian-Hungarian pilot site is located in the Middle Danube, along the common section of Hungary and Slovakia, between rkm 1790-1768 (between Gönyű and Komárom).

- **Reasons** for recommending this pilot site for the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) in **DanubeSediment** project:

The river section situated downstream of the Old Danube and tailrace canal confluence. In relation to changes in sediment balance and river morphology this is particularly significant section of the Danube river.

Reasons are as follows:

- Lack of sediments due to trapping effect of Hrušov reservoir upstream of Gabčikovo hydropower plant (erosion of the riverbed downstream and deposition upstream of Gabčikovo HPP), changes in flow dynamics;
- Significant change in morphological character of the Danube river (it is situated just between lower end of Upper Danube and the beginning of Middle Danube – significant change in longitudinal slope of the riverbed);
- Impact of the Old Danube on sediment regime during floods;
- Groynes fields on both river sides;
- System of side arms along the section.

The Danube here is free flowing. Thy typical width of the main channel is around 400 m, the mean depth is ~5 m, the slope is ~15 cm/km, the mean flow discharge is ~2000 m^3/s, which can reach 10000 m^3/s in extreme flood events. The riverbed is dominated by medium gravel. The main channel is stabilized by bank protection, moreover, groynes were built to maintain the navigational channel at the upstream part of the pilot site. Four side branches can be found along the pilot area, two along the right bank, i.e. in Hungary, and two along the left bank, in the Slovakian side.

- How the proposed pilot site will contribute to the achievement of the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) objective (data availability, diversity):

The morphology of the Danube River along the pilot site is well documented on long-term, thanks to the common Slovakian and Hungarian efforts of the regional water directorates as well as research institutes. Sediment transport data is available for a long period (several decades), moreover, the relevant features for the hydromorphological and ecological risk analysis is available from the Joint Danube Survey 3 (the hydromorphological characterization was led by VUVH).

For the necessary analyses and evaluations in the frame of the project, there are available long-term monitoring data, having hydrological monitoring stations emplaced, where data of water characteristics (velocity, discharge, and bathymetry) and suspended sediments characteristics are collected. In the same time information on sediment regime slightly linked to the main drivers are presented in the frame of the results of expeditions/surveys that took place on the Danube, namely, the Joint Danube Survey (JDS) 2 and 3 and also, NIRD GeoEcoMar "Monitoring Programmes". Thus, according to the "Joint Danube Survey 3 - A Comprehensive Analysis of Danube Water Quality" the most significant changes were defined by interruptions of longitudinal continuity (dams, thresholds), lateral connectivity disruptions (floodplain loss) and hydromorphological changes especially due to navigation, hydropower and flood protection. Significant changes in the amount and composition of sediments as well as the accumulation of sediment and erosion upstream and downstream of Danube River dams constitutes a basin wide issue.

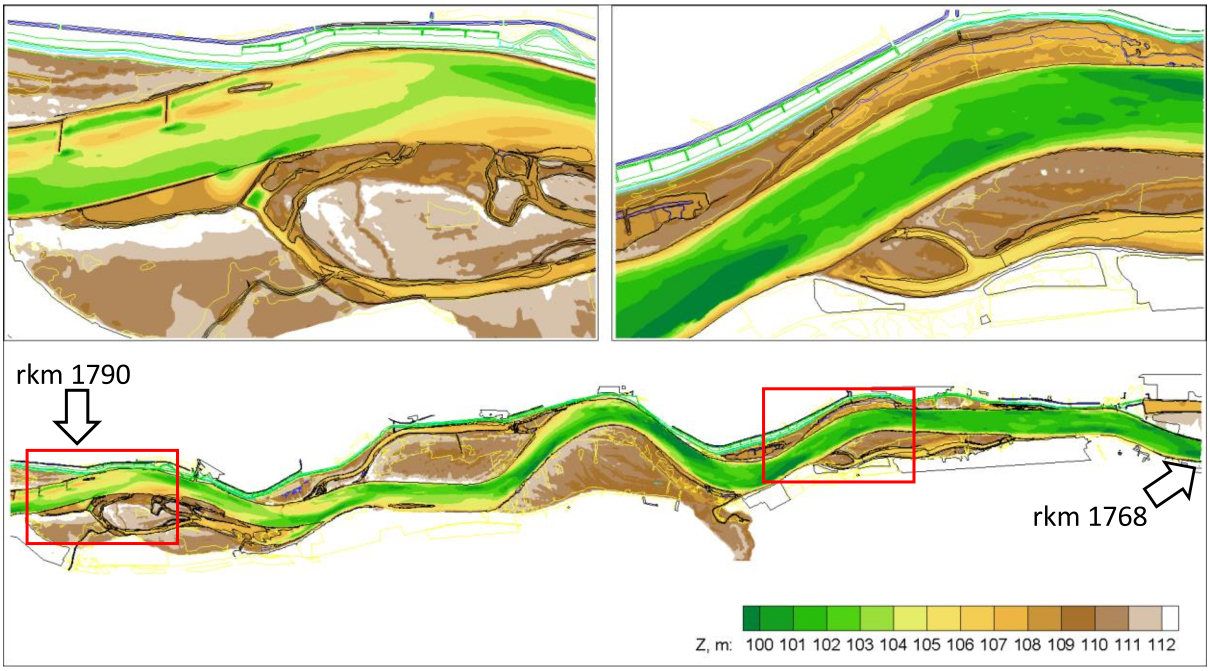
- Mention if your pilot site proposal it based on a study or measures arising from other projects (having similar risk assessment):

No.

- If yes, please indicate the name of the study / projects:

NA.

- If available, insert here a map illustrating the location of the pilot site:


rkm 1790
rkm 1768
Z, m: 100 101 102 103 104 105 106 107 108 109 110 111 112

Annex 7: Romanian Pilot Site proposed in Lower Danube

- Name of the PP proposing the pilot site:

NARW

- Name of the pilot site (if any):

The last unique sector of the Danube River, before Danube Delta.

- The region/country/**river kms/ GIS information**, where the pilot site is located:

The Romanian proposal for the Lower Danube Pilot site within the Danube Sediment project is the Danube section located between river kms 133 (Reni gauging station, downstream Galati harbor) and 80.5 (Ceatal Izmail/Chilia gauging station, upstream Tulcea harbor), being the last unique sector of the Danube River, before Danube Delta, where the Danube River is splitting in 2 and then in 3 branches.

- **Reasons** for recommending this pilot site for the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) in **DanubeSediment** project:

This sector of the Danube River is characterized by the multiannual mean flow discharge of 6650 m^3/s. During the floods the discharges have reached values of more than 16900 m^3/s (at Isaccea in 2010) and 15900 m^3/s (at Ceatal Izmail/Chilia in 2006). During low flow periods the flow reached minimum values of 1970 m^3/s (at Isaccea in 2003) and of 2030 m^3/s (at Ceatal Izmail/Chilia in 2003). A significant influence in this sector is induced by Daube's main tributaries (Siret River and Prut River) represented by significand loads of water and suspended sediments.

- How the proposed pilot site will contribute to the achievement of the Act.5.2 Risk assessment related to sediment regime (continuity and quantity) objective (data availability, diversity):

For the necessary analyses and evaluations in the frame of the project, there are available long-term monitoring data, having hydrological monitoring stations emplaced, where data of water characteristics (velocity, discharge, and bathymetry) and suspended sediments characteristics are collected. In the same time information on sediment regime slightly linked to the main drivers are presented in the frame of the results of expeditions/surveys that took place on the Danube, namely, the Joint Danube Survey (JDS) 2 and 3 and also, NIRD GeoEcoMar "Monitoring Programmes". Thus, according to the "Joint Danube Survey 3 - A Comprehensive Analysis of Danube Water Quality" the most significant changes were defined by interruptions of longitudinal continuity (dams, thresholds), lateral connectivity disruptions (floodplain loss) and hydromorphological changes especially due to navigation, hydropower and flood protection. Significant changes in the amount and composition of sediments as well as the accumulation of sediment and erosion upstream and downstream of Danube River dams constitutes a basin wide issue.

The sediment particles are composed mainly of silica with the apparent density of about 1.65 kg/qdm. The grain size of sediment is diverse, from boulders to clays. In the lower section of the Danube, the granulometric composition of sediments consists from clays to coarse sand (locally with small gravels). Depending of particles size two categories can be distinguished: particles with laminar behavior in the water flow and ones with turbulent behavior (Bondar, 2016).

Sediment regimes are crucial to aquatic and riparian ecosystems in many ways, some species having preferences for a particular type of substrate along developmental stages. For example, the fine sediments and organic matter create a very unstable and easily erodible habitat for aquatic invertebrates. Pan et al. (2012) showed that the gravel substrate creates more stable microhabitats that allow the development of a greater number of species of invertebrates. Therefore, the large particles substrate is a high-quality habitat for benthic invertebrates in contrast to substrates composed of small sand particles. In case of fish fauna, salmonids can be sensitive to excess of fine sediment and they require gravels substrate for spawning. The predators are strongly dependent on suspended sediment and turbidity which can alter the visibility necessary for the food activity. The linkages between riparian plans and sediments in terms of sediment retention have been widely described in the scientific literature.

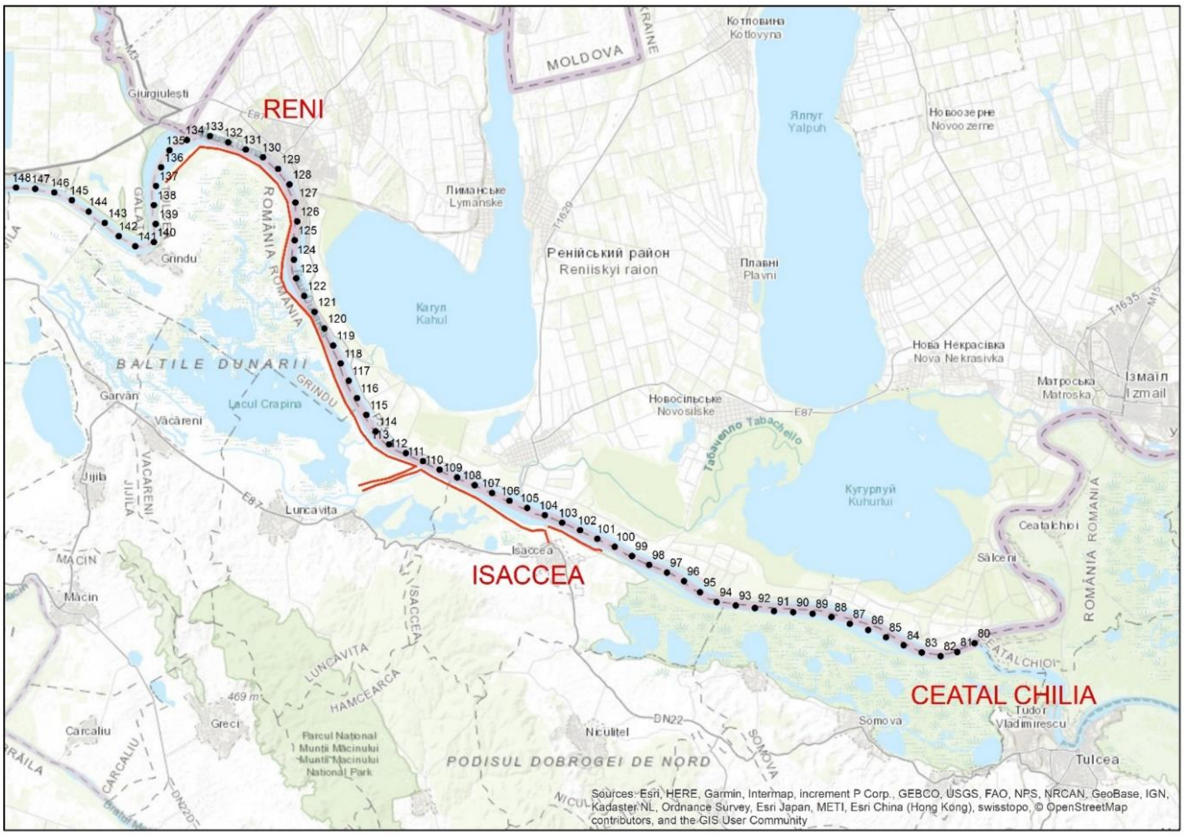
- Mention if your pilot site proposal it based on a study or measures arising from other projects (having similar risk assessment):

No.

- If yes, please indicate the name of the study / projects:

NA.

- If available, insert here a map illustrating the location of the pilot site:


RENI
ISACCEA
CEATAL CHILIA
MOLDOVA
BALTILE DUNARII
Lacul Crapina
Luncavita
Isaccea
Giurgiulesti
Grindu
Garvan
Vacareni
Jijila
Macin
Greci
Niculitel
Somova
Tulcea
Tudor Vladimirescu
Ceatalchioi
Salceni
Parcul National Muntii Macinului
Muntii Macinului National Park
PODISUL DOBROGEI DE NORD
Ренійський район
Reniiskyi raion
Кагул
Kahul
Ялпуг
Yalpuh
Котловина
Kotlovyna
Лиманське
Lymanske
Плавні
Plavni
Новосільське
Novosilske
Нова Некрасівка
Nova Nekrasivka
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