ARUP

Public Water Management Company Srbijavode

European Bank for Reconstruction and Development

Environmental and Social Impact Assessment, Climate Change Assessment and Technical Assessment for Pambukovica Dam in Serbia

Surface Water

Reference: 2025/08

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This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Arup d.o.o. Beograd (Savski venac)
Vojvode Mišića Boulevard 17/4
BIGZ Office Building
11000 Belgrade
Republic of Serbia
arup.com

ARUP

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		Name	Louise Lodenkemper / Multiple	Tom House / Milos Despotovic	Aleksandar Bajovic
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
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Abbreviation	Definition
AOX	Adsorbable Organic Halides
BMP	Biodiversity Management Plan
BOD	Biochemical Oxygen Demand
CHA	Critical Habitat Assessment
CIS	Commonwealth of Independent States
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DRBMP	Danube River Basin Management Plan
DRPC	Danube River Protection Convention
EBRD	European Bank for Reconstruction and Development
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
FASRB	Framework Agreement on the Sava River Basin
FSL	Full Supply Level
GIIP	Good International Industry Practice
GIS	Geographic Information System
GMS	Geographic Management System
GWBs	Ground Water Bodies
HPP	Hydropower Plant
ICPDR	International Commission for the Protection of the Danube River
MAFWM	Ministry of Agriculture, Forestry and Water Management
OECD	Organisation for Economic Co-operation and Development
PGD	Design for the Construction Permit
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PR	Performance Requirement
PWMC	Public Water Management Company
RHMSS	Republic Hydrometeorological Service of Serbia
SEA	Strategic Environmental Assessment
SWMI	Significant Water Management Issues
TOC	Total Organic Carbon
TSM	Thick Shelled Mussel
USLE	Universal Soil Loss Equation
WEMMP	Water and Environmental Management and Monitoring Plan
WFD	Water Framework Directive
WMD	Water Management Directorate
WQ	Water Quality

1. Introduction

1.1 Background

The European Bank for Reconstruction and Development (the "EBRD") is considering providing finance to the Republic of Serbia (the "Borrower", or the "Client"), represented by the Ministry of Finance to enable construction of a water resources reservoir near Pambukovica, Serbia. The Project will be implemented by the Public Water Management Company Srbijavode ("Srbijavode"), the national body responsible for water management, including water use and protection from pollution. Srbijavode is also responsible for management of risks associated with water bodies (such as flood risk). The Project would reduce flooding downstream through water retention in the reservoir and associated attenuation of high flows. Srbijavode operates under the Water Management Directorate (WMD), which in turn is an administrative authority of the Ministry of Agriculture, Forestry and Water Management (MAFWM). The Loan is expected to finance the construction of a new impoundment dam and reservoir infrastructure at Pambukovica including associated works such as upstream sediment traps and road realignment (vertical realignment over the reservoir).

A Serbian Environmental Impact Assessment (EIA) study was prepared by the Energoprojekt - Hidroinženjering on behalf of Srbijavode and was subject to an Environmental and Social Gap Analysis, which indicated that a full Environmental and Social Impact Assessment (ESIA) in accordance with EBRD's Environmental and Social Performance Requirements[1] was required. The assessment of biodiversity impacts, aligned with PR6 and supported by an adequate biodiversity baseline, was identified as a significant gap in the gap analysis report and was subsequently conducted by ARUP in 2023.

As part of the ESIA, a holistic water risk assessment is required to assess the impact of the proposed Project on upstream and downstream uses. This assessment needs to consider the natural dynamic equilibrium of river systems, which provides some level of constancy and predictability for the river's life (World Bank Group, 2018). There is a fundamental relationship between the flow of water and sediment, and the biotas supporting a strong and diverse ecosystem through time. Any impoundment of flow will have the potential to result in a significant shift in a river's equilibrium. All parts of flow are important to refresh channel and floodplain sediment and fine sediment distribution with opportunities for vegetative succession. The degree of seasonality of a river relates to the type of biota a river can support and links to plant and animal life cycles. Changing these elements can alter flow cues so that life cycles are disrupted and species decline.

The more natural flow, sediment, and/or water quality regimes are changed, the more the river ecosystem will respond. The rate of change can differ between ecological variables. Water chemistry changes can occur at an hourly time scale, while geomorphological change can require decades to reach a new dynamic equilibrium. This Water Risk Assessment will consider three major thresholds that can cause state changes in river ecosystems:

- Loss of longitudinal connectivity and thus the free movement of sediments, fish and organic material along the system
- Reduction in magnitude and /or frequency of floods leading to alteration of the river's floodplain wetting regime and loss of lateral connectivity along the river
- Change to baseflow and alteration of low flow regimes leading to periodic drying out of all or part of a previously perennial channel

[1] EBRD (2019) Environmental and Social

(v. April 2019)

1.2 Purpose of this Chapter

1.2.1 Objectives

The objective of this chapter is to outline the purpose and approach of the Water Impact Assessment (WIA) conducted for the Environmental and Social Impact Assessment (ESIA). For Phase 1 (construction and operation of Pambukovica dam for flood defence purposes) and Phase 2 (operation of Pambukovica dam for dual purpose of flood defence and irrigation) this involves:

- Evaluation of the water quantity and quality impacts associated with the construction and operation of the proposed Project, in alignment with Serbian legislation and international standards, including EBRD Performance Requirement 6 (PR6) PR 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources and PR 3: Pollution Prevention and Abatement;
- Identification and assessment of adverse and beneficial impacts on water quantity, water quality and water dependant habitats and biota;
- Development and recommendation of mitigation measures to avoid, minimize, or offset identified impacts, meeting the requirements of Serbian law and EBRD PR6/PR3.

1.3 Legal and Policy Framework

This Section (and Section 2.1 Project in relation to EU Directives) details the National and International Legal and Policy Frameworks relevant to the water environment that have been considered throughout the ESIA process. A summary of Project compliance with regards EU Directives and Transboundary Agreements is provided in the Section 9.

The EBRD is committed to ensuring that projects are structured to meet EU environmental principles, practices and substantive standards, where these can be applied at the project level, regardless of their geographic location. From a PR6/PR3 perspective, this includes for example the European Union's EIA, Habitats and Birds Directives and the Water Framework Directive (WFD). When host country regulations differ from EU substantive environmental standards, projects will be required to meet whichever is more stringent.

Serbia was granted EU candidate status in March of 2012. Since that time, Serbia has taken steps to harmonise water legislation with EU legislation including the Water Framework Directive and the corresponding preparation of a River Basin Management Plan. Approximately 92% of the country lies within the Danube River Basin comprising 10% of the total basin. 90% of renewable water sources originate from outside of Serbia, necessitating international cooperation and transboundary agreements.

1.3.1 Transnational boundary agreements

The International Commission for the Protection of the Danube River (ICPDR) is the organisation founded following the establishment of the Danube River Protection Convention (DRPC) to ensure cooperation and transboundary water management in the Danube River Basin. The main objective of the convention is to ensure surface waters and groundwater within the Danube River Basin are managed and used sustainably and equitably. Serbia became a full member of the ICPDR in August 2003.

The Sava river catchment is legislated through the International Sava Agreement (2002) between Slovenia, Croatia, Bosnia and Herzegonia, Serbia and Montenegro. This agreement in addition to the Protocol on the Navigation Regime (2002) manages issues related to navigation, economic development, comprehensive water management and environmental protection.

1.3.2 National Legislation

A review of the national Serbian legislation regarding water has been summarised in Table 1-1. Much of the national legislation follows on from the translation of the WFD and other EU Directives into the Serbian context.

Table 1-1 Relevant legislation

Legislation	Description
1) Environmental Protection Law	Highest piece of environmental legislation in the hierarchy. Established an integrated system of environmental protection ensuring the right to a healthy environment and economic growth balanced with environmental considerations. Establishes the Environmental Protection Agency. Establishes the Polluter Pays Principle and the Principle of Subsidiary Liability.
2) Law on Strategic Environmental Impact Assessment	Establishes relations between environmental protection policy and other departmental policies (e.g. land use, farming, waste management, transportation, etc.). Establishes permits for certain developments or reconstruction projects affecting the natural environment.
3) Water Law	This law establishes the legal status of waters, integrated water management, and sustainable use, aligning with the EU Water Framework Directive (WFD) and the EU Floods Directive principles. Maintenance of water regime is a responsibility of Public Water Management Companies Srbijavode and Vode Vojvodine, following the division of responsibilities set in Water Act. The Republic Hydrometeorological Service of Serbia (RHMSS) is responsible for management of the hydrological network.
The Water Law is implemented by the following Decrees:	• Decree establishing the Annual Water Status Monitoring Programme for 2022. on 17 Mar 2022 • Decree on the Establishment of the Water Management Program for 2025. on 06 Feb 2025
The Water Law is implemented by the following Orders:	• Order on establishing the Operational Plan for flood defense for 2023. on 01 Dec 2022
The Water Law is implemented by the following Regulations:	• Regulation determining the river sediment extraction plan. on 04 Nov 2021 • Regulation determining the General Plan for flood defense. on 14 Mar 2019 • Regulation determining the plan for extraction of river sediments. • Regulation on the content and manner of keeping registers of protected areas. on 11 Sep 2019 • Regulation determining water units and their boundaries. on 17 Jan 2018 • Regulation determining melioration areas and their boundaries. on 09 Nov 2018 • Regulation determining the criteria for designation of protected water areas. on 08 Feb 2017 • Regulation defining the methodology for making the map of vulnerability and flood risk. on 17 Feb 2017 • Regulation determining the cases in which water permit is required. on 24 Mar 2017 • Regulation on content and form of requests for issuing of water acts, on content of opinion for the procedure of issuance, and on content of reports in the procedure necessary for the issuance of water permits. on 07 Jul 2017 • Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and

Legislation	Description
	deadlines for their achievement. River basin management plan for the Danube river basin in Serbia. on 01 Jan 2014 • Regulation on the conditions in terms of technical-technological equipment and organizational and staff capacity when performing tasks in the field of water management, as well as on the method of keeping records on issued and revoked licenses. on 21 Mar 2012 • Regulation on limit values of pollutants in surface and groundwater and sediment and on deadlines for their achievement. on 10 May 2012 • Regulation on emission limit values of pollutants in water and deadlines for achieving them. Regulation on emission limit values of pollutants in water and deadlines for their achievement. on 25 Aug 2011 • Regulation on the parameters of ecological and chemical status of surface waters and parameters of chemical and quantitative status of groundwater. on 23 Sep 2011 • Regulation on reference conditions for surface water types. on 06 Sep 2011 • Regulation on the content and manner of managing the water information system, methodology, structure, categories and levels of data collection, as well as on the content of data about which the public is informed. on 20 Jul 2011 • Regulation on determining of surface and groundwater bodies. on 10 Dec 2010
The Water Law is implemented by the following Policies and Plans:	• Action plan for the implementation of the Water Management Strategy on the territory of the Republic of Serbia for the period from 2021 to 2023. on 29 Jul 2021 • Water management strategy of the territory of the Republic of Serbia until 2034. on 23 Dec 2016

1.3.3 Local Policies and Plans

Local municipalities in Serbia are required to implement flood risk management plans for the entire territory that may be threatened by torrential fluvial flood risk in line with national legislation. This includes plans not just with protective systems, but also by regulated watercourses with existing protective water management installations.

The Jaroslav Černi Institute created a methodology for torrential flood control in 1998, and it is under constant improvement and development. Serbian Flood Defence methodology combines radar meteorology, torrential (flash flood) hydrology and GIS techniques, enables quick determination and assessment to provide sufficient time for the flood defence system to be put in operation.

Sava River Basin Management Plan (ISRBC, 2021)

With the aim to enhance basin wide policy framework for prevention of further deterioration or/and improvement of the status of all waters and protected areas and to strengthen collaboration towards long-term and sustainable use of the water resources within the Sava River Basin, the 2nd Sava River Basin Management Plan was developed in accordance with WFD requirements, following the provision of the Article 12 FASRB: "The Parties agree to develop joint and/or integrated Plan on the management of the water resources of the Sava River Basin and to cooperate on its preparatory activities". The 2nd Sava RBMP[2] is prepared for the six years period 2022-2027.

Outline on Sava Sediment Management Plan (ISRBC, 2021)

The Sava Basin organises its sediment management under the International Sava River Basin Commission who have ratified the Protocol on Sediment management (ISRBC, 2017) and the Outline on Sediment Management Plan (ISRBC, 2021).

Danube River Basin Management Plan (ICPDR, 2021)

The main Danube countries signed the Danube River Protection Convention (DRPC) in 1994. Today, 14 Danube Basin countries and the European Union are "contracting parties" of the International Commission for the Danube River (ICPDR). In 2000, the EU WFD came into force, establishing a legal framework to protect and enhance the status of aquatic ecosystems, prevent their deterioration, and ensure the long-term, sustainable use of water resources throughout the EU. In response, the ICPDR countries, including non-EU Member States (MS), agreed to implement the WFD throughout the entire basin. The contracting parties made the ICPDR the facilitating platform to coordinate WFD-related work.

The Danube River Basin Management Plan (DRBMP) Update 2021 focuses on five Significant Water Management Issues (SWMI), which are the main pressures and effects that affect water status. These relate to pollution, hydromorphological alterations and effects of climate change. Important changes with respect to the two previous DRBMPs are the addition of the effects of climate change and a new sub-item under 'hydromorphological alterations' to include 'alteration of the sediment balance' which highlight the pressures to sediment dynamics. Research under the International Commission for the Protection of the Danube River (ICPDR)[3] indicated that the sediment balance of the Danube Basin is disturbed and requires immediate action.

According to the WFD, good ecological and chemical status has to be ensured and achieved for all surface water bodies. For those water bodies identified as heavily modified or artificial, good ecological potential and chemical status has to be achieved and ensured. Out of a 29,127 river km (km) network in the DRBD, good ecological status or ecological potential is achieved for 7,006 km (24.1%) and good chemical status for 10,495 km (36.0%). For priority substances in water, good chemical status was achieved at 19,725 km (67.7%).

Altogether, good chemical status was identified in 19 out of 25 national shares of the 12 transboundary Ground Water Bodies (GWBs) and six are in poor chemical status. Out of 12 transboundary GWBs (all 25 national shares evaluated), good quantitative status was observed in nine GWBs (with 18 national shares) and three transboundary GWBs (with 7 national shares) are in poor quantitative status.

Danube Sediment Project (ICPDR, 2021)

Research projects such as the Danube Sediment Project[4] published a Sediment Manual for Stakeholders[5] and Danube sediment management guidance[6]. There was also an assessment of the sediment balance of the Danube[7] and the risk assessment related to the sediment regime of the Danube[8].

1.3.4 Guidelines

Good Practice Handbook: Environmental Flows for Hydropower Projects (World Bank Group, 2018)

[2] 2nd Sava River Basin Management Plan
[3] In 2003 Serbia ratified the Danube River Protection Convention and became a member of the International Commission for the Protection of the Danube River (ICPDR).
[4] DanubeSediment - Interreg Danube (interreg-danube.eu)
[5] Sediment manual for stakeholders
[6] Danube sediment management guidance
[7] Sediment balance of the Danube
[8] Risk assessment related to the sediment regime of the Danube

This Good Practice Handbook provides guidance to practitioners on selecting an appropriate environmental flows assessment level for hydropower project developments. Although the Handbook focuses on hydropower, the issues and concepts are broadly applicable to other types of dam projects, such as for water storage, irrigation, or flood control. Defines EFlows as 'the quantity, frequency, timing, and quality of water and sediment flows necessary to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems'. Appropriate-level EFlows Assessments address the complexity of river ecosystems and their responses to development.

Water Framework Directive: Project Assessment Checklist Tool (JASPERS, 2024)

Published methodologies for the assessment of plans or projects in relation to the WFD in Serbia are currently not available. This document provides background to the WFD and its implementation in EU Member States as well as summarising some of the relevant contents of CIS Guidance Document 36.

1.4 Characteristics and Operation of Scheme

The Kolubara River basin in northwest Serbia has a long history of flooding events, with the floods of May 2014 causing serious damage to the population, economy, infrastructure, and natural resources along the river basin. Following the completion of the Kolubara River Basin Catchment Study in 2018, the Pambukovica Dam was proposed to serve as a retention dam within the catchment (Figure 1-1).

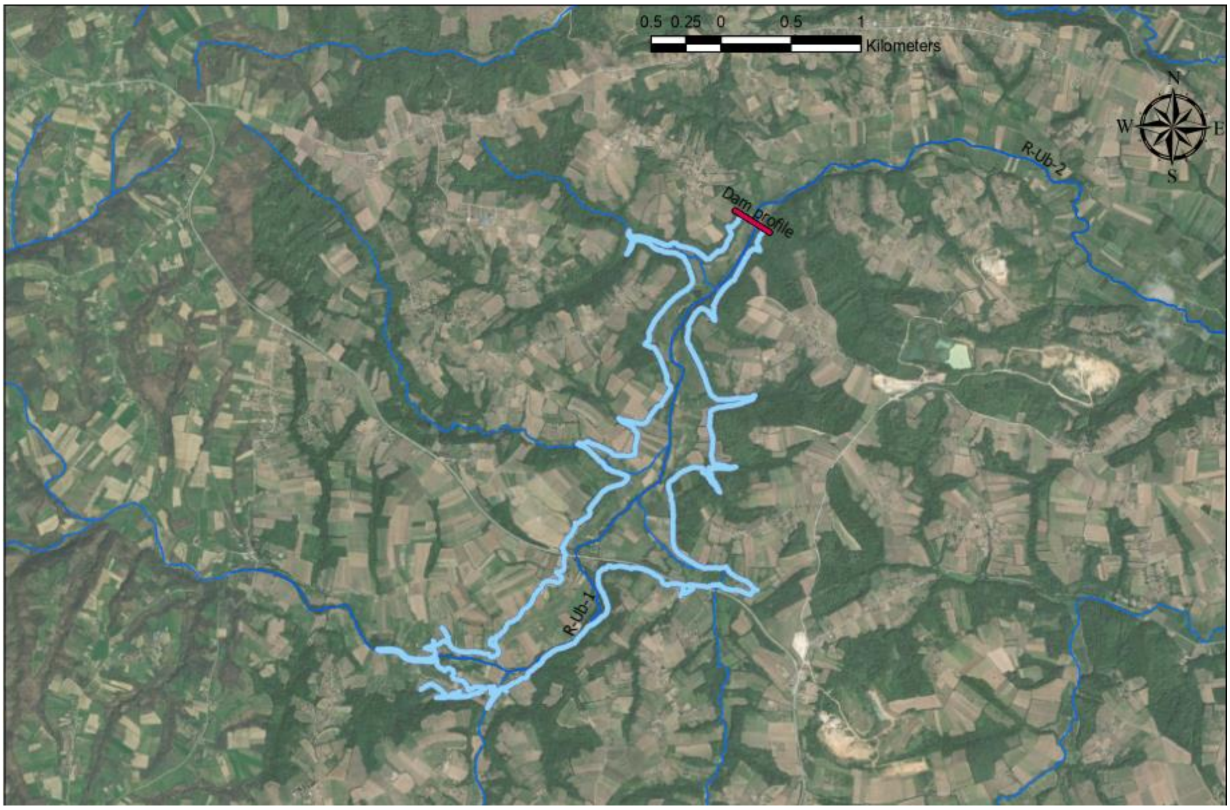


Figure 1-1 The location of Pambukovica dam: the dam profile and the accumulation lake

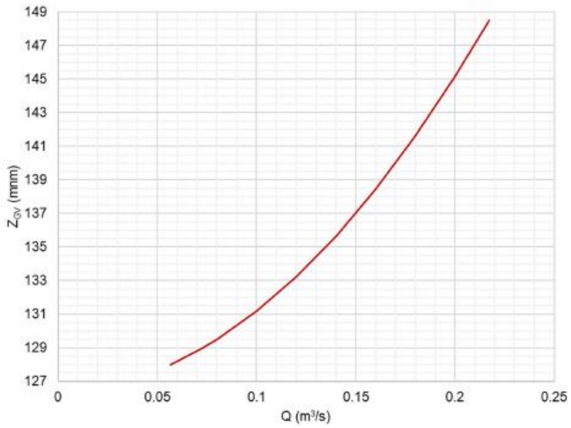
The proposed Project location is along the Ub river. Key features include an earth-filled structure with a clay core, a main height of 30.5 m, and a crest length of 212.6 m. It will incorporate both upstream and downstream sediment traps and various water management systems, including ecological flow outlets and irrigation intakes.

1.4.1 Environmental discharge outlet

The environmental flow pipe (200mm) is to be used as the primary source of Serbian minimum flow. The maximum capacity of this pipe is 200 l/s. There is also a secondary option to deliver the Serbian minim flow via using the 1000mm diameter irrigation supply pipe via T-junction.

It should be noted that the Serbian minimum flow will be augmented by reservoir releases to maintain target reservoir levels, released via the bottom gate). This means that flows in the Ub River, immediately downstream of the dam will exceed the Serbian minimum flow during certain periods and deliver high flow events mimicking the natural conditions (see Section 3.5). Flow downstream of the dam is to be measured with a weir prior to the entering the Ub River. The provision from the supply valve is intended to be automated at the valve and controlled at the control centre. Further information on the outlet structures are detailed in Section 10.3 of the Technical Assessment Report and operating rules for the reservoir are detailed in Appendix 7 – Operational Rules.

The rating curve for the environmental flow pipe (200mm) is provided in Figure 1-2.



Slika 2-41 Kriva protoka kroz glavni sistem EPP-a, za otvorenost regulacionog zatvarača 100%

Figure 1-2 Environmental flow pipe (200mm) rating curve

1.4.2 Bottom gate outlet

The bottom gate outlet is a concrete culvert, 3m by 3m in cross section (Figure 1-5). The invert of the inlet to the outlet is at elevation 125.60 masl. The outlet is equipped with:

- a trashrack, at the upstream end of the outlet;
- emergency/Maintenance gate, operated from the intake tower; and
- service, radial gate, at the downstream end of the outlet, operated from the control room.

The maximum discharge capacity of the bottom gate outlet is 95.95 m^3/s at full supply water level at 145.5m masl (at the Spillway crest).

The bottom gate outlet is to be operated at full capacity/full bore only in case of a reservoir safety emergency, where the integrity of the dam or the appurtenant structures are at risk of failure. In normal operation, the gate percentage opening is to be limited to discharge no more than 50m^3/s, which corresponds to the flood protection standard in the town of Ub and corresponds to around 1 in 10-Yr RP flow without climate change.

The rating curve for the bottom gate outlet is provided in Figure 1-3.

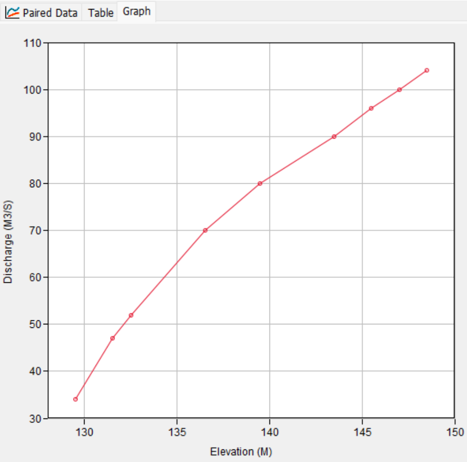
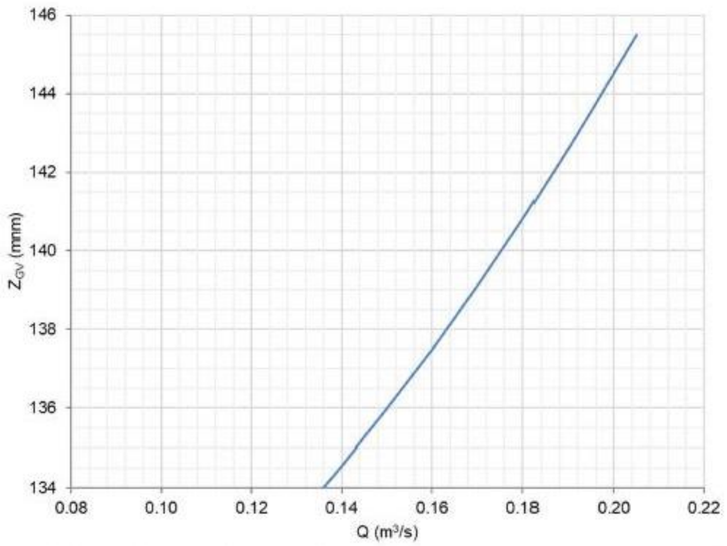


Figure 1-3 Bottom gate outlet rating curve

1.4.3 Irrigation demand outlet

The irrigation pipe is located in a separate “dry” culvert that runs parallel to the bottom gate outlet culvert (Figure 1-5). The irrigation pipe diameter is 1000mm and it is estimated that at full supply level it can discharge up to 1,380 l/s. The inlet invert is at elevation 133.49 masl. It is intended to be controlled by a valve that can be operated both manually and from the control room located on the downstream plateau. A T-junction, in the control room, with a separate valve is intended to provide environmental flows.

The rating curve for the irrigation pipe is provided in Figure 1-4.



Slika 2-44 Kriva protoka kroz alternativni sistem EPP-a, za otvorenost regulacionog zatvarača 100%, kada zahvat za navodnjavanje ne radi

Figure 1-4 Irrigation pipe rating curve

1.4.4 Spillway

The spillway of the dam is designed to be an uncontrolled side-channel weir. It is designed to accommodate flows up to the Safety Check flood of PMF. The spillway crest level is at 145.5masl – when the water in the reservoir exceeds the spillway level, excess water would be freely discharged in the Ub River.

1.4.5 Operational rules

The significant information associated with the design and operation of the dam are given in more detail in Table 1-2.

Table 1-2 Significant information relating to proposed Project

Hydrological data	Longest river length	km	55.6
	Catchment area	km	118.5
	Serbian minimum flow (cold season: Oct to Mar)	l/s	68
	Serbian minimum flow (warm season: Apr to Sep)	l/s	102
Dam data	Total volume of retention reservoir	Mm^3	8.5
	Highest flood water level	masl	146.5
	Spillway crest elevation	masl	145.5
	Minimum water level	masl	138.5
	Irrigation demand outlet	masl	133.4
	Bottom gate outlet	masl	125.6
Sedimentation data	Catchment sediment load over 80 years with no catchment management	Mm^3	2.1
	Catchment sediment yield over 80 years with no catchment management	$m^3/yr/km^2$	221.9
	Catchment sediment load over 80 years with catchment management	Mm^3	1.4
	Catchment sediment load over 80 years with catchment management	$m^3/yr/km^2$	149.3

The detailed operating rules for the reservoir are detailed in Technical Assessment Report Appendix 7 – Operational Rules. The operational rules take into account the following criteria:

- Phase 1, flood control and EFlow releases:
  - Flood management: during high flow periods reducing the risk of River Ub flooding downstream of the proposed dam, and also minimizing risk of dam overtopping;
  - Serbian minimum flow (Qe) releases: water use priorities and schedules during periods of drought
  - Operational flows beyond the Serbian minimum released to meet downstream requirements to ensure that flow patterns for maintaining riverine habitats and other hydro-ecological requirements are clear in the reservoir operation rules (see Section 3.5).

- Phase 2, irrigation, flood control and EFlow releases:
  - During Phase 2 the Serbian minimum flow (Qe) will be maintained whilst accommodating for the use of the reservoir storage for both flood mitigation and irrigation. However, Phase 2 operations (E Flow) downstream of the reservoir typically far exceed the presented Serbian minimal flow, as additional water is required to be released to maintain the Phase 2 target

reservoir level of 145.5 masl (see Section 3.5).

Sediment management for both Phase 1 and 2: the operating rules aim to establish procedures for minimizing sediment build-up in the dam.

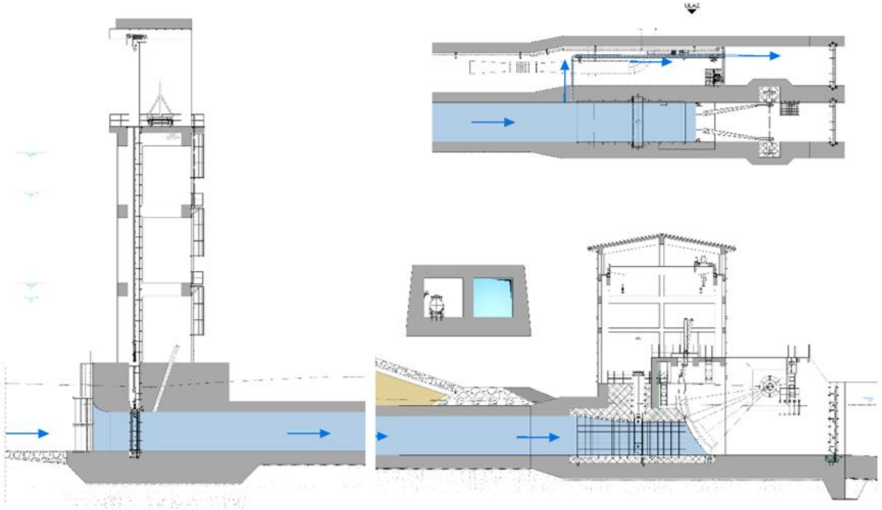
The results of the reservoir operational scenarios modelled can be summarised as follows:

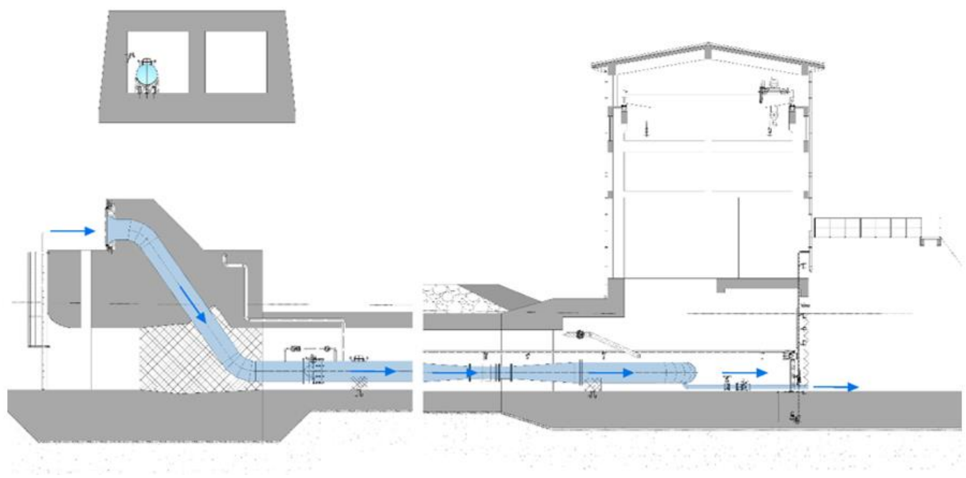
Phase 1: Flood control and ecological discharges

- When the reservoir level is at 138.5masl, there will be no issues with the flood management and management of the Serbian minimum flow, as there is a sufficient storage in the reservoir to attenuate floods. Therefore, it is recommended that the reservoir level is maintained at 138.5 masl.
- Limit discharge through the bottom outlet to 50 m^3/s except in case of a reservoir safety emergency, where the integrity of the dam or the appurtenant structures are at risk of failure. In normal operation, the gate percentage opening at the bottom outlet is to be limited to discharge no more than $50m^3/s$ to avoid downstream flooding.
- Minimized Exceedance of spillway chute capacity: by avoiding keeping the full reservoir level coming to the flood season: Adjust releases to ensure that downstream channel capacity is not exceeded, reducing the risk of flooding.
- The operation of the reservoir will ensure that the Serbian minimum flow is maintained downstream. The Serbian minimum flow of maximum 102 l/s will be delivered either via the environmental flow pipe or irrigation supply pipe.
- Phase 1 flow releases (EFlow) will be greater beyond the Serbian minimum flow. Phase 1 operations (E Flow) downstream of the reservoir typically far exceed the presented Serbian minimal flow, as additional water is required to be released to maintain the Phase 1 target reservoir level of 138.5 masl. The release of additional water to maintain the target reservoir level will be delivered through the bottom gate outlet (see Section 3.5).

Phase 2: Irrigation, flood control and ecological discharges

- Under Phase 2 the target reservoir level is 145.5 masl to accommodate the irrigation demand.
- It will be necessary to provide flood forecasting that would alert the dam operator about the forthcoming floods. It will be necessary to allow for pre-flood drawdown of the reservoir to elevation 138.5 masl 2-3 days before the incoming flood to minimize the peak discharges downstream.
- The operation of the reservoir will ensure that the Serbian minimum flow is maintained downstream. The Serbian minimum flow of maximum 102 l/s will be delivered either via the environmental flow pipe or irrigation supply pipe.
- Phase 2 flow releases (EFlow) will be greater beyond the Serbian minimum flow. Phase 2 operations (E Flow) downstream of the reservoir typically far exceed the presented Serbian minimal flow, as additional water is required to be released to maintain the Phase 2 target reservoir level of 145.5 masl. The release of additional water to maintain the target reservoir level will be delivered through the bottom outlet (see Section 3.5).





A. B.

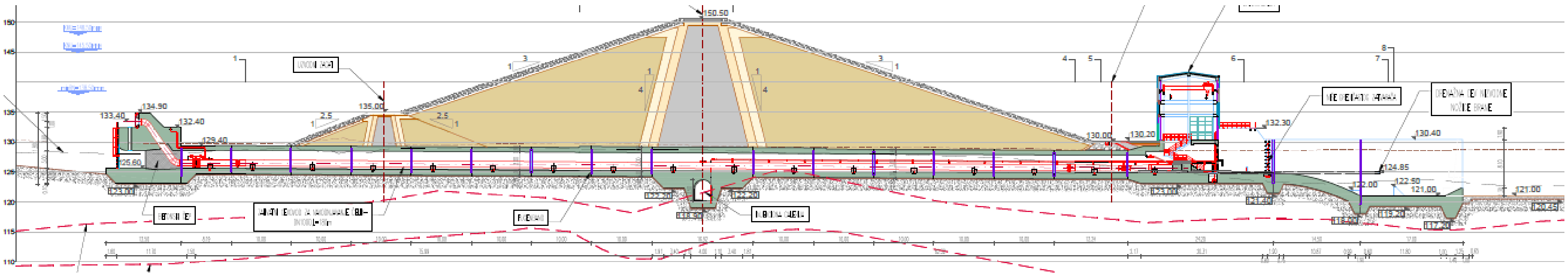


Figure 1-5 Cross section through the outlet facilities with an indication of environmental flow supplied via bottom outlet (A) and via irrigation pipe (B).

2. Methodology

The approach to assessing impacts to water quality and quantity is reliant on an understanding of the elements of surface water systems. Specifically, the biological quality supporting elements supported by the physico-chemical elements and hydromorphology elements. The water risk assessment within the Study Area has been conducted via a combination of desk study and more detailed technical assessments that have been conducted as part of the wider project (e.g. hydrological modelling of operations phase flows). Additional sources of information that define the proposed Project have been reviewed and form the basis of this assessment.

2.1 Project in relation to EU Directives

Serbia's status as a candidate for membership since 2012 requires that the project consider its outcomes and objectives in relation to establish EU Directives; this is also a requirement under EBRD standards (PR6 / PR3). Future accession to the EU will be supported by the consideration of existing EU Directives within the project, although Serbia is not currently required to follow their conditions. The main Directives of relevance to this report are the Floods, Water Framework, EIA, and SEA Directives. The floods and water framework directive require a catchment-based approach to assess the current status of surface and groundwater bodies. Without this baseline status the assessment of the project against the EU Directives can only be conceptual.

The EU WFD sets out a framework for the protection of all waters and obliges Member States to prevent further deterioration, enhance and restore the status of aquatic ecosystems. In relation to the development of new dams, the WFD does completely disallow the development of new dams but places the onus on member states to ensure that the new development does not provoke a failure to achieve good groundwater status, good ecological status, or, where relevant good ecological potential or to prevent deterioration in the status of surface or groundwater bodies. There is a provision in the directive (Article 4.7)[9] for sustainable development which allows for the ability to execute a project resulting in a failure to achieve good status only if the development meets all the following required conditions:

1) All practicable steps are taken to mitigate the adverse impact on the status of the body of water;
2) The reasons for those modifications are of overriding public interest and/or the benefits to the environment and to society of achieving the environmental objectives are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development;
3) The beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental options;
4) It does not permanently exclude or compromise the achievement of the environmental objectives in other bodies of waters within the same river basin district and is consistent with the implementation of the other community legislation; and
5) It is guaranteed at least the same level of protection as the existing community legislation.

Although Serbia does not legally have to apply the WFD, it is stipulated in the Article 3 of the Framework agreement on the Sava River Basin "…the Parties are decisive to cooperate on the basis of, and in accordance with, Directive 2000/60/EC of the EU Parliament and Council of October 23, 2000, establishing

[9] Article 4.7 of the WFD makes provision for exemptions to the achievement of certain WFD objectives which might need to be considered within the context of the objectives of Drought Planning. Exemptions may be invoked where there is a failure to prevent deterioration of status arising from new modifications or new sustainable human development activities where there are reasons of over-riding public interest or where the benefits of achieving WFD objectives are outweighed by the benefits to human health, human safety or sustainable development. Various other criteria must also be met before such exemptions can be considered, along with Article 4.8 and 4.9.

a Framework for Community Activities in the Field of Water Policy (WFD)", and to make all efforts towards implementation of the WFD, on national and the shared international river basins.

The EU Environment Impact Assessment Directive (EIA) requires the assessment of major building or development projects to first be assessed for their impact on the environment before the project can start. In relation to the development of new dams, Member States are obliged to carry out an environmental assessment of dams and other installations designed for holding back permanent storage of water, where a new or additional water held back or stored exceeds 10 million m^3. It also requires that the public be provided with information within a reasonable time in order to allow for the expression of opinions during the various phases of decision making on a development. Once a decision is taken, the Member States must inform the public of the final decision and specify how public contributions were or were not taken into consideration and offer mechanisms for a review procedure.

2.2 Methodology for assessing the environmental flow requirements

The term 'environmental flows' or 'EFlows' can be defined as the quantity, frequency, timing, and quality of water and sediment flows necessary to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems[10]. EFlows are negotiated through a process of data analysis and discussion of the physical, chemical, biological, social, resource-economic, economic, biodiversity, and land management implications of water-resource developments. Appropriate-level EFlows Assessments address the complexity of river ecosystems and their responses to development. They allow a more genuine consideration of a broader suite of possible impacts and increase the chances of achieving sustainability.

Whilst not a hydropower project, the Project has considered *World Bank Good Practice Handbook Environmental Flows for Hydropower Projects* (IFC, 2018)[11] and EBRD's *Environmental and Social Guidance Note for Hydropower Projects* (EBRD, 2018)[12] when structuring the assessment methodology and undertaking the impact assessment. The assessment is made in this Chapter (water) and **Book 4 Biodiversity Impact Assessment**.

World Bank guidance provides an EFlows decision tree to aid in determining the methodology and resolution of EFlow assessment required for hydropower projects. Whilst the proposed dam is not for the purpose of power generation, it is useful to consider this decision tree to help scope and assess the potential impact of post-development flows on environmental and social receptors (Figure 2-1**Error! Reference source not found.**).

[10] Amended from the Brisbane declaration (2007)

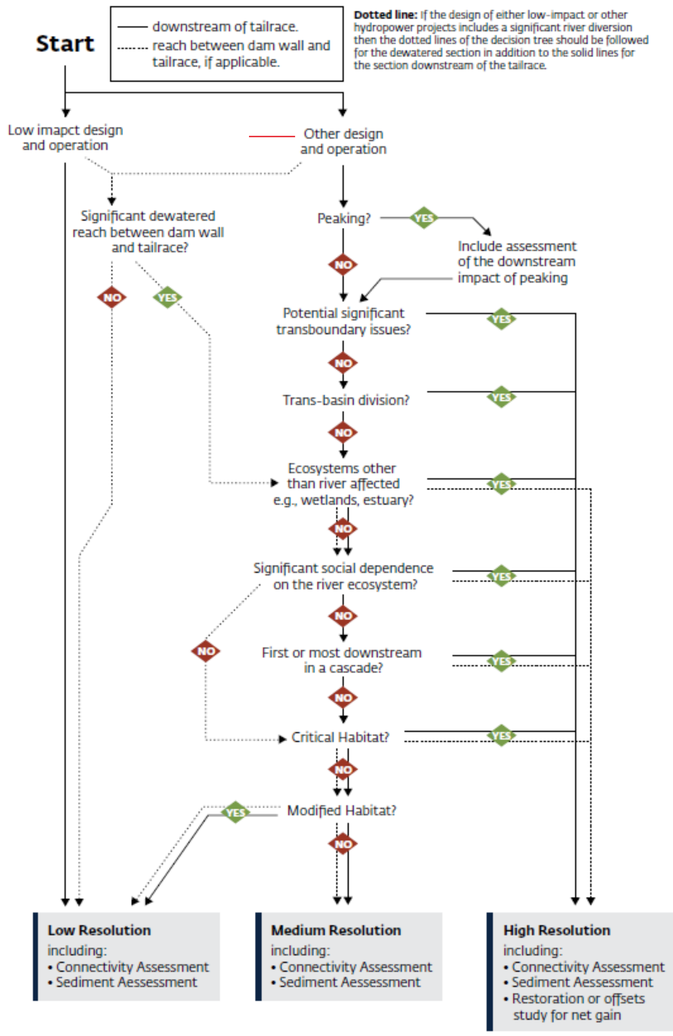


Figure 2-1 EFlows Methodology Project Scoping using World Bank Guidance Decision Tree

The project has been screened against the World Bank EFlows decision tree criteria where appropriate. Whilst not a hydropower project, the proposed project cannot be considered ‘low impact design and operation’ given the size of the dam and so is mapped according to the ‘other design and operation’ route.

The project is not a peaking operation and is not considered to have significant transboundary issues, or trans-basin division. Baseline studies have confirmed that ecosystems other than river habitats (e.g. wetlands / estuary) are not present downstream and social dependence on the river ecosystem are considered low.

However, the Project could be considered the first most downstream project in a cascade (as no other large dams exist on the River Ub). Furthermore, extensive aquatic and riparian biodiversity surveys have identified notable aquatic receptors, including fish that represent Priority Biodiversity Feature (PBF) according to EBRD and thick-shelled mussel (*Unio Crassus*) which is listed in Annexes II and IV of the EU Habitats Directive. For this reason the River Ub is considered to represent Critical Habitat, according to EBRD guidance (see Section Critical Habitat & PBF Assessment in **Book 4 Biodiversity Impact Assessment**).

A high-resolution assessment is therefore required, that considers the assessment of connectivity, sediment and net gain. This chapter considers changes in water quantity / hydrology (Section 3), water quality (Section 4), and fluvial geomorphology / sediment (5). The potential effects of these physical and physico-chemical changes are then assessed pre and post avoidance and/or mitigation measures in **Book 4 Biodiversity Impact Assessment**.

2.3 Desk study

Existing technical studies were reviewed to gather baseline understanding for this assessment. A desk study of the current risk and pressures on surface water resources has been conducted through reviewing relevant basin plans.

2.3.1 Baseline flood risk

A flood risk study emphasised that the Kolubara River basin has a long history of flooding. The tributaries in the central part of the Kolubara river valley contribute flood waters over the vast plain. Floodwaters destroy agricultural lands with torrential waters and silt, create banks in the riverbed, which cause a strong meandering of the flow and cause great damage to settlements, industry and roads. The main role of the proposed Project is to protect the downstream area from flooding through the development and management of a dam.

2.3.2 Baseline hydrology

Hydrological modelling has been undertaken to assess the potential impacts that the proposed Project would have on the baseline hydrological function of Ub River. This modelling focussed on both flood alleviation downstream of the proposed reservoir through storage of storm water, and the anticipated reservoir outflows during Phase 1 and 2 of operation. The results of this modelling has been used to inform the assessment and conclusions of this report. The assessment includes a review of available flow gauge data, estimations of the flow (m^3/s) during both high and low flow events with and without the proposed Project and the flow discharge (m^3/s).

2.3.3 Baseline water quality

There is a lack of long-term water quality sampling, and data, on the Ub River therefore baseline water quality samples were taken from the Ub River for this study. This information is necessary to assess the baseline water quality prior to construction activities and operation of the dam. Both of these will have likely impacts on downstream and upstream water resources.

2.3.4 Baseline sediment yield

Under the 2018 report 'Project of anti-erosion works in the watershed" (16018-PV-11) there was an assessment of the erosion measures upstream of the proposed Project dam profile. This included introduction of two types of intervention: seven sediment traps of 2-3m height made with stone set in cement; five biological works, or double living braids spaced 5-10m apart upstream at the tail of the backwater of the most upstream one. Beyond these physical interventions, prohibition measures were also proposed. This study did not account for a change in sediment yield therefore a separate sediment yield assessment (as part of Technical Assessment Report) was developed for the operational scenarios and incorporated into this report. Sediment yield ($m^3/yr/km^2$) was modelled over the 63 years (1960-2023) of flow dataset available on Ub River.

2.3.5 Baseline ecological condition

Aquatic surveys were undertaken within the Ub River. The surveys informed a baseline assessment of the aquatic ecology including fish and water quality (biological and physiochemical), as well as other protected aquatic species and habitats in the footprint of the proposed Project. Full detailed of the surveys, methodology and data analysis are contained in the **Book 4 Biodiversity Impact Assessment**.

2.4 Surface water resources

2.4.1 Ub River Catchment

The Ub River is a tributary of the Tamnava and Koluba River. The Ub River has headwaters in hilly areas and flows through the region of Šumadija. The Ub River is approximately 55.6 km long (from its highest part of catchment to confluence with Tamnava River) and plays an important role in the local hydrology and ecology.

2.4.2 Kolubara Basin

The Kolubara River is a left tributary of the Sava River. The overall surface River Water Bodies for Kolubara River Basin have an unknown chemical status, with two of nine being in a good chemical status (Table 2-1). Most River Water Bodies have a moderate ecological status (Table 2-2**Error! Reference source not found.**). The predominant pressure for the River Water Bodies was hydromorphological alteration, point pollution and diffuse pollution.

Table 2-1 The overall chemical and ecological status of the Kolubara River Water Bodies (Source: *ISRBC, 2021*)

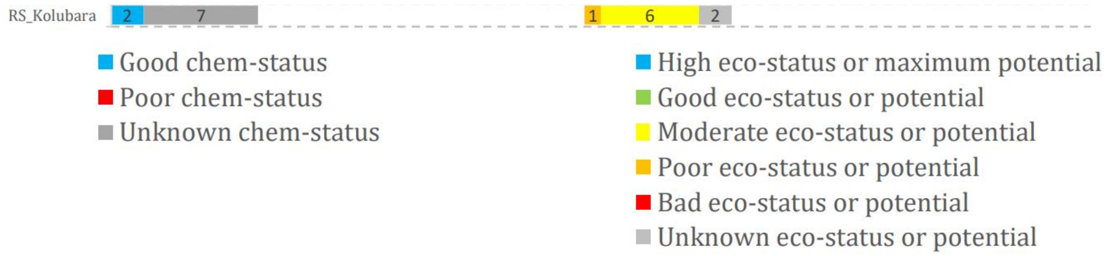


Table 2-2 The surface water quality status and main pressure for the Kolubara River waterbodies (Source: *ISRBC, 2021*)

River	Water body code	Biological Quality Elements													Specific pollutants				Artificial and HMWB			Chemical Status Class		Main Pressure					
		Fish	Bentic invertebrates	Benthic invertebrates-saprobnost	Benthic invertebrates HYMO spremljenost	Phytobenthos	Macrophytes	Phytobenthos and Macrophytes-saprobnost	Phytobenthos and Macrophytes-trofičnost	Phytoplankton	Overall Biological Status	Confidence (Overall Biological Status)	Hydromorphology - High Status (Y/N)	General Physical and Chemical conditions	Other WB Specific pollutants	Confidence (Specific pollutants)	ECOLOGICAL STATUS	Confidence class (Overall Ecol.Status)	Artificial Water Body (Y/N)	HMWB (Y/Preliminary (pY))	Ecological Potential Class	CHEMICAL STATUS CLASS	Confidence class (Chemical Status)	Organic Pollution	Nutrient Pollution	Hazardous Substances	Hydromorphological Alterations	POINT pressure unknown	DIFFUSE pressure unknown
Kolubara	RSKOL_6		3					2			3						3	M	N			U	U	x	x	x	x		
Kolubara	RSKOL_5		3					2			3						3	M	N			U	U					x	
Kolubara	RSKOL_4_C		3					2									3	M	N			U	U					x	
Kolubara	RSKOL_4_B																U	U	N			U	U						
Kolubara	RSKOL_4_A																U	U	N			U	U				x		x
Kolubara	RSKOL_3_B		3					2			3			3	3	M	3	M	N			2	M				x		
Kolubara	RSKOL_3_A		3					2			3						3	M	N			U	U				x		x
Kolubara	RSKOL_2		3					2			3						3	M	N			U	U					x	x
Kolubara	RSKOL_1		4					2			4						4	M	N			2	M				x	x	x

2.4.3 Sava Basin

The Sava River Basin is a major river basin of South-eastern Europe, with a total area of approximately 97,700 km^2. The Sava River Basin, comprising 12% of the Danube River Basin area, represents its most significant sub-basin. The Sava River Basin area is shared among six countries, one of these being Serbia. Up to 17% of Serbia's land coverage is within the Sava River Basin. The Sava River is formed by two mountainous streams: the Sava Dolinka (left) and Sava Bohinjka (right). From the confluence of these two streams, near Slovenian town Radovljica, the main Sava River has a length of 945 km until it joins the Danube in Belgrade. Significant pressure in the Sava River Basin were assessed as organic, nutrient, and hazardous substances pollution and hydromorphological alterations (ISRBC, 2021).

2.4.4 Danube Basin

The Danube River Basin covers more than 800,000 km^2 and extends into the territories of 19 countries. Serbia occurs within the 'Middle Dunube'. Up to 92.6% of Serbia's land coverage is within the Danube River Basin (10.21% of Danube River Basin). There are five river water bodies along the Sava River, within Serbia.

Out of a 29,127 rkm network in the Danube River Basin, good ecological status or ecological potential is achieved for 7,006 rkm (24.1%) and good chemical status for 10,495 rkm (36.0%). Under the Joint Programme of Measures for 2021-2027, hydromorphological pressures are addressed through further restoration measures planned for 222 water bodies in until 2027. In total 424 restoration measures on river continuity for fish migration are planned to be implemented by 2027. Further 23,399 ha of wetlands and floodplains will be reconnected by 2027. In total, 144,659 ha of wetlands and floodplains have been identified for a reconnection potential in the Danube River Basin. It was recognized that hydromorphological measures can play an important role in mitigation of negative effects of climate change. Implementation is also crucial for reaching the targets of the EU Biodiversity Strategy 2030, mainly focusing on the guarantee of environmental flow and restoration of at least 25,000 km of EU rivers to a free-flowing state.

2.5 Hydrologically connect protected areas

There are no Legally Protected or Internationally Recognized Areas of Biodiversity Value areas (as defined by EBRD) in the vicinity of the proposed Project area. The closest legally protected areas to the Project site are the Obedska Bara (Swamp) Nature Reserve and Candidate Emerald Site (CES), located 19 km away, and the Klisura Reke Gradac (Gradac River Gorge) CES, located 18 km away. Neither site is hyrologically connected to the River Ub; Obedska Bara is on the northern banks of the River Sava and the Klisura Reke Gradac is located on the Suvaja/Gradac River, which enters the Kolubara River at Valjevo (i.e. not hydrologically connected to the River Ub or Project area).

2.6 Definition of the Water Study Area

Each element of surface water was assessed at a local scale along the Ub River within four main zones (Table 2-3 and Figure 2-2).

- The **Hydrology** Study Area included the area inundated by the proposed dam and the reach of the Ub River extending downstream from the proposed reservoir to the confluence where the Ub river meets the Tamnava river. The hydrological analysis divided the Ub River Catchment into seven parts. Sub-basin 1 is upstream of the proposed dam, sub-basin 2 is within the proposed reservoir area, sub-basin 3-7 is downstream of the dam. The spatial scope of the Hydrology Study Area is considered appropriate and proportionate as:
    - Hydrological changes in the River Ub itself have been analysed and the predicted changes during both Phase 1 and Phase 2 are minimal (see Section 3.5). Therefore, any change will be less in downstream of the Ub-Tamnava confluence.
    - The Tamnava is a large river which means the minor changes predicted for the Ub will not result in significant changes in the Tamanna. The Ub catchment to the Tamnava confluence is 229.2km^2 and the Tamnava catchment to the Ub confluence is 260km^2. Therefore, at the Ub-Tamnava confluence the discharge is expected to more than double.
    - Flows are further augmented approximately 11km downstream when the Tamnava converged with the Kolubara.
- The **Water Quality** Study Area for included a regional assessment of surrounding pressures and a local scale assessment of the proposed reservoir inundation area (zone 1) and directly downstream of the dam (zone 2).
- The **Fluvial Geomorphology** Study Area was based on regional and local drivers. At the regional scale, sediment dynamics were considered for transboundary basins.
- The **Freshwater Biodiversity** Study Area was based on river habitat mapping along the length of the Ub River within the proposed reservoir inundation area and directly downstream. Note further freshwater biodiversity assessment is contained in **Book 4 Biodiversity Impact Assessment**; these chapters should be read in conjunction.

Table 2-3 Description of the local zones of assessment for each element of surface water resources

	Description	Hydrology	Water quality	Fluvial geomorphology	Freshwater biodiversity
Zone 0	Sub-catchment above reservoir area	Assessment of impact of dam		Assessment of impact of dam	Assessment of impacts

	Description	Hydrology	Water quality	Fluvial geomorphology	Freshwater biodiversity
	inclusive of Ub, Joseva, Ogladenovacka Rivers and Jasenovac and Medveniak Streams	on high, average and low flows for Ub river		on sediment connectivity and morphology of Ub River and associated tributaries	of dam on biodiversity
Zone 1	Sub-catchment of reservoir / inundation area, inclusive of Ub River and Babinac Stream		Assessment of impacts of the reservoir on water quality		
Zone 2	Sub-catchment of Ub River downstream of proposed dam up to the confluence of two tributaries (Dokmirca and Bukovica Rivers)				
Zone 3	Sub-catchments of Ub River inclusive of town of Ub, up to the confluence with Tamnava River			Assessment of impact of dam on sediment connectivity	

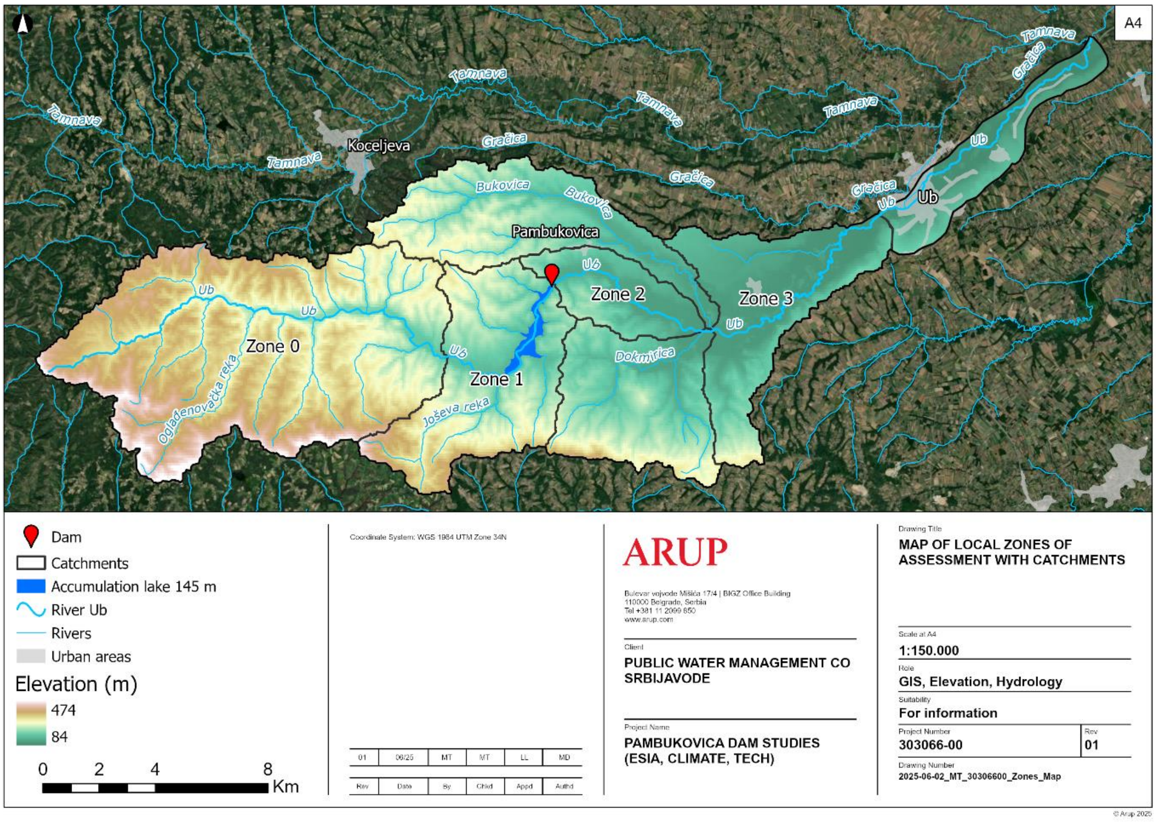


Figure 2-2 Study area inclusive of the zones of analysis for the impact on surface water resources from the proposed Project (Elevation in meters above sea level)

3. Hydrology

3.1 Objectives

This section provides the baseline flow regime of the study area for the proposed Project. A detailed hydrological assessment is provided in the Technical Assessment Report (Appendix 1). This section provides the summarised outputs of relevance to the water impact assessment. The assessment area (zones 0 – zone 3) covers upstream of the proposed dam to the town of Ub. Potential for impacts on hydrology further downstream are provided in **ESIA Volume 3 - Cumulative Impact Assessment**.

3.2 Assessment methodology

The objectives of the assessment are to allow for:

- Assessing changes in flow rates and water levels of the Ub River downstream from the proposed Project;
- Identifying measures to avoid, reduce, mitigate or compensate proposed Project impacts on water quantity.

3.3 Climate

3.3.1 Temperature

The average air temperature in GMS Valjevo from 1991 to 2020 was 12°C (Figure 3-1). On average, the hottest month is July at 22.6°C, and the coldest is January at 1.1°C. The highest recorded temperature is 42.4°C, and the lowest is -23.2°C. On average, there are 78.5 frost days (with minimum temperatures below zero) and 38.9 tropical days (with maximum temperatures above 30°C) throughout the year. The average annual air temperatures at the GMS Valjevo from 1949 to 2021 show an increasing temperature trend after 1990 (Figure 3-2).

The year is classed as:

- the 'cold' season from October to March
- the 'warm' season from April to September

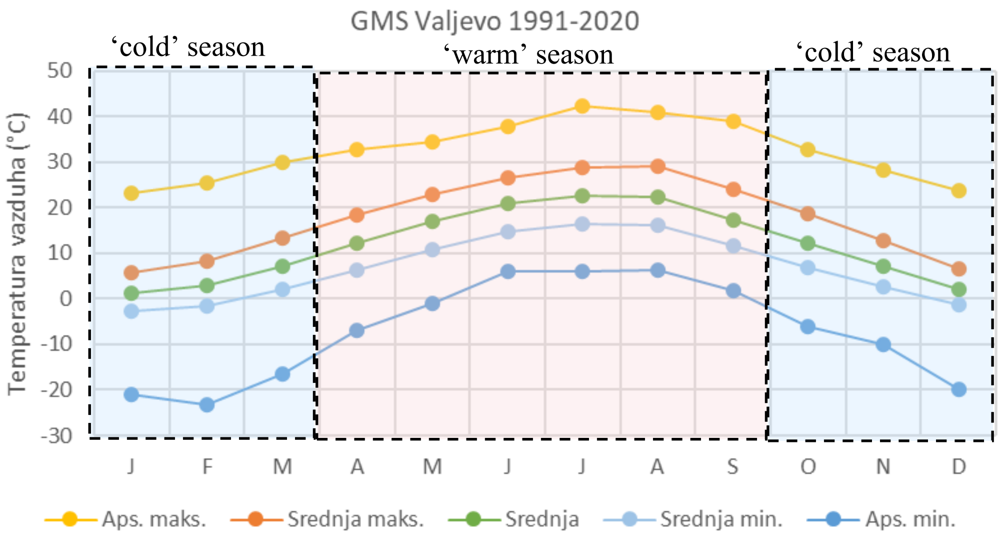


Figure 3-1 The monthly mean, minimum and maximum temperature variability in Veljevo (Source: 16018-PV-12)

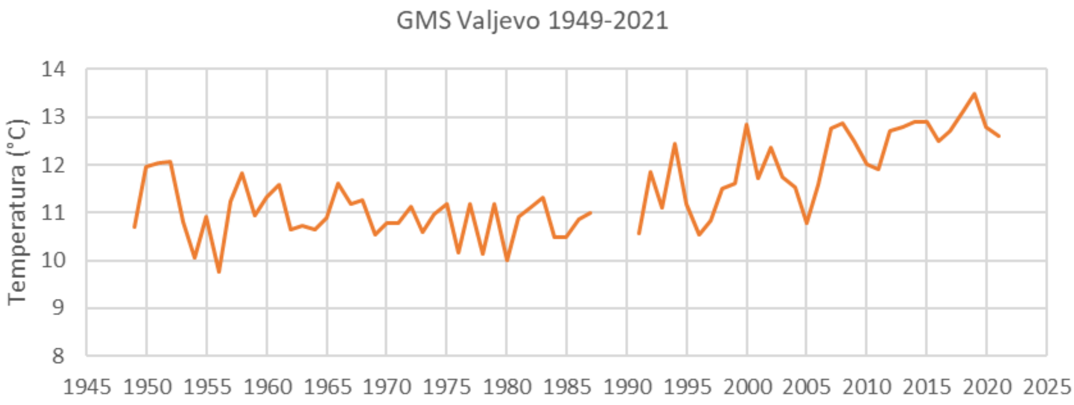


Figure 3-2 The average annual temperature trend in Veljevo from 1949 to 2021 (Source: 16018-PV-12)

3.3.2 Precipitation

The average annual precipitation at GMS Valjevo for the period 1991-2020 was 802 mm (Figure 3-3). The highest precipitation occurred in the warm part of the season in June, with an average of 103 mm of rain, while the lowest rainfall was in the cold part of the season in January, with an average of 49.3 mm. The average annual number of days with snow was 30.2. The highest daily precipitation during 1991-2020 was recorded in 2014 and amounts to 108.2 mm. The monthly total precipitation in May 2014 was 323.7 mm, which is 3.5 times higher than the May average. The 2014 event was synoptic in nature as a large-scale cyclone maintained presence over most of the Balkan's countries with slow trajectory movements.

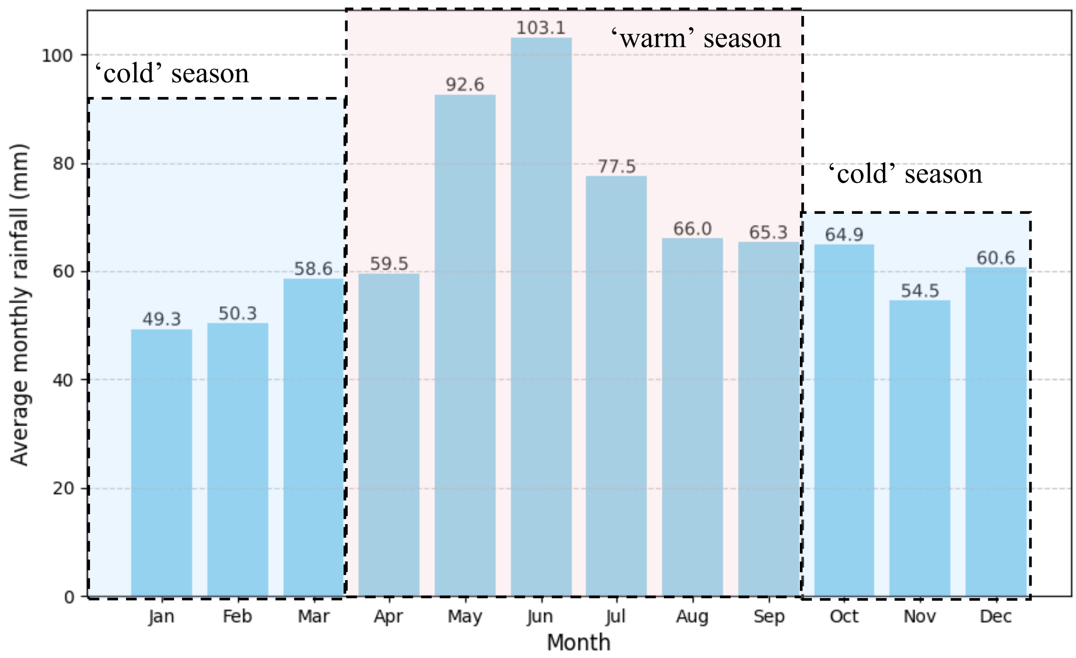


Figure 3-3 The average monthly precipitation at GMS Valjevo (1991-2020) (Source: Technical Assessment Report (Appendix 1 - Hydrology and Climate Change))

3.3.3 Evaporation and transpiration

The average monthly evaporation from the water surface and potential reference evapotranspiration for 1991-2020 are highest in the warm part of the season in June, July and August (Table 3-1).

Table 3-1 Evaporation and potential reference evapotranspiration at GMS Valjevo (Source: 16018-PV-12)

The average evaporation from open water surfaces for GMS Valjevo. (mm/day)											
Jan	Feb	Mar	Apr	Maj	Jun	Jul	Avg	Sep	Okt	Nov	Dec
0.69	1.32	2.51	3.84	4.98	5.91	6.33	5.66	3.68	2.10	1.09	0.60
The average potential reference evapotranspiration for GMS Valjevo. (mm/day)											
Jan	Feb	Mar	Apr	Maj	Jun	Jul	Avg	Sep	Okt	Nov	Dec
0.41	0.87	1.73	2.70	3.56	4.28	4.60	4.09	2.58	1.39	0.68	0.35

3.4 Baseline hydrology

3.4.1 Precipitation

The resulting estimates of the depth-frequency curve based on daily rainfall at the gauges is provided in Table 3-2. The rainfall estimates applied to the hydrological model are the average of the three stations to reflect the spatial heterogeneity.

Table 3-2 Depth-frequency estimates based on daily rainfall records at the gauges and the average.

	N Years	2yr	5yr	10yr	25yr	50yr	100yr	500yr	1000yr	10000yr	PMP*
Loznica	67 (1951 - 2021)	45.7	60.8	71.7	86.4	**98.1**	**110.4**	142.2	157.5	216.3	419.7
Valjevo	68 (1948 - 2021)	43.5	56.7	66.2	78.9	**89.0**	**99.6**	126.9	139.9	189.8	349.3
Ub	58 (1960 - 2021)	42.1	59.0	72.3	91.5	**107.7**	**126.0**	176.6	202.8	314.2	369.7
Average		416	55.9	66.5	81.3	**93.4**	**106.4**	141.1	158.4	228.1	379.6

The estimate of Probable Maximum Precipitation (PMP) was derived by averaging the result from the three rainfall stations. The estimate was 379.6mm in 24hours.

3.4.2 Peak Flows

The peak flow estimates for different return periods from different methods utilised as provided in Table 3-3. It shows that the Hec-HMS model results are conservative compared to statistical estimates but are within the upper 95% confidence interval of the statistical estimate.

The Hec-HMS results are more conservative than the statistical method for events >1 in 25year event. At the 1 in 50year return period and the 1 in 100 year return period the peak flow estimates from the Hec-HMS model are similar to the estimates from the previous study at Ub station. Table 3-4 below uses the calculated area-scaling factor to convert the statistical estimates from Ub to Pambukovia. The Hec-HMS results have been taken directly from the node representing the dam location. The preferred estimates from the previous study from the unit hydrograph approach have been presented for comparison.

The Probable Maximum Flood (PMF) was estimated as 788m^3s^{-1} at Ub and 525.2 m^3s^{-1} at Pambukovica using the 24hour- PMP and the Hec-HMS model. These estimates are significantly lower than the previous study.

Table 3-3 Comparison of Peak Flow estimates for Ub station from the different methods

Return Period	Annual Exceedance Probability (%)	Ub station Peak Flow Estimate, m^3s^{-1} (0.05% CI)	Ub station Peak Flow Estimate*, m^3s^{-1} (0.05% CI)	Estimates for Ub Station from Hec-HMS model**	Feasibility Study Flow Estimate, statistical method, m^3s^{-1}
10,000	0.01	-	-	486.6	-
1000	0.1	217.7 (302.2)	232.7 (327.9)	299	271 (373)
500	0.2	188.6 (256.7)	200.7 (277.4)	252	233 (317)
200	0.5	153.7 (203.7)	162.5 (218.7)	-	
100	1	129.8 (168.4)	136.5 (179.4)	163	159 (207)
50	2	107.9 (137.0)	112.8 (144.8)	129.5	131 (167)
25	5	81.8 (100.9)	84.8 (105.3)	97.2	
10	10	64.0 (76.7)	65.8 (79.6)	57	76 (93)
5	20	47.5 (55.6)	48.4 (57.2)	-	56 (66)
2	50	26.9 (30.8)	26.9 (31.0)	-	31 (36)

* Peak flow value for 2014 amended to 214m^3s^{-1}

** results presented are for the 24hour (daily) storm

Table 3-4 Peak Flow estimates for Pambukovica from the different methods

Return Period	Annual Exceedance Probability (%)	Statistical Peak Flow Estimate, m^3s^{-1} (0.05% CI)	Statistical Peak Flow Estimate*, m^3s^{-1} (0.05% CI)	Estimates from Hec-HMS model** m^3s^{-1}		Feasibility Study Flow Estimate, m^3s^{-1}
				No Climate Change	With Climate Change	
PMF	-	-	-	525.2	525.2(1)	756
10,000	0.01	-	-	286.8	351.8	525
1000	0.1	150.2 (208)	160.6 (226)	177.8	220.9	335
500	0.2	130.1 (177)	138.5 (191)	150.4		290
200	0.5	106.1 (140)	112.1 (151)	-		-
100	1	89.6 (116)	94.2 (124)	98.5	124.9	195
50	2	74.5 (95)	77.8 (100)	78.9	102	160
25	5	56.4 (70)	58.5 (73)	60.1	80.8	-
10	10	44.2 (53)	45.4 (55)	36.8		88

5	20	32.8 (38)	33.4 (40)	-		-
2	50	18.6 (21)	18.6 (21)	-		-

(1) No climate change on PMF

3.4.3 Impact of Climate Change on Peak Flows

The ensemble median change Rx1day annual maximum rainfall for each scenario was rounded to a 9% and 15% increase in 1-day precipitation. These uplifts were applied to the hyetographs in the HEC-HMS model to estimate the possible changes in magnitude for the flood hydrograph. They resulted in estimated increase of ~29% for the more extreme climate change scenario.

3.4.4 Hydrological Regime

The daily and monthly flows for the proposed dam location at Pambukovica were estimated using an area-scaling factor of 0.69. The flow duration curves derived for Pambukovica are shown in Figure 3-4. The purple line was estimated by fitting the Log-Pearson 3 distribution through the monthly average daily average flows and is the source of the flow statistics used in the estimation of the Serbian minimum flows.

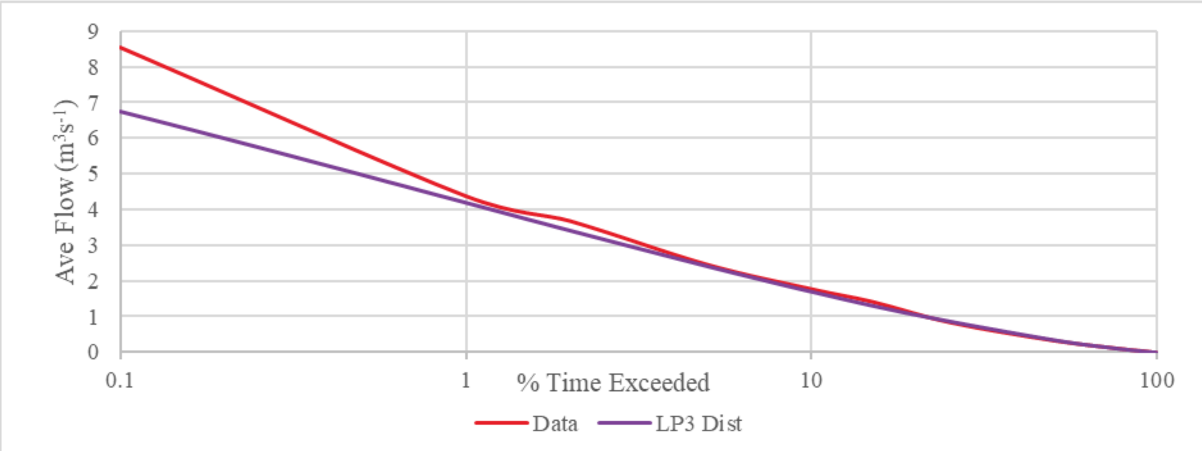


Figure 3-4 Estimated flow duration curves at Pambukovica (1960-2023- red, Log-Pearson3 fitted distribution 1960-2023- purple

3.4.5 Serbian minimum flows

The flow estimates required for the Serbian standard methodology and the final estimates of ecological flows is presented in Table 3-5.

Table 3-5 Key low flow parameters estimated for Pambukovica (1960-2023)

	Qave	Q95	Cold Season GEP	Warm Season GEP	7Q10
Flow (m^3s^{-1})	0.68	0.0124 , 0.0061	0.068	0.102	0.117

3.5 Impact of Proposed Project on hydrology

3.5.1 Change to flow regime during Phase 1

Phase 1 – Under Serbian legislation there is a requirement to deliver a seasonal minimal flow (Qe) which has been evaluated at 68 l/s for the cold season (Oct-Mar) and 102 l/s for the warm season (Apr-Sep). The warm season is higher than the cold season to support an important period -the beginning of fish spawning[13]. The Serbian minimum flow will be delivered either via the environmental flow pipe or irrigation supply pipe.

However, operations phase flows downstream of the reservoir typically far exceed the presented Serbian minimal flow, as additional water is required to be released to maintain the Phase 1 target reservoir level of 138.5 masl. The release of additional water to maintain the target reservoir level will be delivered through the bottom outlet.

The Serbian minimal flow (Qe) for warm season and cold season and the E Flow in an average year (Figure 3-5) dry year (Figure 3-6) and wet year (Figure 3-7) is shown below for Phase 1. From a hydrological perspective, these plots demonstrate the following for Phase 1 of operation:

- A minor reduction in monthly average flows during winter (i.e. cold season) and spring (i.e. warm season), associated with storage in the reservoir.
- Monthly flows will mimic that of the baseline (albeit reduced) maintaining a natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream.
- In both the modelled 'average' and 'dry' year scenarios the operations phase flow will be higher than that under the baseline scenario for some months between July and December (depending on the year), delivering drought resilience for ecosystems along the Ub, Tamnava and Kolubara Rivers downstream. For example, the operations-phase E Flow in an average year (Figure 3-5) will be higher than the baseline scenario in the months of July, August and September.

In addition, the storage in the reservoir for the retention of flood water will also result in a reduction in the magnitude of downstream flood events in the River Ub. Stored water will be released at a slower rate following a storm event which change the flood hydrology of the river downstream of the proposed dam.

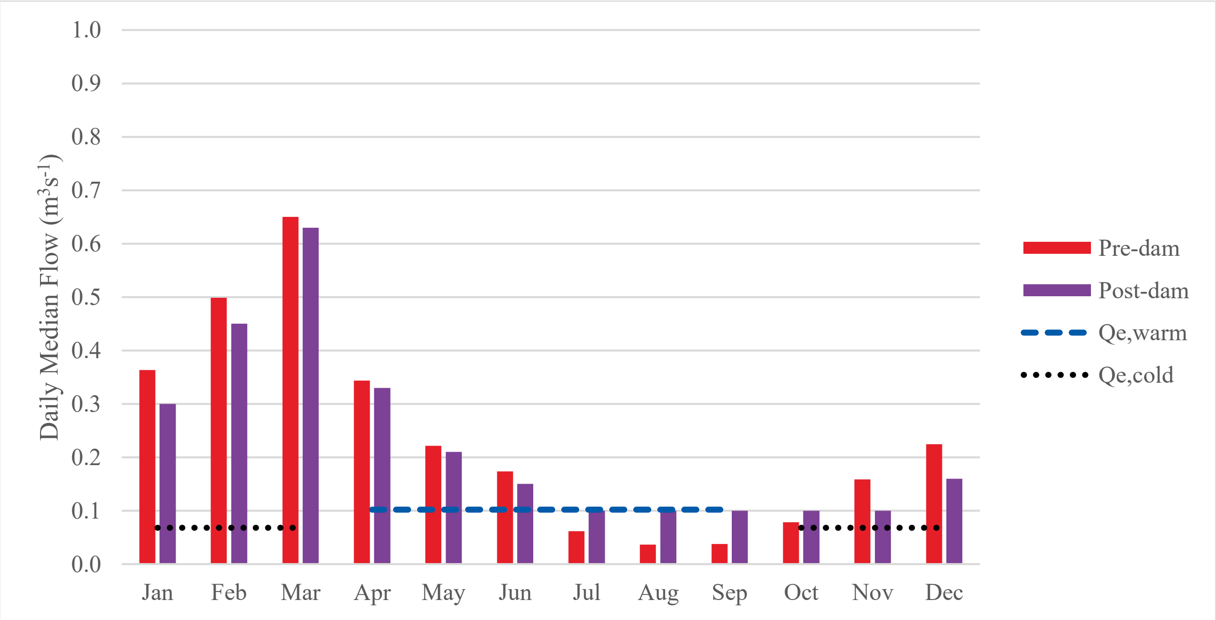


Figure 3-5 1991- 2023 Monthly median (q50) daily average flow at Pambukovica dam estimated from observed data (scaled from Ub station, red) and modelled with scheme (purple)

[13] ON THE METHOD AND MEASUREMENT CRITERIA FOR DETERMINING MINIMUM SUSTAINABLE FLOW demo.paragraf.rs/demo/combined/Old/t/t2023_11/SG_096_2023_006.htm

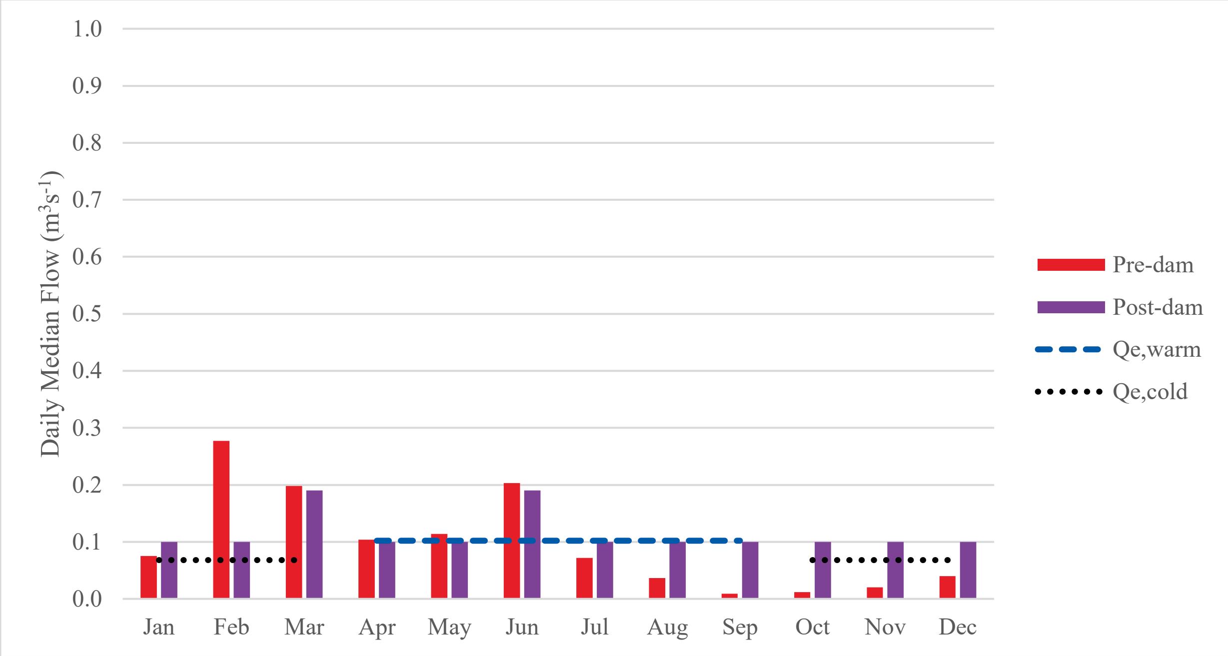


Figure 3-6 **Example dry year (2020) monthly median (q50) daily average flow at Pambukovica dam estimated from observed data (scaled from Ub station, red) and modelled with scheme (purple)**

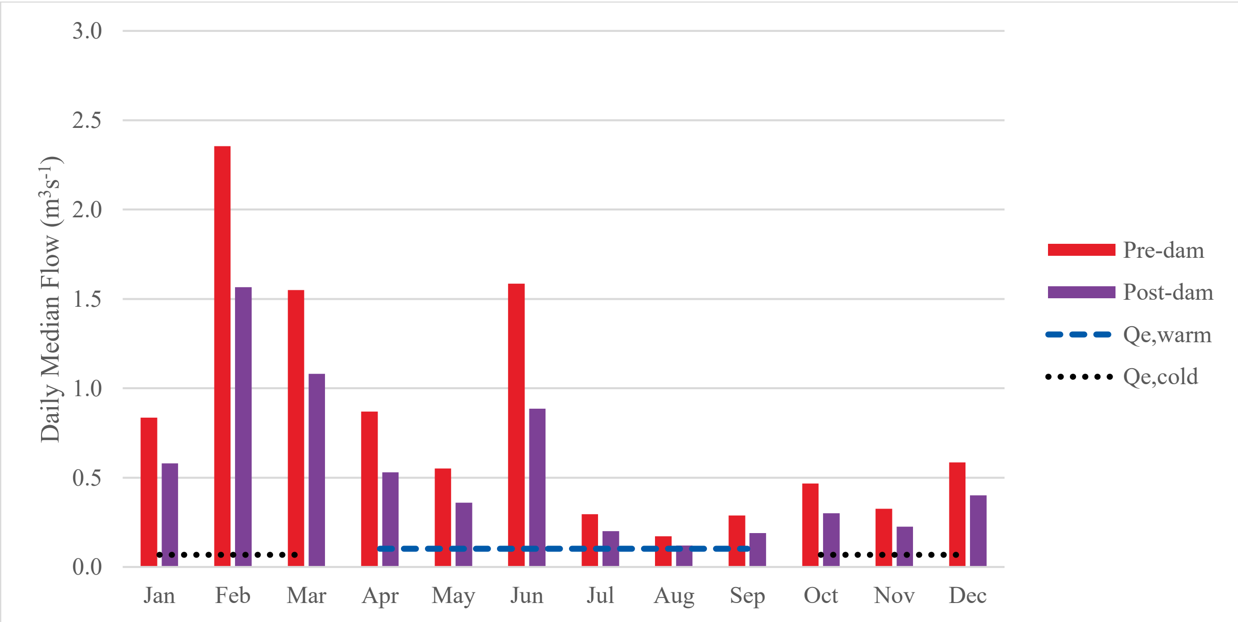


Figure 3-7 **Example wet year (2005) monthly median (q50) daily average flow at Pambukovica dam estimated from observed data (scaled from Ub station, red) and modelled with scheme (purple)**

3.5.2 Changes to flow regime during Phase 2

Phase 2 – Under Serbian legislation there is a requirement to deliver a seasonal minimal flow (Qe) which has been evaluated at 68 l/s for the cold season (Oct-Mar) and 102 l/s for the warm season (Apr-Sep). The Serbian minimum flow will be delivered either via the environmental flow pipe or irrigation supply pipe During Phase 2 the Serbian minimum flow (Qe) will need to be maintained whilst accommodating for the use of the reservoir storage for flood mitigation and irrigation, and maintaining downstream and E Flow to support downstream habitats.

Phase 2 operations (E Flow) downstream of the reservoir typically far exceed the presented Serbian minimal flow, as additional water is required to be released to maintain the Phase 2 target reservoir level of 145.5 masl. The release of additional water to maintain the target reservoir level will be delivered through the bottom gate outlet.

The Serbian minimal flow (Qe) for the warm season and cold season, and the operations-phase E Flow (purple line: outflow to river) and baseline scenario (red line: inflow to dam) for an average year **(**Figure 3-8**)** , wet year (Figure 3-9) and dry year (Figure 3-10) is shown below for Phase 2. The reservoir storage volume (indicated by the blue line) considers an irrigation demand of 4.2 4.2Mm^3 per year, split over June-August, with higher demand assumed in July and August (see Technical Assessment Report Appendix 7 – Operational Rules). From a hydrological perspective, these plots demonstrate the following for Phase 2 of operation:

- For the representative **average year (2007)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir (indicated by the blue line). The E Flow to the River Ub downstream of the dam (purple line: outflow to river) matches the natural baseline regime (red line: inflow to dam), other than for a short period in October / December where reservoir filling occurs. With the exception of this period of filling, daily flows will maintain a natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream.
- For the representative **wet year (2005)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir (indicated by the blue line). The E Flow to the River Ub downstream of the dam (purple line: outflow to river) matches the natural baseline regime (red line: inflow to dam), other than for a short periods in June to September where reservoir filling occurs. With the exception of this period of filling, daily flows will maintain a natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream
- For the representative **dry year (2020)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir. However, the reservoir storage would not fully recover to target level during Autumn / winter and further recharge in January February of the following year would be required. However, water availability is high at this time of year (indicated by the peaks on the lefthand side of the graph) and recharge to target is expected to be quick. Once the reservoir target level is achieved E flows would again mimic the natural regime. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream
- In dry years the E Flow will be higher than that under the baseline scenario as a result of delivery of the Serbian minimum flow, delivering drought resilience for ecosystems along the Ub, Tamnava and Kolubara Rivers downstream. This can be seen in Figure 3-10 (2020 - representative dry year) where the operations-phase flows downstream of the dam (purple line: outflow to river) is higher than the natural baseline regime (red line: inflow to dam) between the months June and October.

In addition, the storage in the reservoir for the retention of flood water will also result in a reduction in the magnitude of downstream flood events in the River Ub. Stored water will be released at a slower rate following a storm event which change the flood hydrology of the river downstream of the proposed dam.

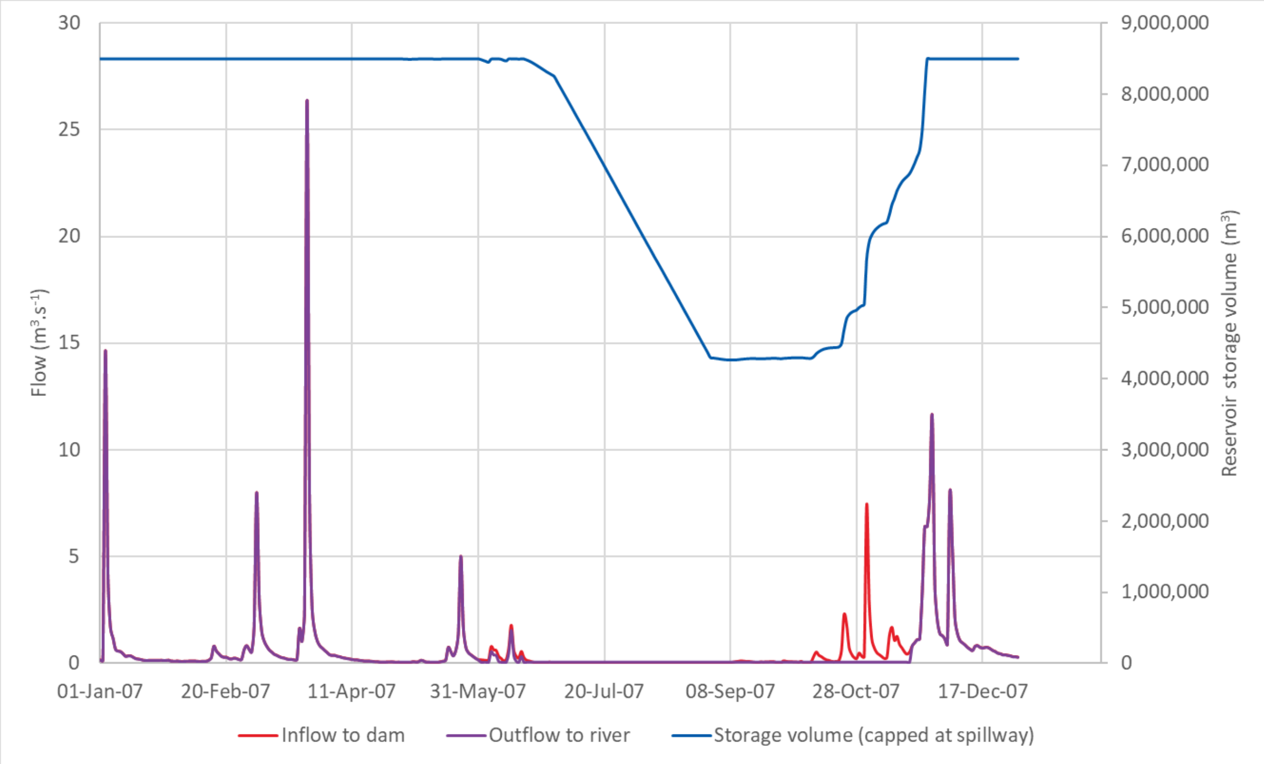


Figure 3-8 Example average year (2007) daily flow into Pambukovica dam, out of the dam to Ub RIver and the change in stored water volume within the dam, when capped at the spillway

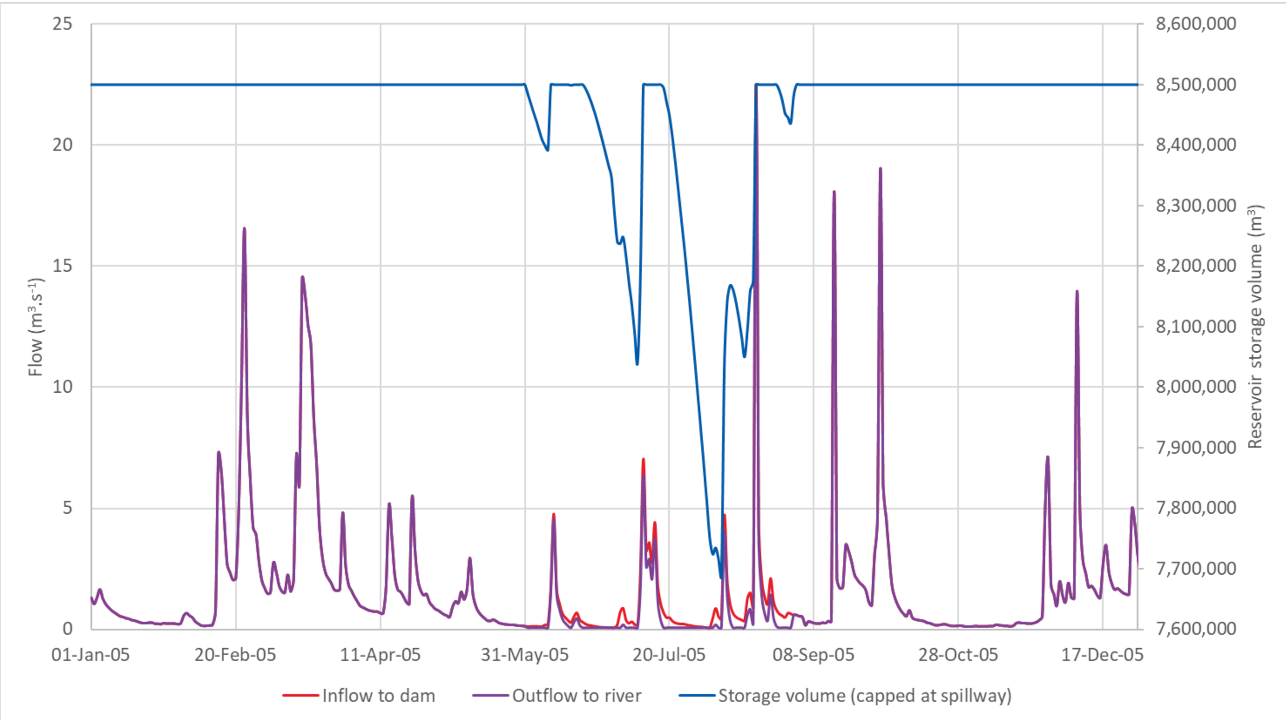


Figure 3-9 Example wet year (2005) daily flow into Pambukovica dam, out of the dam to Ub River and the change in stored water volume within the dam, when capped at the spillway

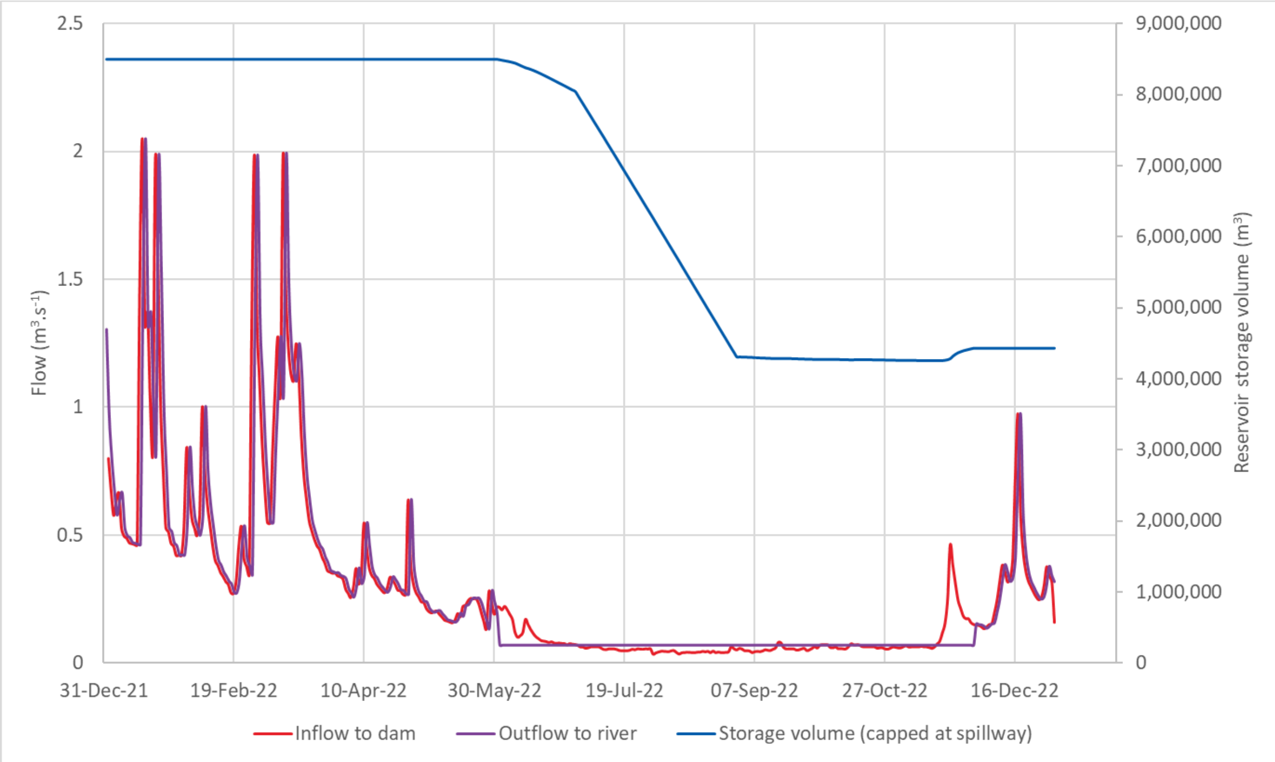


Figure 3-10 Example dry year (2020) daily flow into Pambukovica dam, out of the dam to Ub River and the change in stored water volume within the dam, when capped at the spillway

4. Water quality

4.1 Objectives

The water quality of the reservoir for dam projects can be modified by increased nutrient loading originating from flooded soils and biomass, particularly during initial years post commissioning. Under certain conditions, nutrient loading can lead to eutrophication and algal blooms in the reservoir, resulting in a reduction in the dissolved oxygen concentration and changes to the pH of the water in the reservoir. These changes may impact aquatic ecology within the reservoir and modify downstream water quality and ecology as a result. This assessment will focus on an evaluation of this risk specifically.

4.2 Assessment Methodology

The objectives of the assessment are:

- Describe the baseline water quality in the Ub River;
- Qualitatively assess the potential impact of the reservoir on the quality of the water;
- Identify potential risks for water users and aquatic biodiversity which are assessed in other parts of the assessment (Book 4 Biodiversity Impact Assessment).

4.3 Water quality surveys

Water quality surveys were undertaken each month from the warm season to the cold season, from August – November 2024. The results and list of Serbian and international limits are presented in this subsection. Water quality samples were taken at several locations along the Ub River and its tributaries (Figure 4-1). Due to low flows, many of the sampling points contain data gaps due to insufficient water in the channel. Thus, WQ UB 03 is not included in the baseline assessment and WQ UB 04 contains less data points than the other stations.

Table 4-1 Water quality sampling points

#	Location
WQ UB 01	River Ub – u/s of reservoir location
WQ UB 02	River Ub – main road crossing
WQ UB 03	River Ub – at bridge with gauge
WQ UB 04	River Ub – d/s/ of redundant fish farm weir
WQ UB 05	River Ub – d/s of the town of Ub at minor road bridge
WQ Trib 1	River Joševa
WQ Trib 2	River Kokanovac
WQ Trib 3	River Sigrada
WQ Trib 4	River Babinac

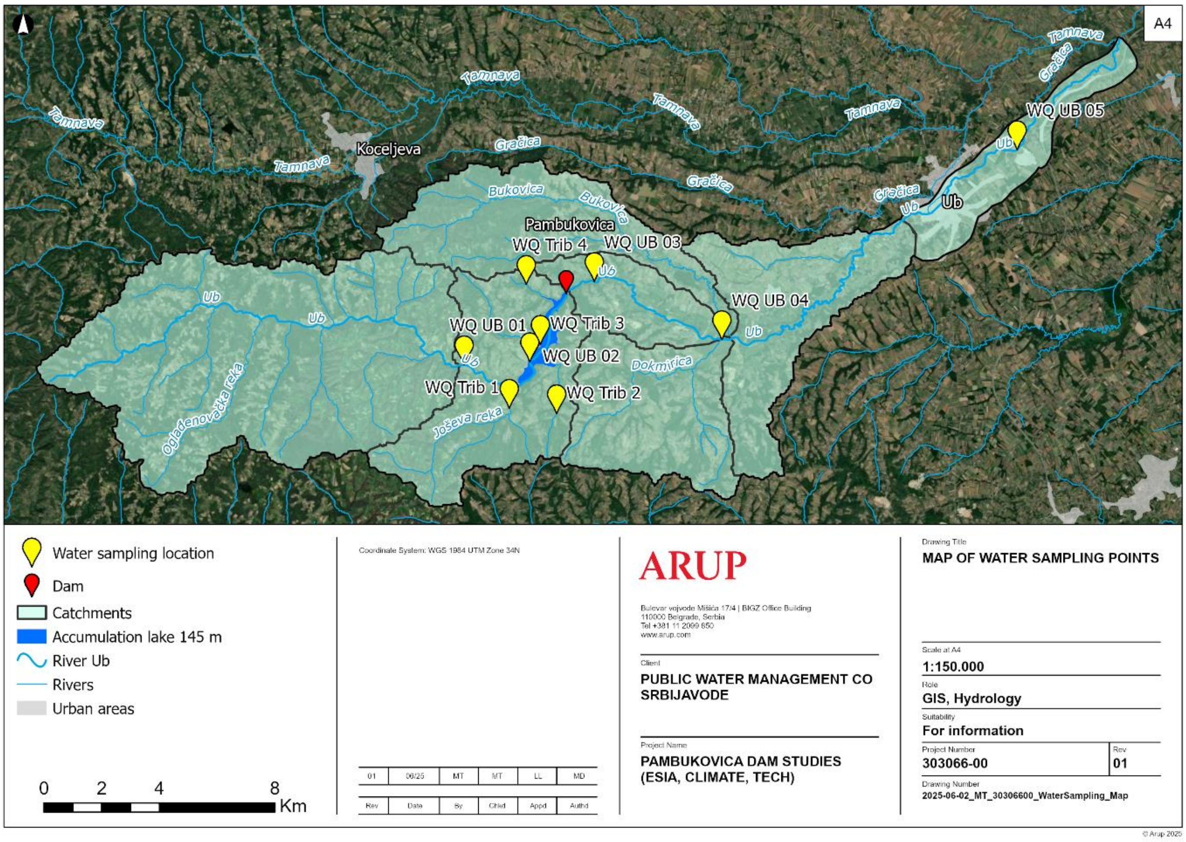


Figure 4-1 Map of water quality sampling points and the proposed dam location.

Table 4-2 Range of General Water Quality Parameters across 5 locations on the River Ub over 4 months

Parameter	Units	WQ UB 01	WQ UB 02	WQ UB 04	WQ UB 05
Temperature	°C	9.6-25	9.4-24.6	7.5-21.4	10.8-30.1
pH	---	7.2-7.4	7.1-7.5	7.1-7.4	7.1-7.3
Suspended Solids	mg/L	2.1-24	2.5-12	10	32-214
Dissolved Oxygen (DO)	mg/L	3.2-6.3	2.3-5.9	4.7-4.8	1.2-3.8
Oxygen Saturation	%	36-55.3	28-52	16-55	16-64
BOD5	mg O_2/L	3-8	3-12	5-109	9-520
COD (K2Cr2O7)	mg O_2/L	8.6-25	8.7-32	16-244	25-1490
Total Organic Carbon (TOC)	mg/L	2.1-6.5	2.2-10	4.2-61	5.1-501
Total Nitrogen	mg N/L	<0.1-1.9	<0.1-0.41	0.56	0.25-26
Nitrates	mg N/L	<0.01-1.8	<0.01-0.4	0.39	<0.01
Nitrites	mg N/L	<0.01	<0.01	<0.01	<0.01-0.05
Total Phosphorus	mg P/L	0.017-0.18	0.019-0.055	0.032	0.29-4

Parameter	Units	WQ UB 01	WQ UB 02	WQ UB 04	WQ UB 05
Orthophosphates	mg P/L	0.015-0.066	0.017-0.031	0.023	0.21-2.9`
Chlorides	mg/L	6.5-6.8	7.9-8.9	8.2	10-84
Sulfates	mg/L	19-33	21-32	12	11-15
Total Mineralisation	mg/L	244-294	240-298	344	198-780
Conductivity at 20 °C	µS/cm	422-437	417-428	397-585	895-1231
Arsenic	µg/L	0.3-1.0	0.3-1.4	1.9-2.3	2.4-4.0
Copper	µg/L	0.6.-2.0	0.6-3.3	0.6-1.4	1.4-26.0
Zinc	µg/L	1.3-17.0	2.0-16.0	1.3-8.1	5.6-74.0
Total Chromium	µg/L	1.6-1.8	1.4-1.9	1.8-2.8	3.8-32.0
Total Iron	µg/L	3.8-335.0	29.0-215.0	21.0-313.0	535.0-4369.0
Boron	µg/L	12.0-27.0	11.0-18.0	26.0	81.0-89.0
Total Manganese	µg/L	12.0-66.0	14.0-287.0	77.0-103.0	198.0-266.0
Mercury	µg/L	66.0	287.0	--	255.0
Nickel	µg/L	2.9-5.3	2.7-7.0	4.7-5.0	4.6-24.0
Phenolic Compounds	µg/L	<1	<1	<1	<1
Petroleum Hydrocarbons	µg/L	<1	<1	<1	<1
Surface-Active Substances (as Lauryl Sulfate)	µg/L	<30	<30	<30	<30-350
AOX (Adsorbable Organic Halogen)	µg/L	<10	<10-150	<10	<10
Fecal Coliforms	cfu/100ml	<10-240	<10-150	<10-2400	<10-24000
Total Coliforms	cfu/100ml	<10-2400	40-2400	<10-2400	230-24000
Intestinal Enterococci	cfu/100ml	<10-230	<10-230	<10-230	2400-24000
Number of Aerobic Heterotorphs	cfu/100ml	$5.0x10^4$-$2.6x10^6$	$6.0x10^4$-$8.8x10^5$	$6.0x10^4$-$3.9x10^5$	$9.8x10^4$-$4.3x10^7$

Table 4-3 Surface water quality parameters for Serbia

Water Quality Parameter		Surface Water Quality Parameters[14]					Unit
	Typical value for good water quality river[15]	As per the above regulation					
		Class 1	Class 2	Class 3	Class 4	Class 5	
pH value	6.0-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	<.6.5 or 8.5	
Suspended solids		25	25	-	-	-	mg/L
Dissolved oxygen	<10	8.5	7.0	5	4	<4	mg O_2/L
Oxygen saturation		90-110	70-90	50-70	30-50	<30	%
BOD$_5$	<2	1.8	4.0	7	25	>25	mg O_2/L
COD ($K_2Cr_2O_7$)	<20	10	15	30	125	>125	mg O_2/L
Total organic carbon (TOC)	<10	2.0	5.0	15	50	>50	mg/L
Total nitrogen		1	2	8	15	>15	mg N/L
Nitrate	11	1.5	3.0	6	15	>15	mg N/L
Nitrite	<0.1 / 0.1-5	0.01	0.03	0.12	0.3	>0.3	mg N/L
Ammonia nitrogen		0.10	0.30	0.6	1.5	>1.5	mg N/L
Un-ionized Ammonia		0.005	0.025	-	-	-	mg NH_3/L
Total phosphorus	0.005-0.02	0.05	0.10	0.4	1	>1	mg P/L

[14] Official Gazette of the Republic of Serbia, No. 50/2012

[15] Chapman, Deborah V, World Health Organization, UNESCO & United Nations Environment Programme. (1996). Water quality assessments : a guide to the use of biota, sediments and water in environmental monitoring / edited by Deborah Chapman, 2nd ed. E & FN Spon. https://iris.who.int/handle/10665/41850

Water Quality Parameter		Surface Water Quality Parameters[14]					Unit
	Typical value for good water quality river[15]	As per the above regulation					
		Class 1	Class 2	Class 3	Class 4	Class 5	
Orthophosphate		0.02	0.05	0.2	0.5	>0.5	mg P/L
Chloride		50	100	150	250	>250	mg/L
Total residual chlorine		0.005	0.005	-	-	-	mg HOCl/L
Sulfates		50	100	200	300	>300	mg/L
Total mineralization		<1000	1000	1300	1500	>1500	mg/L
Conductivity at 20^{0}C	10-1000	<1000	1000	1500	3000	>3000	mS/cm
Arsenic	8	<5	10	50	100	>100	µg/L
Copper	50	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300	500	1000	>1000	µg/L
Zinc	110	30 (T=10) 200 (T=50) 300 (T=100) 500 (T=500)	300 (T=10) 700 (T=50) 1000 (T=100) 2000 (T=500)	2000	5000	>5000	µg/L
Chromium (total)	120	25	50	100	250	>250	µg/L
Iron (total)		200	500	1000	2000	>2000	µg/L
Total Manganese		50	100	300	1000	>1000	µg/L

Water Quality Parameter		**Surface Water Quality Parameters**[14]					**Unit**
	Typical value for good water quality river[15]	**As per the above regulation**					
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**	
Phenolic Compounds		<1	1	20	50	>50	µg/L
Petroleum Hydrocarbons		without	without	without	without	without	
Surface-Active Agents		100	200	300	500	>500	µg/L
AOX		10	50	100	250	>250	µg/L
Fecal coliforms		100	1000	10000	100000	>100000	cfu/100ml
Total coliforms	<100	500	10000	100000	1000000	>1000000	cfu/100ml
Intestinal enterococci		200	400	4000	40000	>40000	cfu/100ml
Aerobic heterotrophic bacteria		500	10000	100000	750000	>750000	cfu/100ml

4.4 Baseline water quality

4.4.1 Thermal conditions

In contrast to lakes, the thermal regime of reservoirs can be more variable. Unnatural variability is added as a result of the terminal location of-some reservoirs at the downstream end of a drainage basin, their tendency to develop density currents, their operating regime (which can result in modification of the thermal profile), and morphology (which tends to be less deep than natural lakes and, therefore, more likely to encourage periodic water mixing).[16] Water temperature is a main factor affecting aquatic ecosystems. Water releases must be managed to avoid thermal pollution from dam discharges and to ensure temperatures match the natural river conditions. Fish species will respond to temperature increases with varying response according to their thermal tolerances and life stage; however, a negative response is expected for cold-water species.[17]

The baseline water quality surveys provide temperature data for the Ub River over the course of four months in 2024. The results for four locations are presented in Figure 4-2. Values are missing for several months at sampling site WQ UB 04. As shown in the data, temperature increases are noted downstream of the town of Ub at WQ UB 05. Stations north of the town have similar temperatures ranging from 7.5-25 ˚C across the four months. These are in line with normal temperature ranges for their location. The Ub River may be receiving additional inflows from Ub town and raising the temperature of the river.

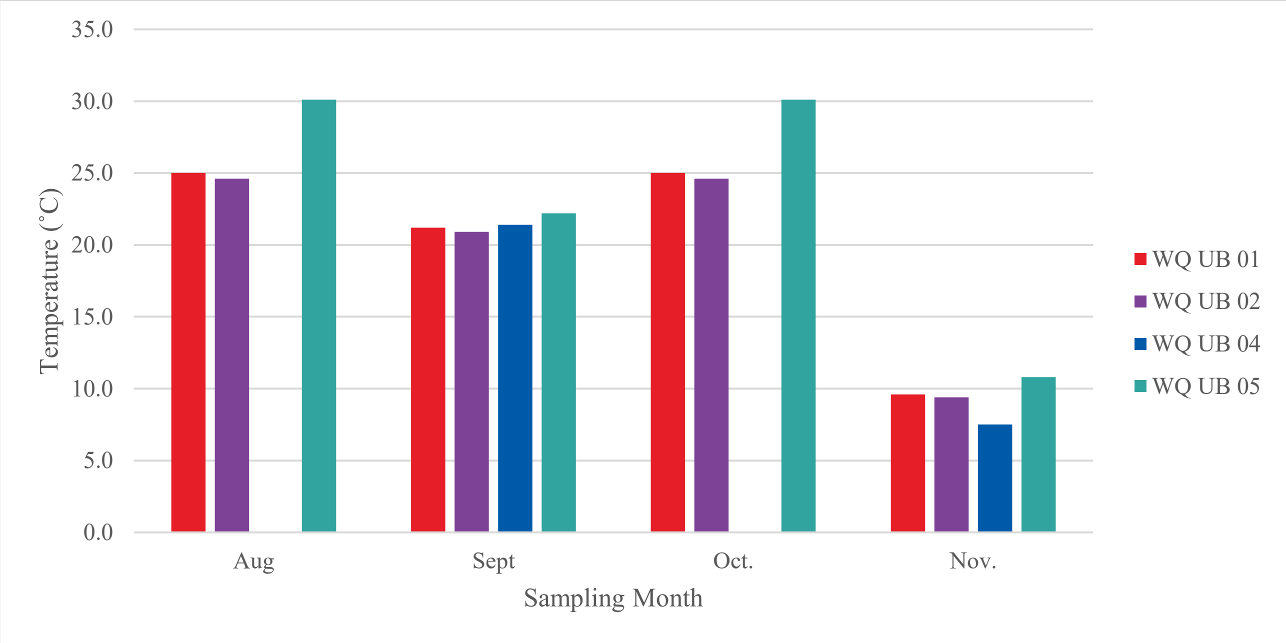


Figure 4-2 Temperature change in the River Ub at 4 locations over 4 months in 2024.

4.4.2 Oxygenation conditions

Oxygenation conditions were assessed through Dissolved Oxygen (DO), Biochemical oxygen demand (BOD) and Chemical oxygen demand (COD). Water temperature affects DO concentrations in a river or waterbody, DO generally increases as the water temperature decreases as cooler water is able to carry more

[16] Chapman, Deborah V, World Health Organization, UNESCO & United Nations Environment Programme. (1996). Water quality assessments : a guide to the use of biota, sediments and water in environmental monitoring / edited by Deborah Chapman, 2nd ed. E & FN Spon. https://iris.who.int/handle/10665/41850

[17] Inland Fisheries Ireland, 2018. Climate change mitigation research programme. Salmonids in hot water, Summer 2018. IFI/2019/1-4465

dissolved oxygen.[18] The flow rate of a river, stream or turbulence in a lake can also impact upon the DO concentration. Rapidly moving water tends to contain higher DO concentrations whereas stagnant water typically contains lower DO concentrations. BOD is a parameter used to describe the amount of dissolved oxygen required by microorganisms to break down organic matter in water and is a crucial indicator of water quality. BOD is a measure of the amount of oxygen that aerobic microorganisms need to decompose organic substances in a water sample over a five-day period in the dark at 20 °C, expressed in O_2/litre. COD is another method of estimating the amount of pollution in a water sample; COD is the amount of oxygen required to chemically breakdown the pollutants (as opposed to BOD which is the amount of oxygen required to do this biologically through micro-organisms).

Figure 4-3 shows the DO concentrations across the four sampling months (Aug.-Nov. 2024). The results are consistent with those illustrated in the temperature analysis. DO decreases for the downstream sampling point WQ UB 05 which aligns with the higher water temperatures recorded at the site. DO concentrations at all four locations all fall within Class III or lower per the Serbian surface water quality standards.

The baseline oxygenation conditions are considered further in Figure 4-4 where BOD, DO, and COD mean values across the four sampling sites are presented. The high COD values at sampling site WQ UB 05 indicate the potential of wastewater or other point source pollution entering the river at Ub town. BOD and COD values fall mostly within the Serbian Class II and Class III ranges across the entire river. Upstream at WQ UB 01 and 02, the river is in generally good condition with regard to international standards for COD values, but decreases sharply in quality downstream. Poorer water quality at WQ UB 05 is also reflected in the higher conductivity values recorded (Section 4.4.3).

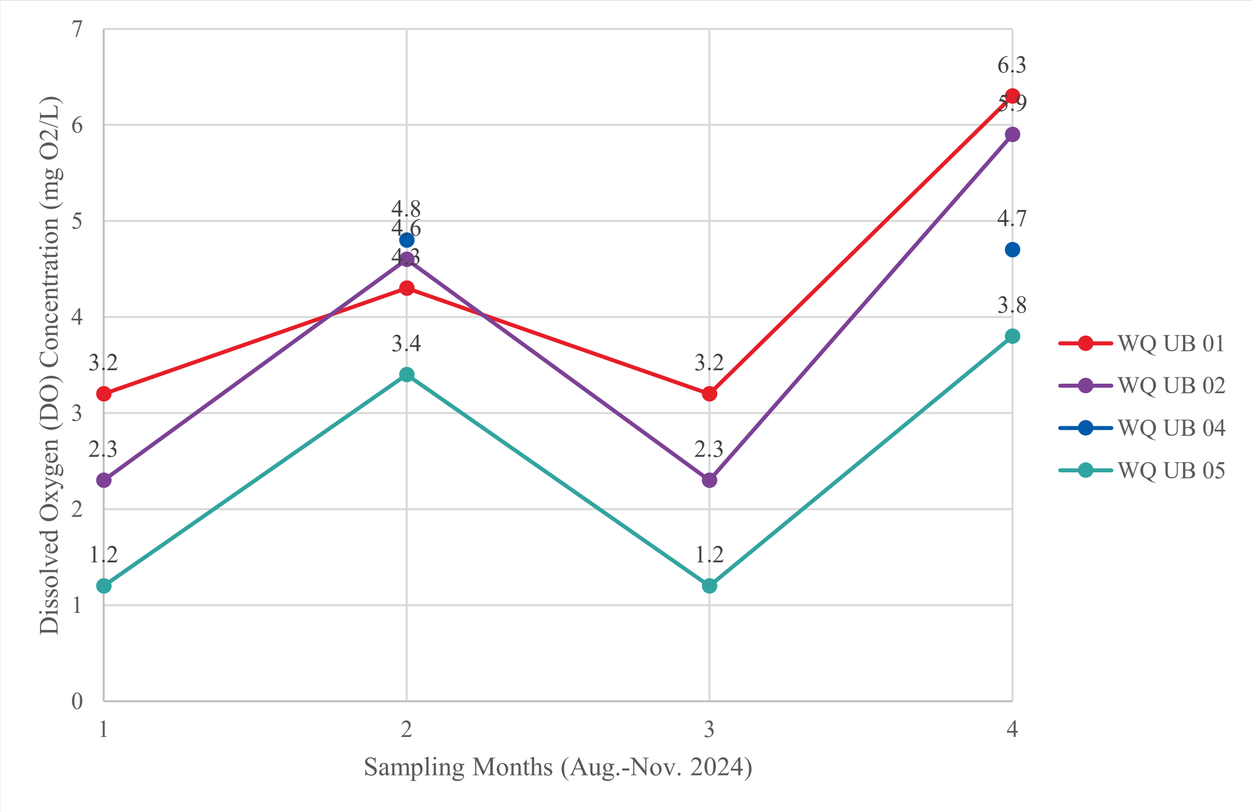


Figure 4-3 Dissolved Oxygen Concentrations along four Ub river sampling sites over four months in 2024.

[18] USGS, 2018. https://www.usgs.gov/special-topics/water-science-school/science/dissolved-oxygen-and-water

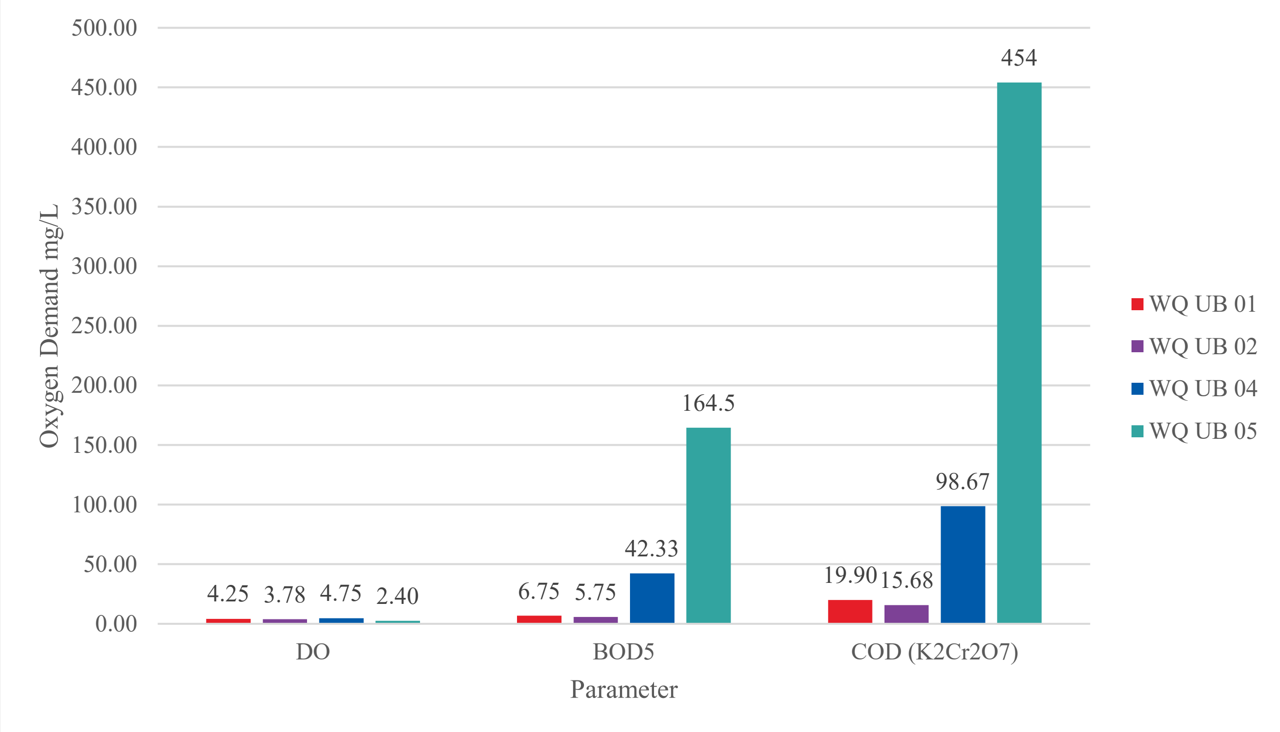


Figure 4-4 Baseline oxygenation conditions in the Ub River.

4.4.3 Conductivity

Electrical conductivity is a measure of the ability of an aqueous solution to carry an electrical current. Conductivity is useful as a general measure of water quality. Each water body tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes to electrical conductivity can indicate that unknown pollutants have entered the waterbody and that further detailed laboratory analysis on a range of parameters is warranted.

International standards for good river quality indicate conductivity can range anywhere from 10-1000 uS/cm. In Serbia, the national government has set Class I (best quality) as <1000. Only sampling point WQ UB 05 exceeds this limit and would fall between Class II and Class III with an average conductivity of 1124.5 uS/cm at 20˚C. Salinity data is summarised in Table 4-4.

Table 4-4 Baseline Salinity of Ub River at Four Sampling Sites.

Sample site	Parameter	Unit	Max	Min	Average	No. Samples	Date Ranges	Class (based one mean)
WQ UB 01	Conductivity @20°C	uS/cm	437	422	426.75	4	Aug-Nov 2024	Class I
WQ UB 02	Conductivity @20°C	uS/cm	428	417	422	4	Aug-Nov 2024	Class I
WQ UB 04	Conductivity @20°C	uS/cm	585	397	491	2	Aug 2024; Nov 2024	Class I
WQ UB 05	Conductivity @20°C	uS/cm	1231	895	1124.5	4	Aug-Nov 2024	Class II

4.4.4 Acidification

The pH of a water body is the measure of how acidic or alkaline the water is on a scale of 0-14. Serbian standards set the optimal Class I range for pH in surface waters to be between 6.5-8.5 with international standards of good rivers slightly widening this range to 6.0-8.5. Overall, all sampling sites fall within the Class I range as recorded in Table 4-5.

Table 4-5 pH Levels in the Ub River

Sample site	Parameter	Unit	Max	Min	No. Samples	Date Ranges	Class
WQ UB 01	pH	pH units	7.4	7.2	4	Aug-Nov 2024	Class I
WQ UB 02	pH	pH units	7.5	7.1	4	Aug-Nov 2024	Class I
WQ UB 04	pH	pH units	7.4	7.1	2	Aug. 2024; Nov. 2024	Class I
WQ UB 05	pH	pH units	7.3	7.1	4	Aug-Nov 2024	Class I

4.4.5 Nutrient conditions

Agriculture is a main contributing nutrient pressure on the Ub River. The presence of excess nutrients such as phosphorous and nitrogen primarily originate from agricultural fertilisers and wastewater sources. Excess concentrations of nitrogen and phosphorus in lakes can cause algae to grow at rapid rates which can overwhelm natural ecosystems. Significant increases in algae can adversely impact upon water quality, food resources, habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms that can lead to hyper saturated water in the daytime (as the algae photosynthesis) and severely reduce or eliminate oxygen at night (when the algae respire). This, along with the reduction in oxygen through the decay of dead algae can lead to fish kills as a result of extreme oxygen depletion. Algal blooms may also potentially be harmful to humans and terrestrial animals because they produce elevated toxins and bacterial growth that can cause sickness after contact with polluted water, or consume tainted fish or shellfish, or drink contaminated water.

The sampling indicated Total N values ranging from <0.1 to 26 mg N/L. This wide variation can be attributed to a steep jump in total nitrogen quantities at sample site WQ UB 05. Nitrates and nitrites fall within generally acceptable ranges of Class I and Class II across the sampling sites. The contribution to the increase in total nitrogen is attributed to the presence of both ammonium ions and unionized ammonia, likely from domestic pollution entering the river at Ub town. Thus, agricultural runoff does not appear to be impacting the Ub river at significant levels for the short sample period studied. Future tests will need to be undertaken to determine the extent of agricultural runoff influence on the catchment.

Table 4-6 Baseline nitrogen values in the Ub river

	Total Nitrogen		Nitrates		Nitrites		Unionized Ammonia		Units	Class
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
WQ UB 01	<0.1	1.9	<0.01	1.8	<0.01	<0.01	<0.01	<0.01	mg/L	Class 1
WQ UB 02	<0.1	0.41	<0.01	0.4	<0.01	0.4	<0.01	<0.01	mg/L	Class 1
WQ UB 04		0.56	0.39	0.39		<0.01		0.15	mg/L	Class 1
WQ UB 05	0.25	26	<0.01	<0.01	<0.01	0.05	0.19	18	mg/L	Mostly Class 1

Total phosphorus values ranged from 0.13-0.055 mg/L across the sampling points north of Ub town. Orthophosphase is a form of reactive phosphorus that essentially demonstrates the amount of phosphorus available for chemical and biological reaction. As with other pollutant measurements, total phosphorus increased sharply for WQ UB 05 south of Ub town, recording total phosphorus concentrations as high as 4 mg/L. Apart from WQ UB 05, other sample points fall within Class III or below for all measurements. WQ UB 05 recorded class V values for total phosphorus and orthophosphates for all months measured. Baseline values are presented in Table 4-7.

Table 4-7 Baseline phosphorus values in the Ub river

	Total Phosphorus		Orthophosphate		Units	Class
	Min.	Max.	Min.	Max.		
WQ UB 01	0.017	0.018	0.015	0.066	mg/L	Class 1
WQ UB 02	0.019	0.055	0.017	0.031	mg/L	Class 1
WQ UB 04		0.032		0.023	mg/L	Class 1
WQ UB 05	0.29	4	0.21	2.9	mg/L	Class 3

4.5 Impact of Proposed Project on water quality

The construction and operation of the reservoir will affect the water quality both in the impounded area and downstream as a result of significant changes to how chemicals and nutrients in the water interact. More intensive water quality modelling may be completed as the dam design concept is developed.

4.5.1 Release of anaerobic water to downstream ecosystems

Downstream water quality may be affected by the potential release of water that has formed an oxycline[19], a sharp gradient in dissolved oxygen concentration with depth, under specific environmental conditions. In deep, stratified reservoirs, the oxycline often forms at the boundary between the epilimnion (well-mixed, oxygenated surface layer) and the hypolimnion (colder, deeper, and less oxygenated layer). The precise depth depends on the reservoir's thermal structure, mixing patterns, and biological activity. The depth of the oxycline is strongly influenced by:

- Thermal stratification: Stronger stratification leads to a deeper and more stable oxycline.
- Reservoir morphometry: Deeper reservoirs tend to have deeper oxyclines.
- Oxygen consumption rates: High biological or chemical oxygen demand in deeper layers (e.g., due to organic matter) can cause the oxycline to form higher in the water column

DO plays a vital role in biogeochemical cycling and the evolution of ecosystem structure and function. Low DO concentration (anaerobic state) in the lower water layer may be harmful due to the location of the EFlow to downstream biota (like fish).

Two scenarios for reservoir characteristics were assessed for the potential conditions for formation of an oxycline. These were when the reservoir was full and when the reservoir was at minimum volume (maintained for downstream EFlow releases) (Table 4-8). During Phase 1 of the dam operation, the operating conditions are such that only 5-6m of water depth is expected to be kept in the reservoir. Under these conditions, formation of an oxycline is unlikely. During Phase 2 the reservoir will fluctuate between the minimum storage volume and maximum storage volume according to flood releases and irrigation demand throughout the year. Residence time at full volume will fluctuate.

[19] An *oxycline* is a layer in a water body where the concentration of dissolved oxygen changes rapidly with depth, typically separating oxygen-rich upper waters from oxygen-poor or anoxic deeper waters.

Table 4-8 Reservoir and flow characteristics

Maximum reservoir volume	Reservoir volume	8.5	Mm^3
	Water level	145	masl
Minimum reservoir volume	Reservoir volume	2	Mm^3
	Water level	138.5	masl
Inflow	Average discharge	0.68	m^3/s
Outflow	Bottom outlet discharge	50	m^3/s
	Bottom outlet maximum discharge	95.53	m^3/s

It was not possible to calculate the reoxygenation rate without additional water quality modelling and sampling, but it was possible to calculate a high-level estimation of the reaeration rate. The reaeration rate describes the rate at which oxygen is reintroduced into a column of water at any given time. In conjunction with the deoxygenation rate which is based primarily on the temperature and presence of organic matter, the reaeration rate is included within the Streeter Phelps [20]equation to predict the dissolved oxygen concentration in a river or stream. The ratio of the two values describes the ability of a reservoir or stream to self-purify with regards to oxygen level.

Under the Serbian minimum flow conditions assuming a minimum reservoir storage volume of 2 Mm^3 and the Serbian minimum flows of 68 L/s for the cold season (Oct-Mar) and 102 L/s for the warm season (Apr-Sep.), the hydraulic residence time is between 227-340 days. This long residence time allows for the potential for thermal stratification within the reservoir and thus the potential for deoxygenation in lower levels as well as less reaeration. It was not possible to calculate the reoxygenation rate without additional water quality modelling, but it was possible to calculate a high-level estimation of the reaeration rate. The reaeration rate describes the rate at which oxygen is reintroduced into a column of water at any given time. In conjunction with the deoxygenation rate which is based primarily on the temperature and presence of organic matter, the reaeration rate is included within the Streeter Phelps equation to predict the dissolved oxygen concentration in a river or stream.

The height of the water column assumed within the reservoir at the environmental discharge outlet is 12.9m between the minimum water level and the invert of the bottom outlet. Based on the Streeter Phelps equations for calculating the reaeration rate coefficient (see below), reaeration rates are tabulated in Table 4-9Table 4-9. The reaeration rates were estimated for several water temperature and operating conditions to determine which situations result in the lowest reaeration rates. Temperatures were estimated from those measured in the water quality sample data from Section 4.4.

$$k_2 = \frac{3.9(v)^{0.5}\left[(1.025)^{(T-20)}\right]^{0.5}}{H^{1.5}}$$

where:

k_2 = reaeration rate constant

v = horizontal velocity of water within the reservoir

T = water temperature (˚C)

H = height of the water column (depth of the reservoir)

[20] Schnoor, J. (1996). Environmental Modelling, Fate and Transport of Pollutants in Water, Air and Soil. Wiley-Interscience, ISBN 978-0-471-12436-8. https://www.wiley.com/en-us/Environmental+Modeling%3A+Fate+and+Transport+of+Pollutants+in+Water%2C+Air%2C+and+Soil-p-9780471124368

Table 4-9 Reaeration rates across various operating and seasonal conditions

Reservoir characteristics		Serbian minimum flow		Operational releases during Phase 2	
		Cold season low flow at TWL	Warm season low flow at TWL	Maximum supply capacity at TWL	Operational flood protection gate discharge limit
Water level	m	138.5	138.5	145	145
Reservoir volume	Mm^3	2	2	8.5	8.5
Height of water column (H)	m	12.9	12.9	19.9	19.9
Residence time of water within the reservoir	d	340	227	1.02-145	1.97-145
Outflow	m^3/s	0.068	0.102	95.53	50
Velocity of reservoir (v)	m/s	0.000161	0.000161	0.000161	0.000161
Temperature	˚C	9.4	24.6	20	20
k_2	k_2, d^{-1}	0.00034	0.00041	0.000057	0.000057

* *Note further modelling is required to improve the estimate for the residence time of maximum stored water*

Based on this analysis the k_2 values are lower than the k^2 values for deep reservoirs[21]. Further detailed analysis is needed to rule out deoxygenation risk, considering the operations of Phase 2 (see WEMMP Action 3).

4.5.2 Release of nutrient enriched water to downstream ecosystems

For now, in absence of a full-scale water quality model, an assessment of eutrophication risk is completed through comparison of pre- and post-impoundment differences in relation to Greenhouse Gas (GHG) emissions.

Eutrophication occurs when there is an excessive development of primary and secondary producers (algae, macrophytes, zooplankton) resulting in the depletion of oxygen within the reservoir area and subsequent algal blooms. Eutrophication is caused by a multitude of factors but can be attributed principally to excess nutrients (N and P) entering a water body, encouraging the growth of algae and plants.

For the purposes of this ESIA, eutrophication was assessed using a basic mass balance equation, with the last term representing the process of sedimentation:

$$V\frac{dC}{dt} = Q_{in}C_{in} - Q_{out}C - (vAC)$$

V = volume of the reservoir

$\frac{dC}{dt}$ = change in concentration

Q_{in} = flow into reservoir

C = concentration

[21] Gonçalves, J.C.S.I., Silveira, A., Júnior, G. B. L., Sérgio da Luz, M. & Simões, A. L.A. (2017). Reaeration Coefficient Estimate: New Parameter for Predictive Equations. *Water, Air, & Soil Pollution, 228 (307)*. https://link.springer.com/article/10.1007/s11270-017-3491-5

v = settling velocity, assumed value of 10mm/y (typical value for reservoirs or lakes with high sedimentation)

A = area of the reservoir

In order to assess the worst-case scenario, maximum sampled values were taken from WQ UB 02 and WQ UB 04 (the sampling sites closest to the dam) and the volume of the reservoir was assumed to be completely filled to its maximum volume. The flow values in and out were assumed to be the average multi-year flow of the Ub river in the dam profile, calculated by Energoprojekt in the conceptual design phase. These values are recorded in Table 4-10.

Table 4-10 Parameters for eutrophication mass balance analysis

Parameter	Value	Units
Volume of reservoir (calculated by Energoprojekt)	8.15×10^6	m^3
Area of reservoir (calculated by Energoprojekt)	118.5	km^2
Average multi-year flow, Qsr (calculated by Energoprojekt)	0.72	m^3/s
Max concentration of total nitrogen WQ UB 02 (upstream)	0.41	mg/L
Max concentration of total nitrogen WQ UB 04 (downstream)	0.56	mg/L
Max concentration of total phosphorus WQ UB 02 (upstream)	0.055	mg/L
Max concentration of total phosphorus WQ UB 04 (downstream)	0.032	mg/L
Assumed sedimentation rate (for reservoirs)	10	mm/y

It was not possible to use WQ UB 05 further downstream due to additional unreported pollutant sources in Ub town affecting samples. Therefore, the eutrophication analysis instead relied on phosphorus values.

The change in concentration of phosphorus within the reservoir is calculated to be 4.32×10^{-8} mg P/s/L. Previous studies have shown that exceeding a surface water mean TP threshold of 12-15 µg/L causes an imbalance in algal, macrophyte and macroinvertebrate assemblages, resulting in the potential for eutrophication.[22] This results in a detention time of approximately 3.2 days before eutrophication may be a possibility in this reservoir based on this threshold.

There are important caveats to this elementary analysis of eutrophication risk. Eutrophication is a complex process resulting from a multitude of factors including depth of the reservoir, flow velocity of water/stagnation, presence of aerobic heterotrophs, water temperature, and resuspension of sediments. Current nitrogen and phosphorus levels upstream of the dam are within good/moderate ranges and agricultural runoff does not appear to be contributing significantly to Ub flows which is helpful in preventing nutrient overloading during heavy storm periods when excess N and P may be washed into the reservoir.

Further detailed analysis is needed to rule out eutrophication risk, considering the operations of Phase 2.

[22] Richardson CJ, King RS, Qian SS, Vaithiyanathan P, Qualls RG, Stow CA. Estimating ecological thresholds for phosphorus in the Everglades. Environmental Science and Technology. 2007;41(23):8084–8091. doi: 10.1021/es062624w.

5. Fluvial geomorphology

5.1 Objectives

Both the Danube and Sava Rivers are transboundary and have associated legal instruments for cooperation between countries. An important part of cooperation has been managing a sediment balance. The assessment of sediment considers the proposed Project's impact on the downstream sediment budget for Danube and Sava Rivers. The catchment controls and reach controls on river behaviour were also assessed to determine the impact of the proposed Project on longitudinal, lateral and vertical connectivity of sediment.

5.2 Assessment Methodology

The methodology for the fluvial geomorphology assessment relied on an initial desktop review of existing datasets and reports on the sediment regime at the regional scale. This included the Danube and Sava Basins, Kolubara Sub-Basin and Ub catchment (Table 5-1 and Figure 5-1).

Table 5-1 Relevant catchments within the Danube Basin

Catchment	Area (km^2)
Ub	118
Kolubara (inclusive of Ub and Tamnava catchments)	3,650
Sava (inclusive of Kolubara Basin)	97,200
Danube (inclusive of Sava Basin)	801,463

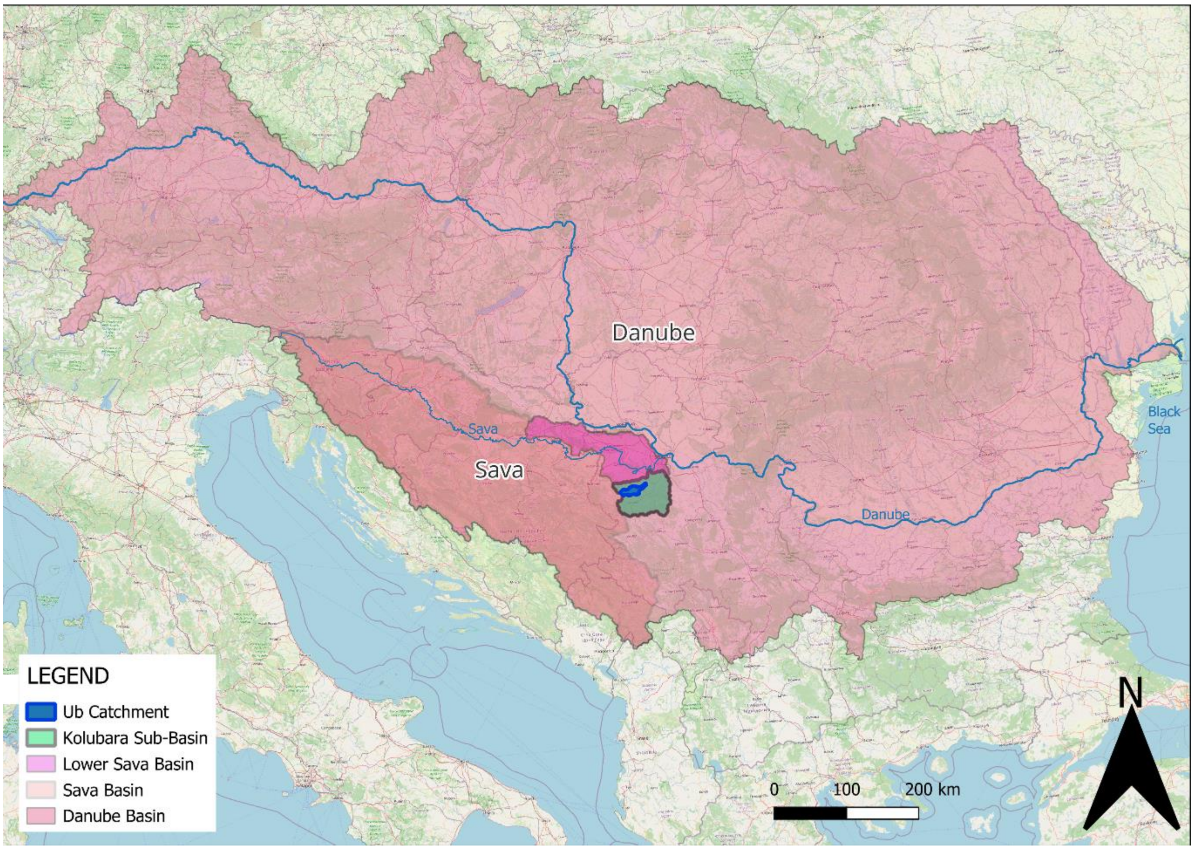


Figure 5-1 Relevant catchments within the Danube Basin (Source: HydroSHEDS)

River habitat mapping was conducted along the entire length of the Ub River within the proposed inundation (reservoir) area, as well as 1 km upstream and 1 km downstream (Book 4 Biodiversity Impact Assessment). The sampling was carried out in May 2023. This approach was used to assess and understand the river's habitat characteristics and dynamics over a significant stretch, considering both the impact of the dam reservoir and the conditions in the surrounding areas. In-stream habitat conditions of the river were recorded which relate to channel bed substrate, water depth, flow velocity and vegetation cover.

Further to in-stream habitat, additional features of the watercourse were recorded and mapped to provide a broader understanding of the watercourse, anthropogenic modifications and any pressures which may alter the suitability of the river for fish. Where present, these include:

- In-stream and riparian habitat features such as width-depth measurements, exposed substrate, bars, macrophytes, redds and coarse woody debris,
- In-stream obstacles to fish passage including natural obstacles, weirs, sluices, dams, flap gates, culverts and fords. These obstacles were assessed for fish passability based on professional judgement,
- River abstractions and details on fish screening facilities.

5.3 Erosion and sediment yield modelling

An analysis of erosion upstream of the proposed Project was presented in Project of anti-erosion works in the watershed (Ref: 16018-PV-11) which used an existing erosion map for Kolubara Sub-Basin. Erosion was ranked from ‘very weak’ to ‘excessive’ according to erosion coefficients derived from the USLE. This map indicates that higher levels of erosion occur in the steeper upper hillslopes of the catchment, with the highest levels occurring within Ogladjenovacka river sub-catchment (Figure 5-2). Erosion control measures were proposed which accounted for reducing erosion at source through biological (afforestation) and biotechnical (double living braids) measures, as well as stopping the movement of sediment in the beds of torrential watercourses through construction of consolidated landfill partitions (Figure 5-3, Table 5-2).

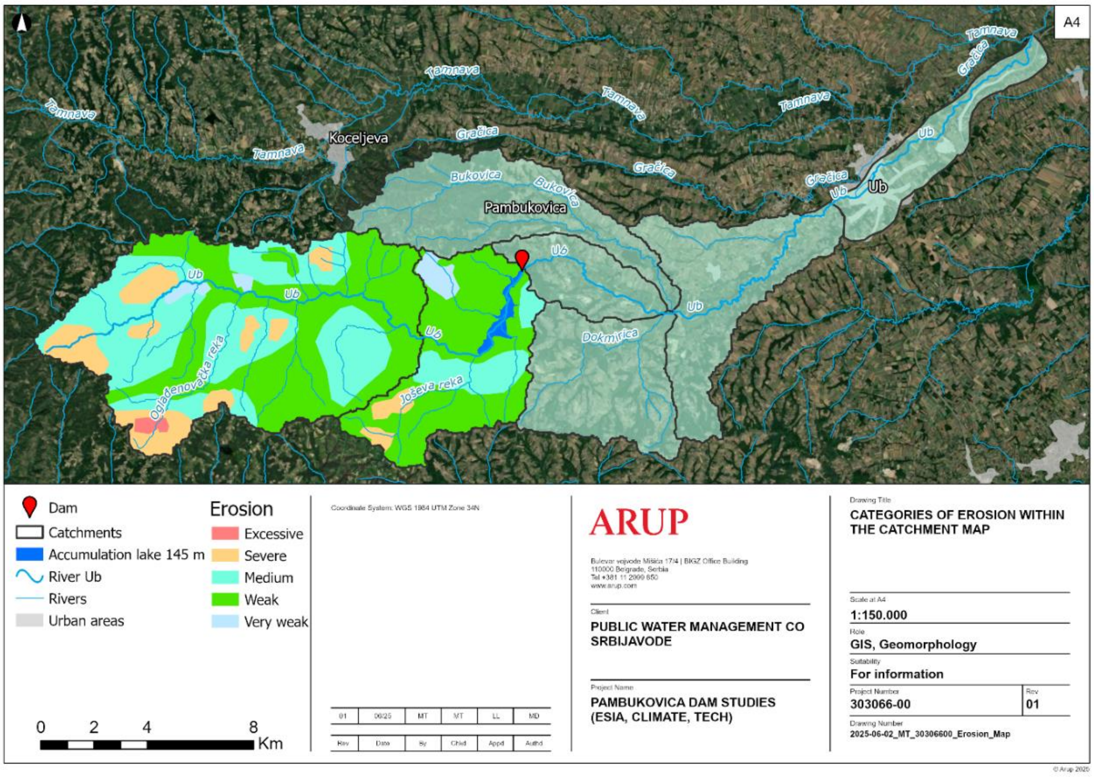


Figure 5-2 Categories of erosion within the catchment of proposed Project (Source: Project of anti-erosion works in the watershed (Ref: 16018-PV-11))

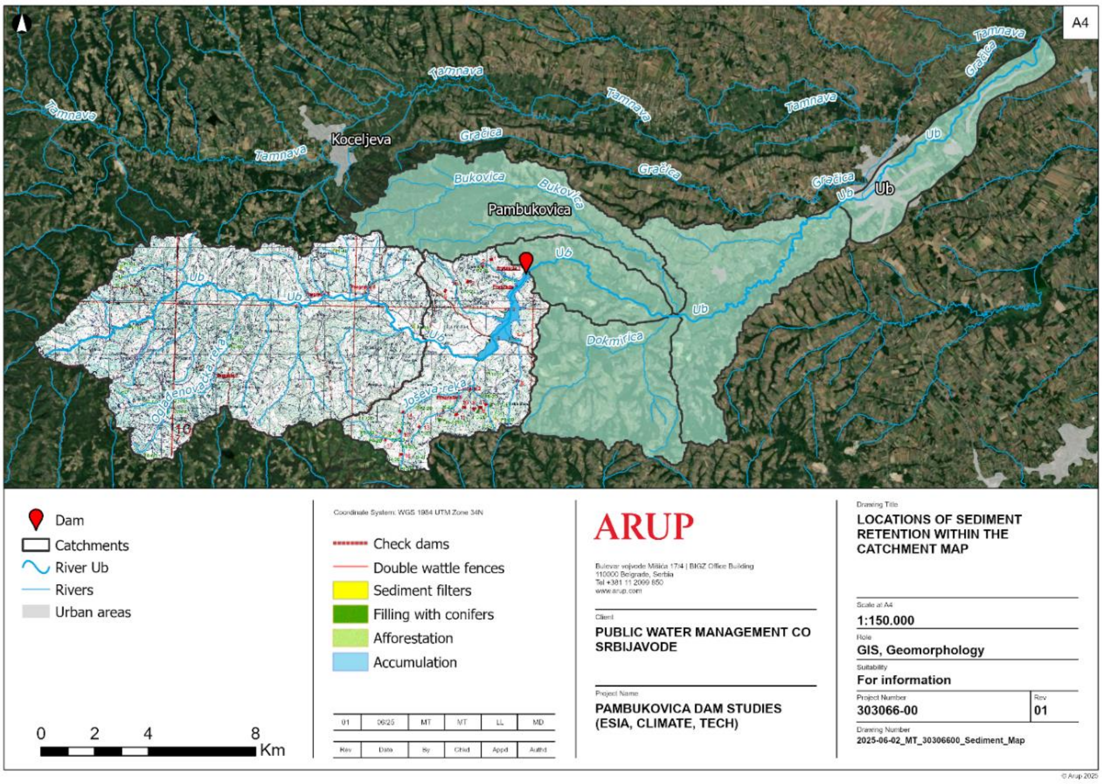


Figure 5-3 Locations of sediment retention within the catchment of proposed Project (Source: Project of anti-erosion works in the watershed (Ref: 16018-PV-11))

Table 5-2 The sediment retention options proposed upstream of the proposed Project (Source: Project of anti-erosion works in the watershed (Ref: 16018-PV-11))

Method	Design	Location	Monitoring
Sediment traps	Seven sediment traps of 2 to 3 m with underlain tooth and ridge berm.	Babinic Stream, Jasenovac Stream, Medednjak Stream, Yosheve River, Ogladjenovayka River	Removal of alluvial deposits needed which needs to be accessible for possible commercial exploitation (gravel, sand)
Double living wicker	Five braids at a distance of 5-10m. Up to 90 braids to be planted.	Planted in the upper reaches of the direct tributaries of future reservoir. Babinac Stream, Sigraye Stream, Kokanovac Stream, Yosheva River	Monitor braid and bank stability.
Afforestation	Black and white pine seedlings planted in pits. Conifers replenishing existing stands	Mostly within Joseva sub-catchment and areas of erosion.	Vegetation growth and erosion. Trees substrate is eroded-parapodzolic soil, which is prône to erosion.
Ilofilters (forest grass belts)	Planted at 10m width from height of normal slope.	Planted in the narrow accumulation zone of the proposed reservoir	Sediment accumulation monitored

Method	Design	Location	Monitoring
Anti-erosion measures	Improved agricultural practices and prohibition on poor agricultural practices.	Ub River Catchment	Erosion and sediment deposition in agricultural land monitored

The quantities of sediment that would accumulate in the proposed Pambukovica reservoir over a historical record from 1960-2023 were modelled in a HEC-HMS model with data from the Ub base station to demonstrate the effectiveness of sediment traps and sediment yield results over the period of 63 years (Technical Assessment Report Appendix 1 - Hydrology and Climate Change). The results indicated that inclusion of the erosion mitigation upstream of the proposed Project will improve the storage potential (Figure 5-4).

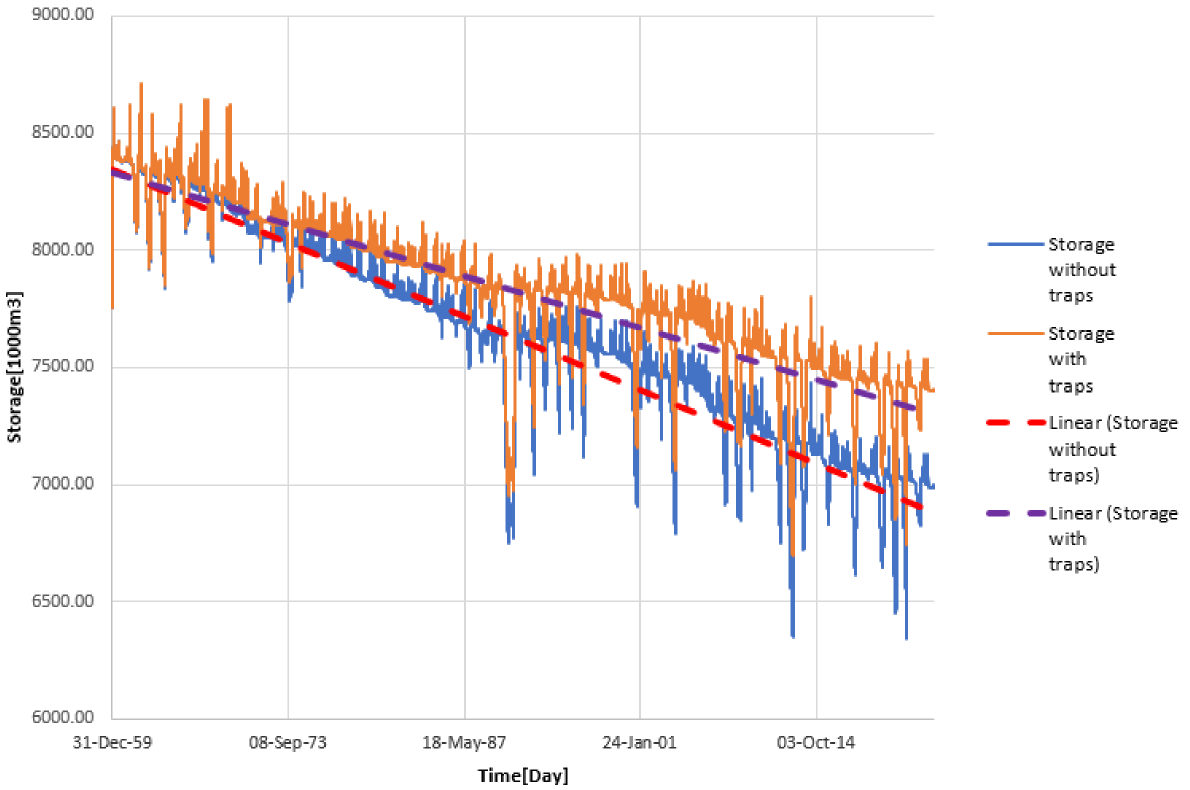


Figure 5-4 Storage over time within the proposed Pambukovica reservoir as modelled over a historical timeline (1960-2023) (Source Technical Assessment Report (Appendix 1 - Hydrology and Climate Change).

5.4 Sediment analysis

The sediment yield model used a granulometric curve which indicated that most of the sediment within the Ub Catchment was gravel and sand (Table 5-3 and Figure 5-5).

Table 5-3 Summary of sediment quality (Source: Technical Assessment Report (Appendix 1 - Hydrology and Climate Change))

Parameter	Size (mm)	Sediment percentage (%)
Silt	<0.06	11
Sand	<0.06-2	14
Gravel	2-64	75

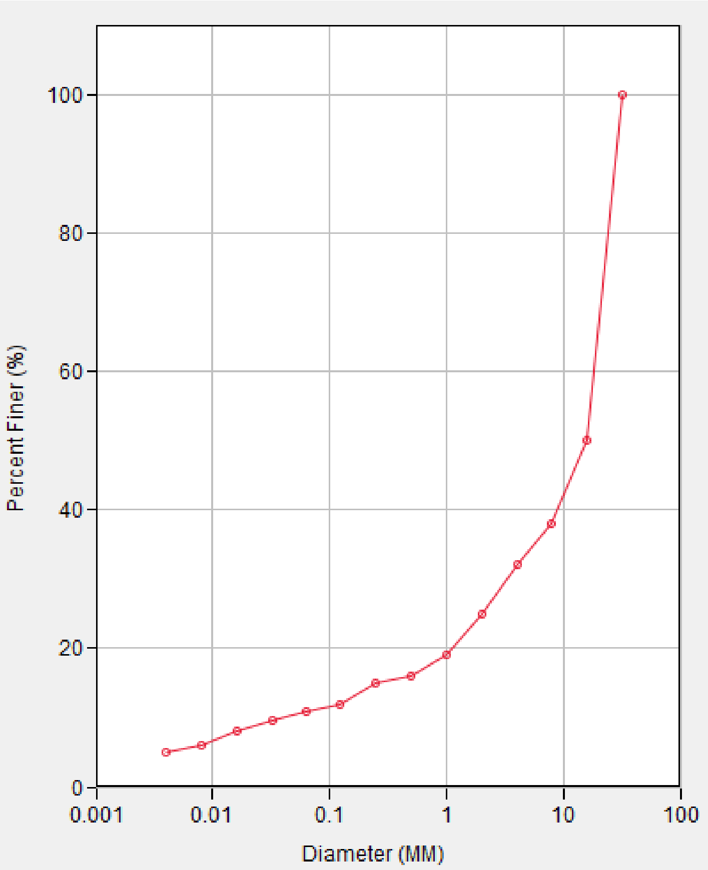


Figure 5-5 Granulometric curve for sediment analysis (Source: Technical Assessment Report (Appendix 1 - Hydrology and Climate Change))

5.5 Scour analysis

An analysis of downstream scour at the stilling basin was assessed (Technical Assessment Report Appendix 5 – Hydraulic Model of Spillway, Chute and Stilling Basin). The design for the proposed dam includes a spillway on right side with a crest is at an elevation of 145.5m. The spillway includes a side-channel weir where water enters on the right bank of the reservoir, conveys downstream through a 10m wide chute, that ends in a stilling basin. The stilling basin discharges to a loose rock riprap apron (50-70cm thick) that is connected with the main downstream channel, which controls tailwater conditions. Elevation of the stilling basin and apron is 118.4m which ramps up a 1:4 slope to an outlet channel bottom at elevation of 124.5m.

The tailwater discharges to Ub River that has capacity of design bottom outlet flow of 95,95cms without overflowing its banks. The channel is proposed in length of 900m, from the dam to the new Pambukovica gauging station.

The definitive criterion for sizing the accumulation space for substantial water flow, established in previous phases of the design process, is the retention of the flood wave corresponding to the 50-year high water level at the 10-year high water level. The retention capacity for accumulation is low. The flood defence is designed to utilize controlled discharge with significant capacity. Upon surpassing operational capacity, overflow occurs over the edge of the free spillway.

The results of the analysis indicated that additional measures were needed for protection from scour. Measures include:

- Apron riprap requires grouting in concrete to form semi-rigid structure to reduce the potential for scour
- Stilling basin concrete foundation should be extended to an area of unaltered rock mass to reduce the emphasis on scour protection in events greater than the design 1 in 10,000 year flood.

5.6 Freshwater habitat mapping

The **Book 4 Biodiversity Impact Assessment** details river habitat mapping that was conducted along the entire length of the river within the proposed inundation (reservoir) area, as well as 1 km upstream and 1 km downstream. Sampling sites included the upstream sediment trap sites. The sampling was carried out in May 2023. The approximately 7 km survey stretch of river can be characterised as semi-natural gravel bed river of medium size (river width ranged from 6 m to 12m) and depth ranged from very shallow (<20cm) to up to a maximum of 2m in pools. The freshwater habitat mapping was reviewed to assess the freshwater indicators within the Ub Catchment. The upper Ub tributaries where sediment trap dams are proposed are characterised by more organic matter and silt, whilst the proposed reservoir inundation area and downstream channel are characterised by gravel habitat types.

Fish surveys were conducted using a combination of eDNA and electric fishing methodologies. In-stream habitats for fish recorded were diverse and varied with riffle, glide and pool sequences present and extensive areas of habitat meeting the flow, depth and substrate requirements of fry, parr and adult stage species. It was noted that gravel was often the dominate substrate type and extensive areas of gravel that would be suitable for fish spawning were recorded. All fish species are indicative of gravel bed streams, but many can also inhabit stillwater environments. Spawning typically occurs on gravel substrate, with some species more adaptable, spawning on gravel and vegetation. All fish in the Biodiversity Study Area are late spring/summer spawning species. No species present are cold water / winter spawners. Some fish species observed in the project area meet the threshold as 'threatened/priority' species in accordance with EBRD PR6 and were therefore selected for evaluation in the Critical Habitat Assessment (CHA). These species are:

- Balkan Loach (*Cobitis elongata*) (IUCN Europe LC and IUCN Global LC LC; Habitats and Species Directive Annex II, Bern Convention R6; Strictly protected under Serbian regulation)
- Spined Loach (*Cobitis taenia*) (IUCN Europe LC and IUCN Global LC; Habitats and Species Directive Annex II, Bern Convention R6; Strictly protected under Serbian regulation).

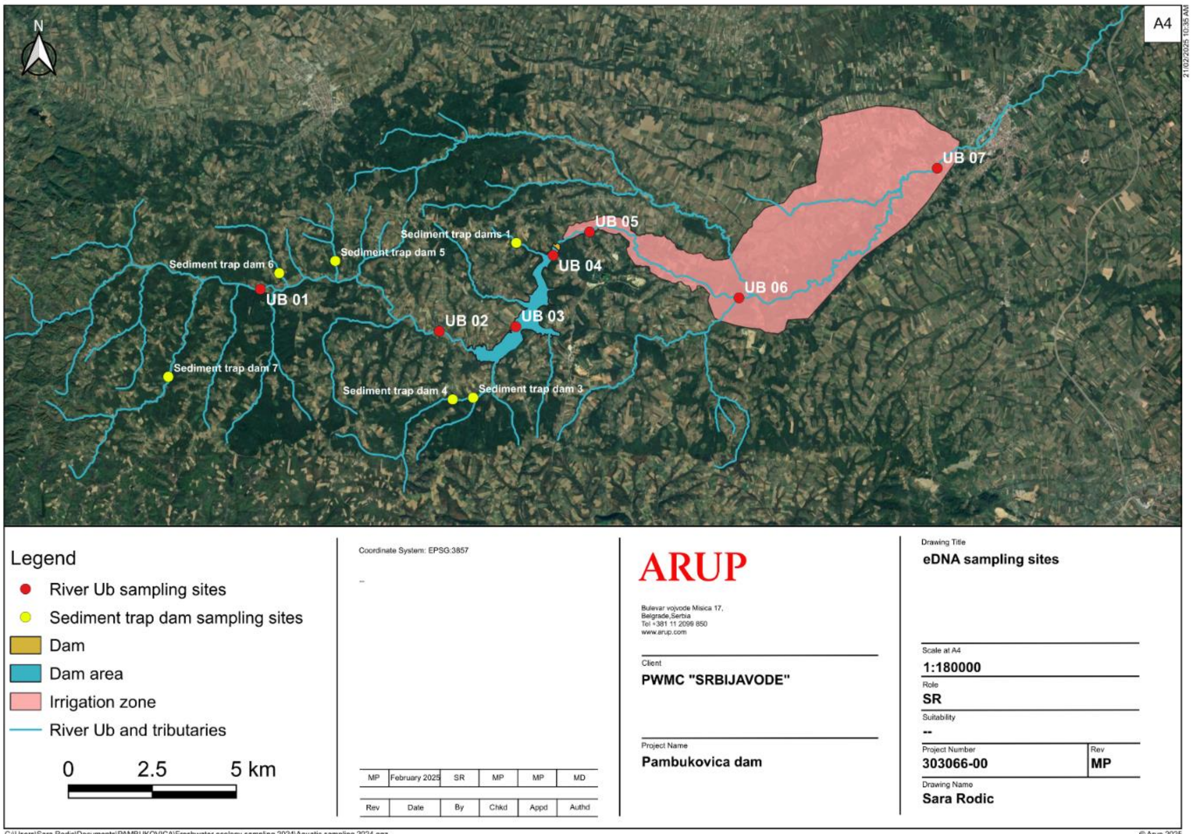


Figure 5-6 Biodiversity eDNA sampling sites (Source: Book 4 Biodiversity Impact Assessment)

Invertebrate sampling consisted of a 3-minute kick sample and a one-minute hand search following benthic invertebrates sampling techniques. Sampling was conducted in 2023 and 2024. The aquatic ecosystem of the Ub River and its tributaries presents a complex and diverse habitat for a range of macroinvertebrate species. In the Ub River, sites like UB 01 and UB 02 provide the ideal conditions for Mayflies and Stoneflies, where clean, gravel-rich substrates offer the perfect environment for their nymphs to thrive. The Caddisflies are another prominent group in the river's ecosystem. The mix of moderate current and stable substrates in sites like UB 01 and UB 02 supports a high diversity of Caddisfly species. These insects are often found attached to the riverbed or submerged vegetation, where their larvae continue to build cases while feeding on detritus and algae. In the Ub River, sites such as UB 01 and UB 02, with their mix of substrates and moderate flow, support a diverse beetle population, with species found both on the water's surface and in submerged vegetation. In the Ub River, UB 01 and UB 02 provide the ideal conditions for Gammaridae, where they are an essential part of the food web, serving as prey for fish species and other predators. Their presence also indicates the overall health of the river ecosystem, as they require high-quality water and undisturbed habitats.

In the Ub River, slower tributaries like UB 06 and sediment trap dams, such as those found in Stream Babinac, provide the ideal conditions for Earthworms to thrive. These sites, with their higher organic content and lower water flow, support large populations of Oligochaeta, which feed on decaying plant material and contribute to the overall health of the ecosystem. Similarly, Non-biting Midges are prevalent in these areas. These species are highly tolerant of low-oxygen conditions and organic enrichment, making them particularly abundant in slow-moving waters or sites with poor water quality. In the Ub River, sediment trap dams and areas with organic accumulation, such as Stream Babinac and Stream Jasenovac, provide a habitat for their larvae. Sites such as Stream Babinac, Stream Jasenovac, and River Oglađenovačka provide sheltered, organic-rich conditions with slower currents, are perfect for water mites, which play a role in controlling the populations of smaller invertebrates and contributing to the nutrient cycling in the ecosystem. In the Ub River, sites with slow-moving waters and organic accumulation, like UB 06 and UB 05, provide ideal habitats for Gastropods. These species contribute to the health of the ecosystem by grazing on algae and detritus, helping to maintain water quality and prevent excessive algal growth.

Notable aquatic invertebrate species, including 'threatened species' as defined by EBRD criteria (EBRD GN6) were recorded during surveys. These were all dragonflies listed on Annex II and/or IV of the Habitats Directive; the Green Hawker - Aeshna viridis, the River Clubtail - Stylurus flavipes and the Green Snaketail - Ophiogomphus cecilia.

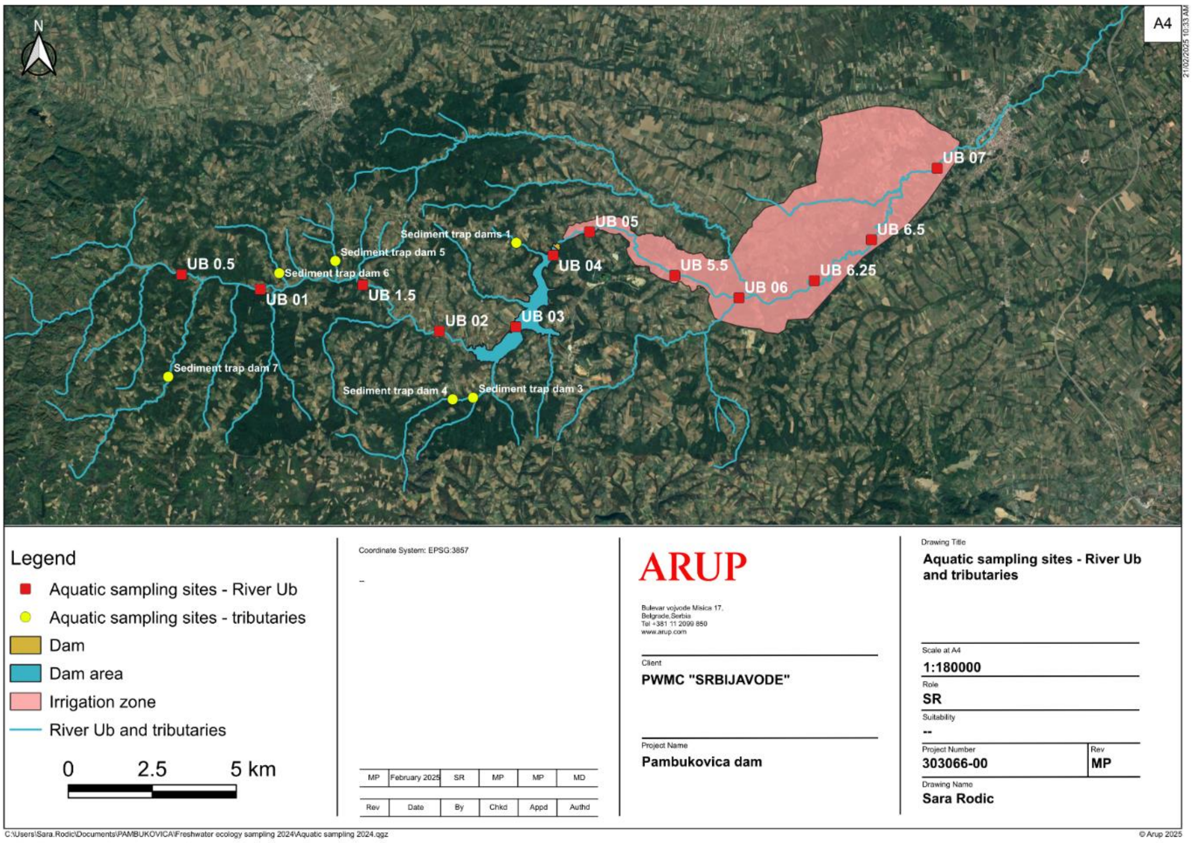


Figure 5-7 Aquatic sampling sites (Source: Book 4 Biodiversity Impact Assessment)

The IUCN desk study screening identified the potential for presence of Depressed River Mussel *Pseudanodonta complanata*. Presence of Thick-shelled Mussel (TSM) *Unio crassus* was confirmed in 2023, both from physical (shell) records and subsequent eDNA analysis. Follow up TSM survey were carried out in 2024. TSM surveys were carried at the 11 locations; each site had optimal habitat was identified within a 500 m river length. The findings indicate that suitable habitats for TSM exist in the Ub River, particularly downstream of the Pambukovica Dam. However, surveys results indicate that they are present in very low abundance at the sites surveyed. There are factors that may be driving the low abundance, such as poor water quality. Drought and extreme floods, as well as the availability of host fish may also be factors. Based on local researchers' professional experience, TSM in Serbia prefers deep water stretches of stream.

Hydrology and physical characteristics of aquatic habitat are also considered important factors in TSM population health and conservation. Hydrological and substrate characteristics of TSM habitat are broader than expected, contrary to the assumption that the species depends on moderate to high flows (>0.3m/s). Streams with low water flow and soft substrate were also identified as suitable habitats. Functional characteristics of the substrate, especially stability and areas with low shear stress, seem to be of great importance for the persistence of the species, and monitoring protocols used at present (2016) for habitat assessment of TSM should be updated accordingly. Areas with high mussel densities were characterized by low flow velocities, low mean sediment penetration resistances, as well as by low near-bed shear stress compared with non-colonized sites.

TSM is a benthic, filter-feeding animal as so is susceptible to any changes of water chemistry, and subtle differences in water chemistry can influence the occurrence of this species. In general, TSM prefers waters which are not eutrophicated and pollution-free.

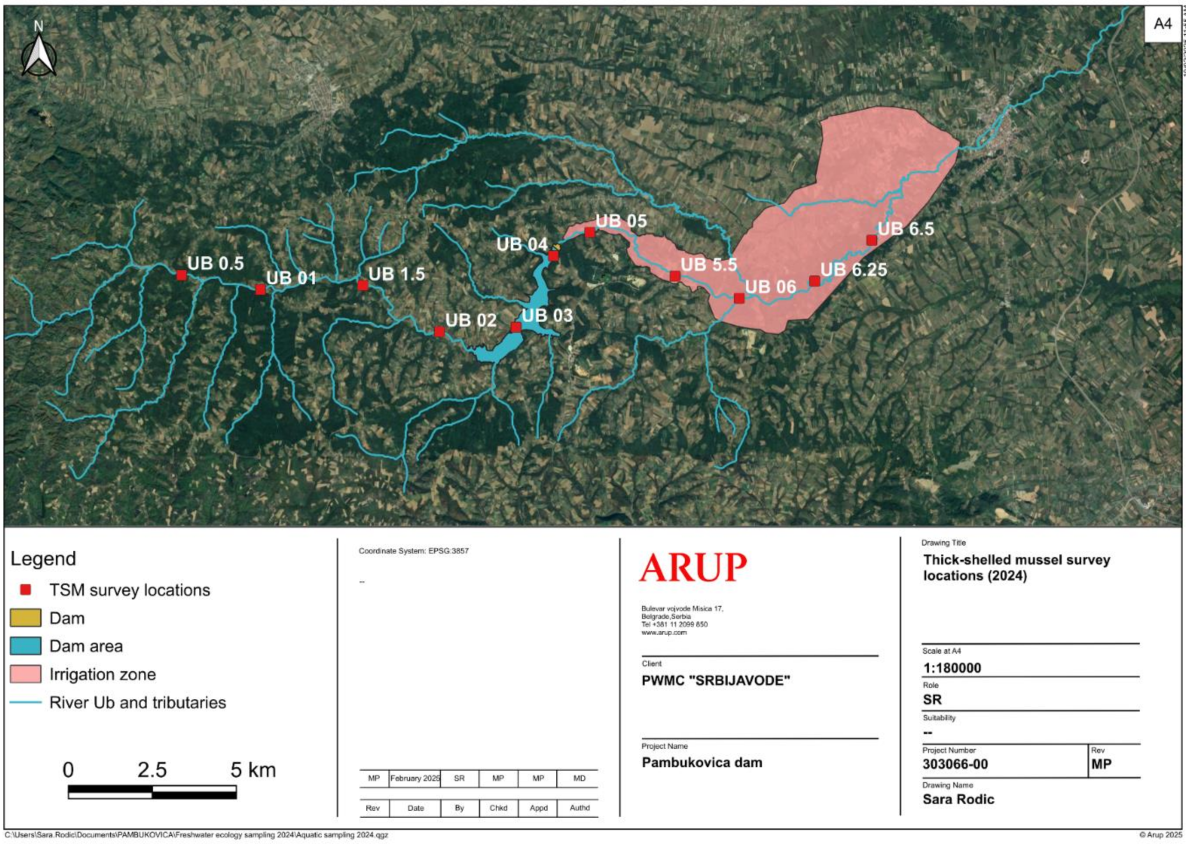


Figure 5-8 Thick-shelled mussel survey locations in 2024 (Source: Book 4 Biodiversity Impact Assessment)

As part of the study, the macrophyte assemblage was determined at each site where electric fishing and aquatic macroinvertebrates was undertaken. The findings from these surveys indicate that the macrophyte community along the Ub River is relatively sparse, with few species present in comparison to other freshwater ecosystems. The presence of a few species such as *Typha latifolia* and *Potamogeton nodosus* suggests that the river may support some aquatic vegetation, although hydrological conditions during the year and other environmental factors likely limit macrophyte growth in many sections. The presence of green algae, particularly *Cladophora* sp., at certain sites is noteworthy, as these organisms contribute significantly to the river's trophic dynamics. Continued monitoring of macrophyte and algae populations will help to assess the long-term health of the river ecosystem, especially in relation to changes in water quality and hydrological conditions.

5.7 Baseline fluvial geomorphology

5.7.1 Ub Catchment

The Ub River headwaters occur in the Vlašÿiÿ mountain at an elevation of about 450 meters above sea level near the town of Oseÿina in Podgorina. In the upper part of its course, the river flows past the villages of Druzetiÿ, Pambukovica and ÿuÿuga, where it receives its left tributary Bukovica. In the central stream are the towns of Tvrdojevac, Zvizdar and the small town of Ub. The Ub River flows almost parallel to the Tamnava River, into which it flows near the village of Rupljani.

The Ub River Catchment was separated into assessment ‘zones’ as per Section 2.1. The zone above the dam reservoir is Zone 0, the inundation zone of the dam is Zone 1, directly below the dam is Zone 2 and further below is Zone 3 (inclusive of contributions from two tributaries). The geomorphic characteristics of each zone were assessed using existing information from previous studies, including soil (Figure 5-9) and landcover (

).

Table 5-4 Catchment characteristics of the Ub River Catchment (source: Technical Assessment Report Appendix 1 – Hydrology and Climate Change)

Zone	Zone Description	Ub River length [km]	River slope [m/m]	Basin slope [%]
Zone 0	Sub-catchment above reservoir area inclusive of Ub, Joseva, Ogladenovacka Rivers and Jasenovac and Medveniak Streams	6.68	0.00389	19
Zone 1	Sub-catchment of reservoir / inundation area, inclusive of Ub River and Babinac Stream	7.51	0.00266	15
Zone 2	Sub-catchment of Ub River downstream of proposed dam up to the confluence of two tributaries (Dokmirca and Bukovica Rivers)	11.17	0.00125	8
Zone 3	Sub-catchments of Ub River inclusive of town of Ub, up to the confluence with Tamnava River	21.89	0.013	7

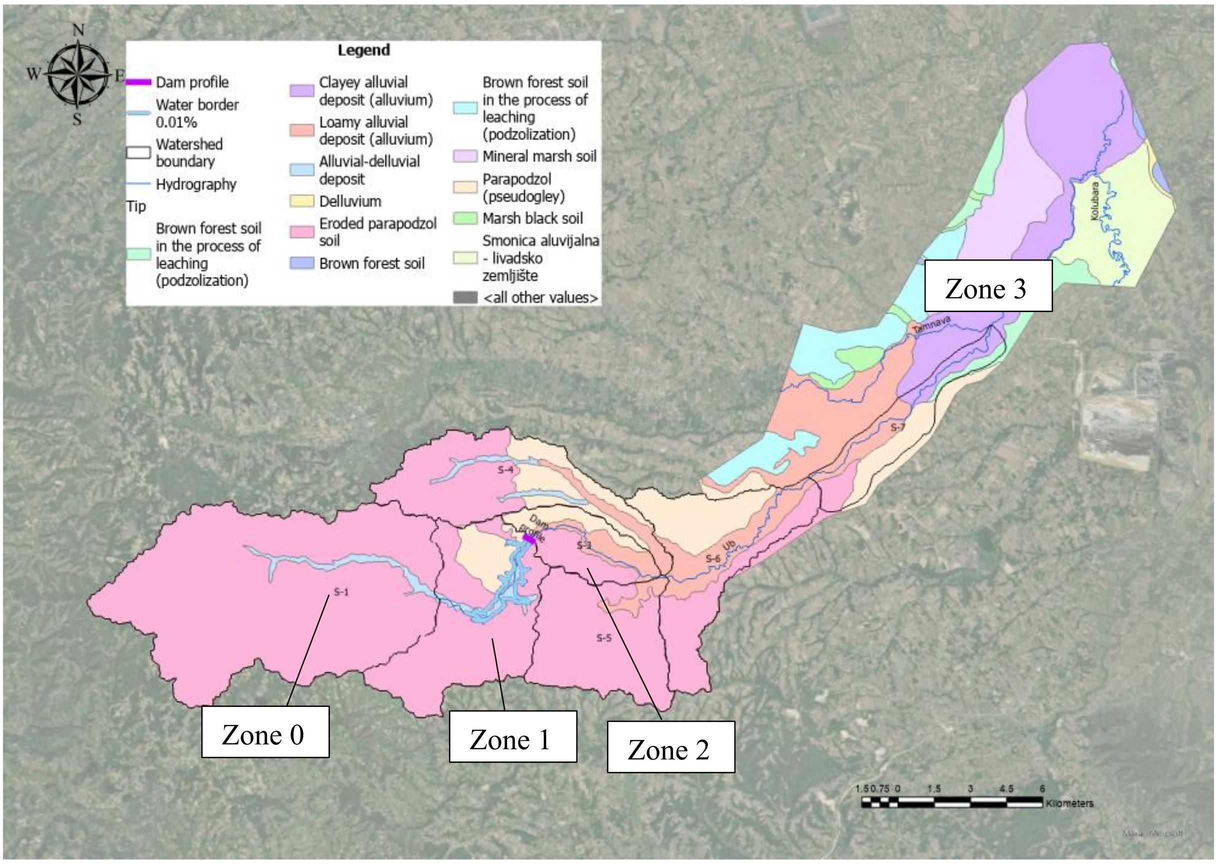


Figure 5-9 Soil groups of the study area (Ref: 16018-PV-11)

Zone 0

Zone 0 includes the upper Ub Catchment with a mainstem of Ub River length of 6.68 km. The Ub River has a characteristic steepened longitudinal profile in its headwaters before declining into the valley (Figure 5-10). The slope of zone 0 catchment is 19% (Table 5-4).

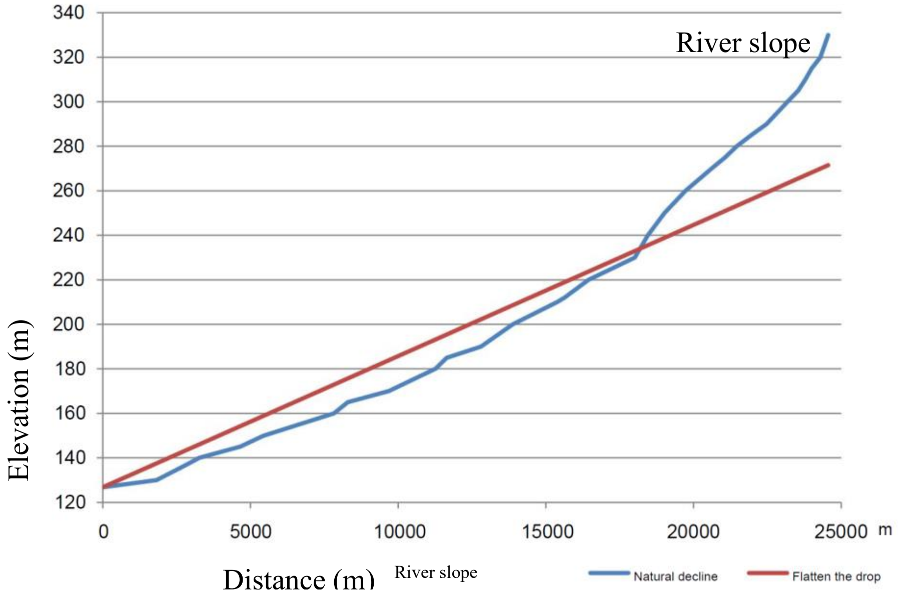


Figure 5-10 Maximum and levelled drop of the mainstem of the Ub River to the dam profile (source: Source: Project of anti-erosion works in the watershed (Ref: 16018-PV-11))

Zone 0 is underlain by eroded-parapodzolic soil (Figure 5-9). On the right of Zone 0 there is mostly metamorphosed sandstones, sandstones, phyllites, argilophyllites, breccias and conglomerates. On the left side of zone 0, is conglomerates, layered marls with occasional intercalations of tuffites and true tuffs, tuffaceous clays, sandy clays, sandy marls, sandy-clay marls, foliated bituminous clays and sandstones of different composition. Most of the upper Ub Catchment is under arable landuse with patches of forest (Figure 5-11).

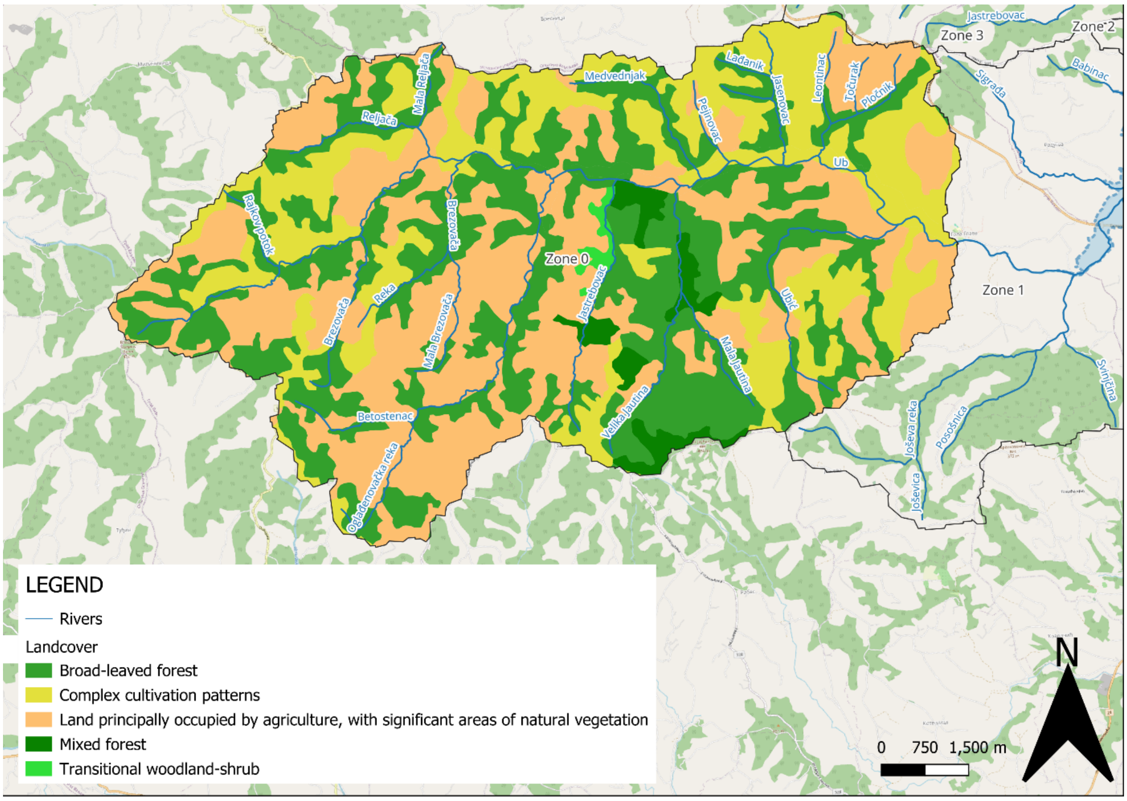


Figure 5-11 Landcover and rivers of Zone 0 of the study area (Source: Copernicus, 2018)

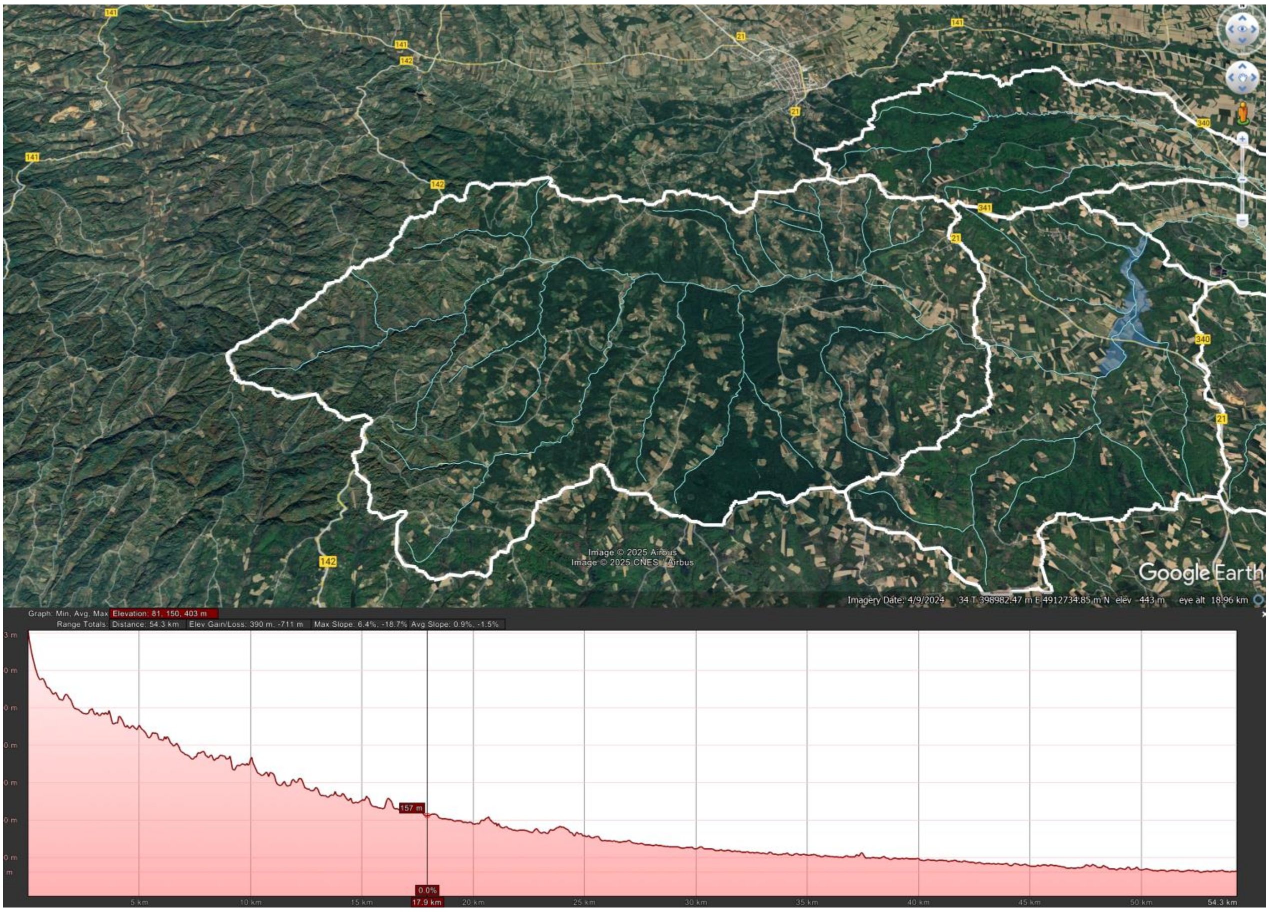


Figure 5-12 Satellite imagery of Zone 0 looking upstream showing surrounding farms and forests (Source: Google Earth)

Figure 5-13 Proposed sediment trap dam location on Joseva River (A) and Jasenovac Stream (B)

Figure 5-14 Proposed sediment trap dam location on Medvednjak Stream (A) and Ogladenovacka River (B)

Zone 1

Zone 1 includes the Ub River (with the proposed inundated river length of 4733 m). The slope in the upper part of zone 1 catchment is 15% (Table 5-4) and is underlain by eroded-parapodzolic and Parapodzol soil (Figure 5-9). Most of zone 1 is under agriculture landuse (Figure 5-15**Error! Reference source not found.**). The stretch of river can be characterised as semi-natural gravel bed river of medium size (river width ranged from 6 m to 12m) and depth ranged from very shallow (<20cm) to up to a maximum of 2m in pools.

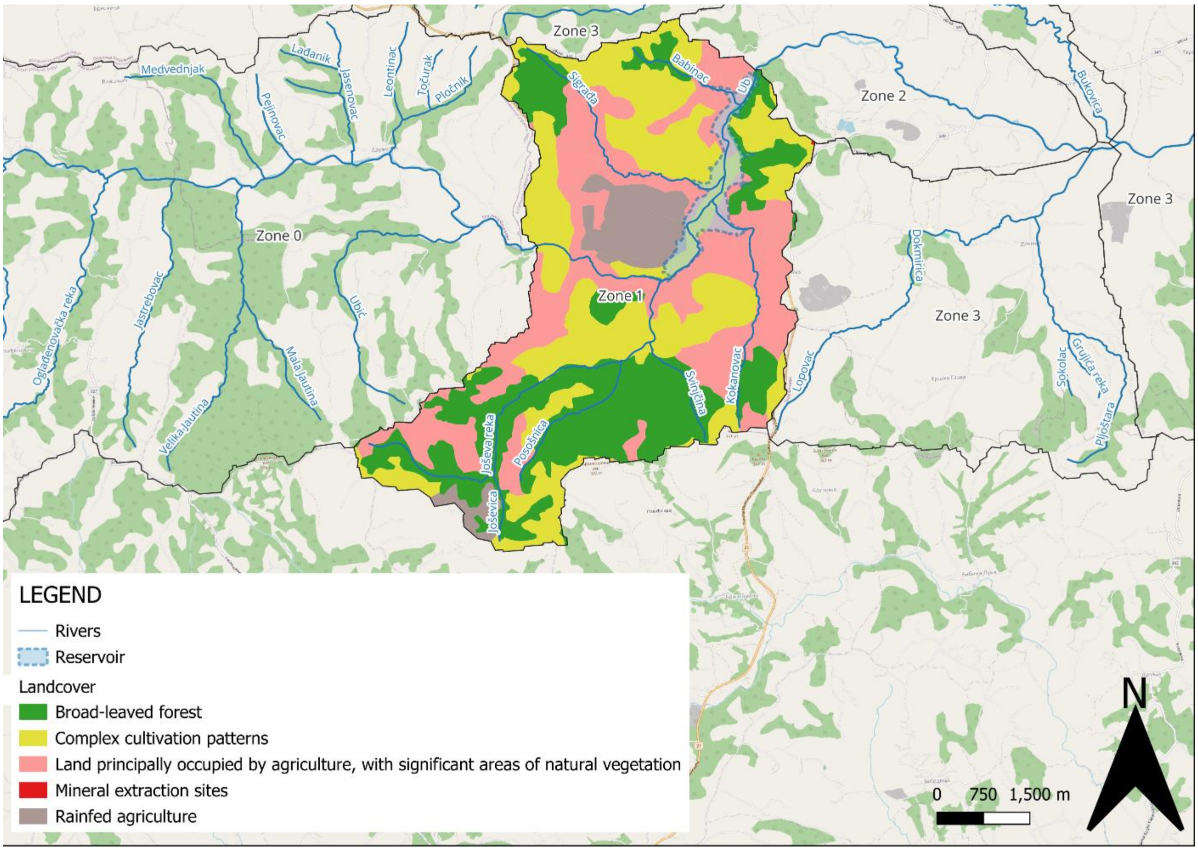


Figure 5-15 Landcover and rivers of Zone 1 of the study area (Source: Copernicus, 2018)

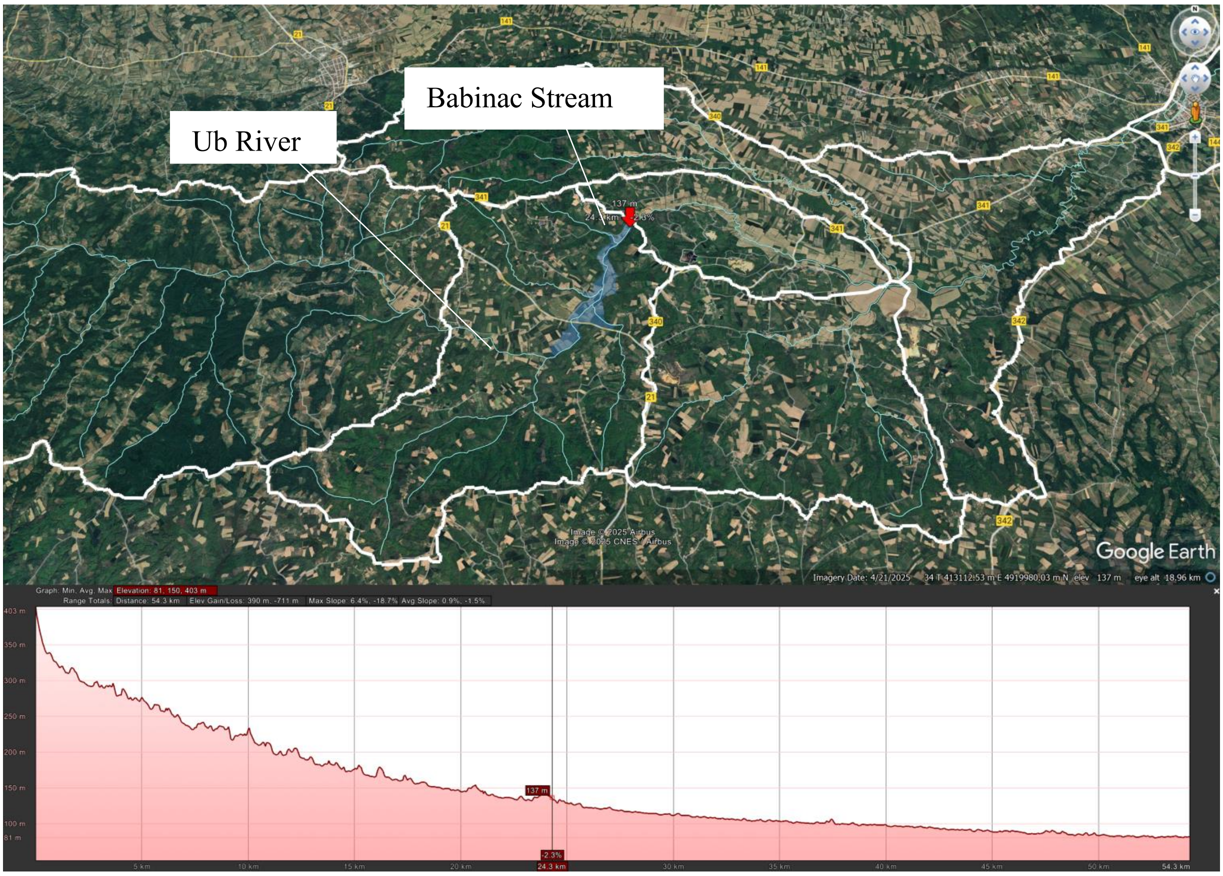


Figure 5-16 Satellite imagery of Zone 1 looking upstream showing surrounding farms and forests

Figure 5-17 Freshwater aquatic sampling site UB 01 (A) and UB 07 (B) along Ub River within Zone 1 and Zone 2

Figure 5-18 Proposed sediment trap dam location on Babinac Stream (A and B)

Zone 2

Zone 2 occurs below the proposed dam and extends to the point of confluence of two smaller tributaries (Dokmirica and Bukovica Streams). The main Ub River length is 11.17 km (Table 5-4) which is underlain by loamy alluvium (Figure 5-9). Most of zone 2 is under agriculture landuse (Figure 5-19**Error! Reference source not found.**). At the confluence with Dokmirica Stream there is a weir, which seems to have been related to former aquaculture. This weir is considered a complete barrier to fish migration and during surveys ecologists observed an adult chub trying, and failing, to jump the weir. Although the surrounding landcover is classes as 'inland marsh' the riparian edge has been transformed and is surrounded by agricultural landuse.

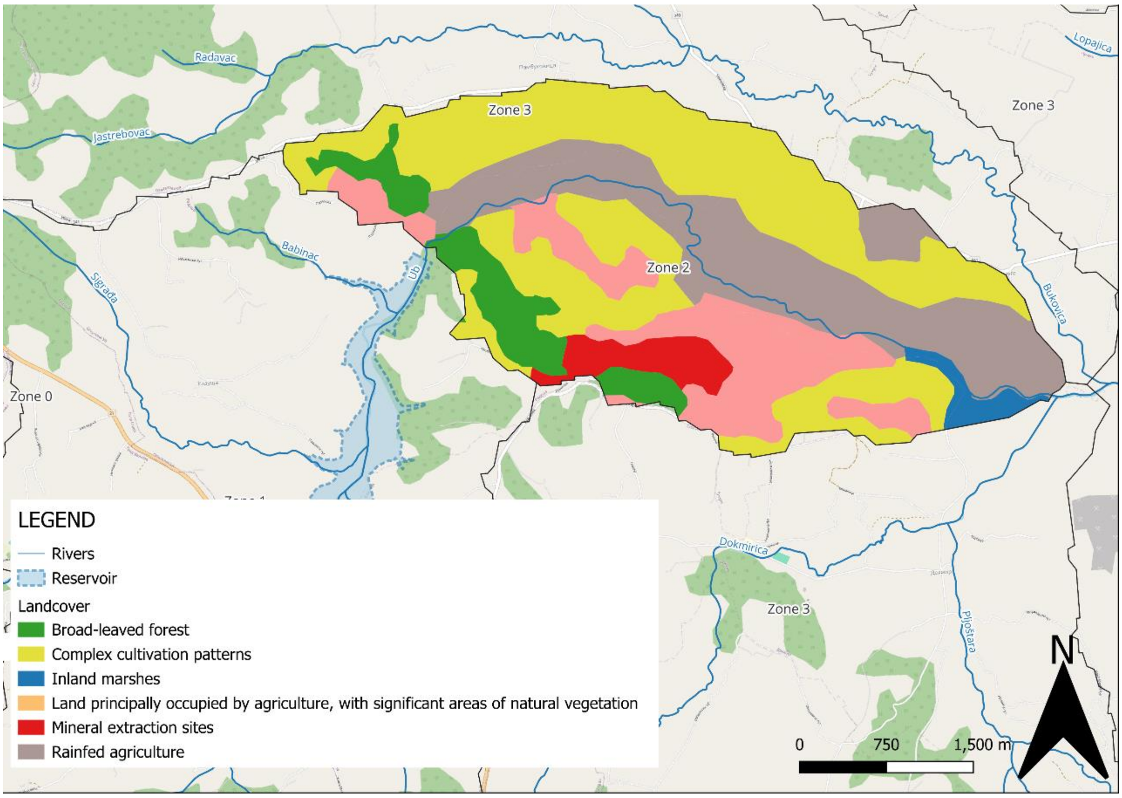


Figure 5-19 Landcover and rivers of Zone 2 of the study area (Source: Copernicus, 2018)

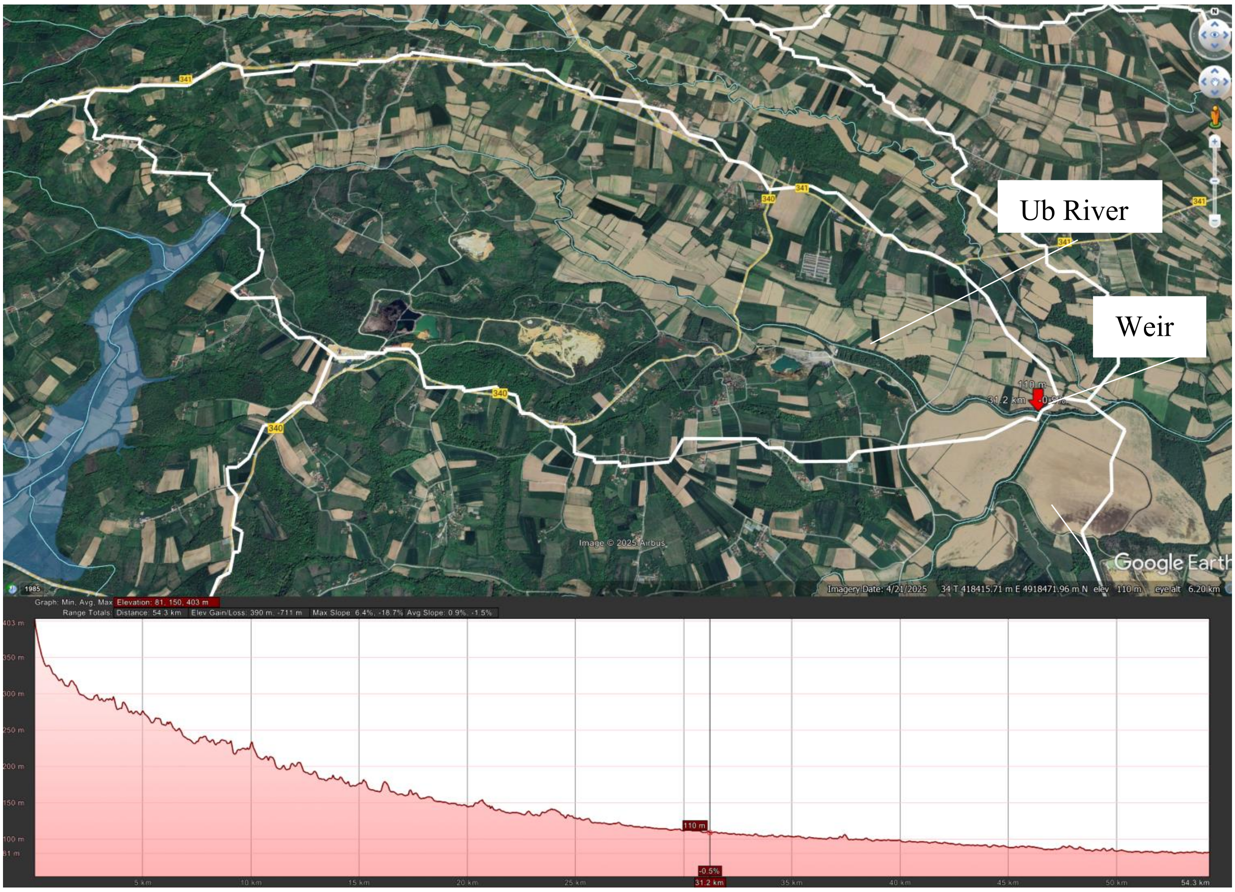


Figure 5-20 Satellite imagery of Zone 2 looking upstream showing surrounding farms and forests

Figure 5-21 Satellite image of an impassable weir on Ub River (Source: Google earth)

Figure 5-22 Upstream (A) and downstream (B) of an impassable weir on Ub River

Zone 3 habitat

Zone 3 includes the contribution of two tributaries. It extends from this point of confluence downstream through the town of Ub up to the confluence with the Tamnava River. The main river length is 21.89 km (Table 5-4) which is underlain by loamy and clayey alluvium (Figure 5-9). Most of zone 3 is under agriculture landuse (Figure 5-23). The river has been heavily modified for flood defence purposes within Ub town, with the channel and streambed being confined (Figure 5-24).

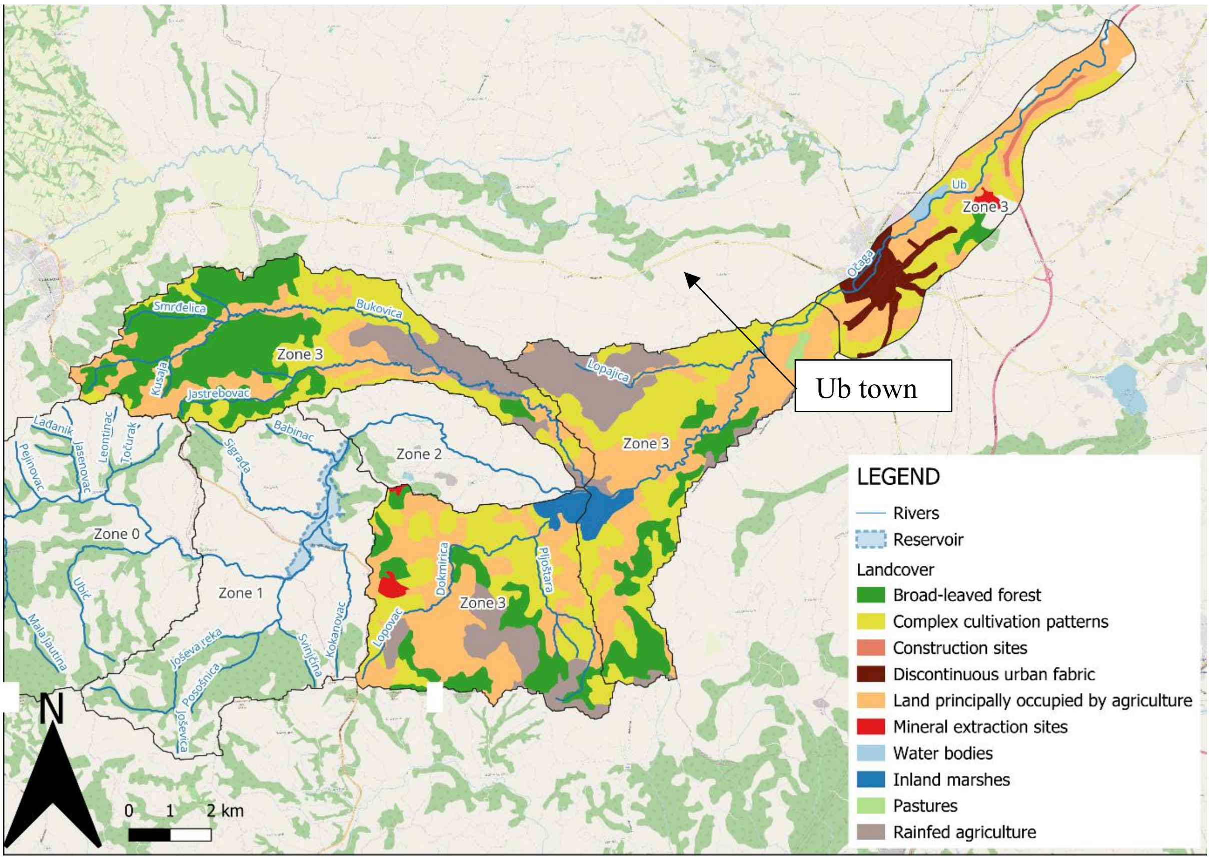


Figure 5-23 Landcover and rivers of Zone 3 of the study area (Source: Copernicus, 2018)

Figure 5-24 River Ub within the town of Ub

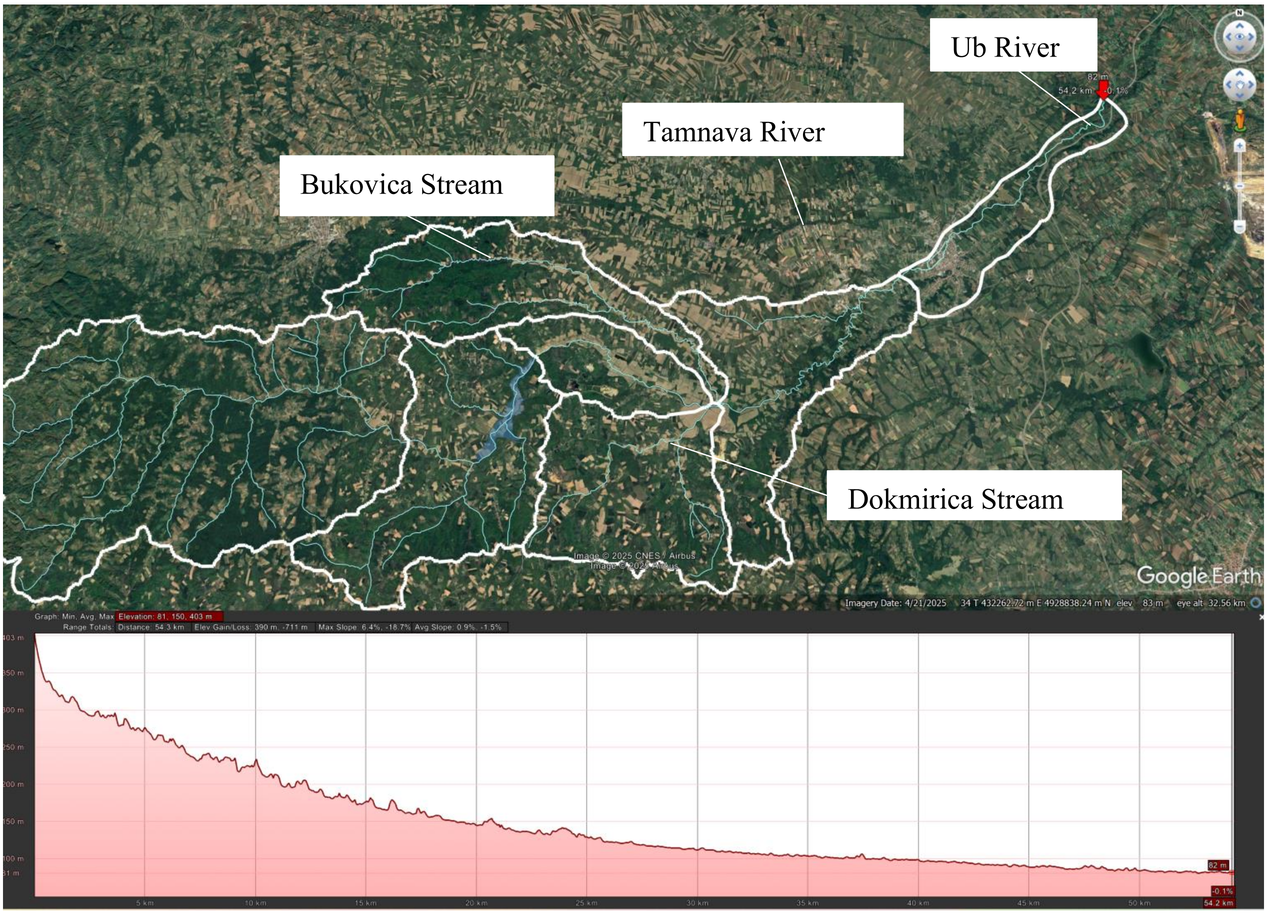


Figure 5-25 Satellite imagery of Zone 3 (Source: Google earth)

Figure 5-26 Confluence of Ub and Tamnava Rivers looking upstream (A) and downstream (B)

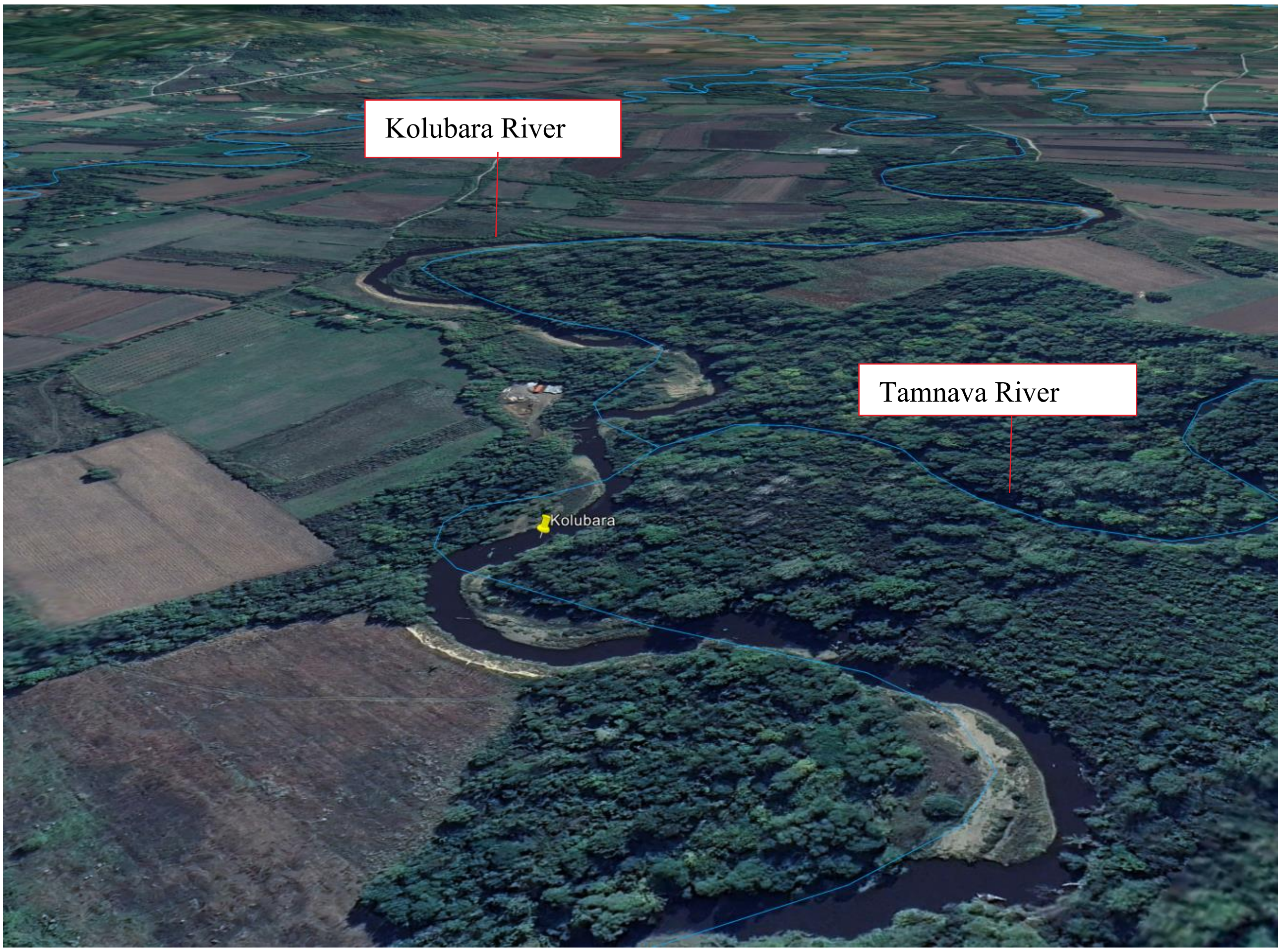


Figure 5-27 Satellite imagery of confluence of Tamnava and Kolubara Rivers looking upstream

Figure 5-28 Confluence of Tamnava and Kolubara Rivers looking upstream (A) and downstream (B)

5.7.2 Kolubara Sub-Basin

The Kolubara River is the largest tributary in Serbia, with a river length of 86.4 km and a basin area of 3.650 km^2. It discharges into Sava River about 28 km upstream of Belgrade. The sub-basin holds a very large river network, most of the rivers having the torrential hydrological regime. The Ub River is a tributary of the Kolubara sub-basin.

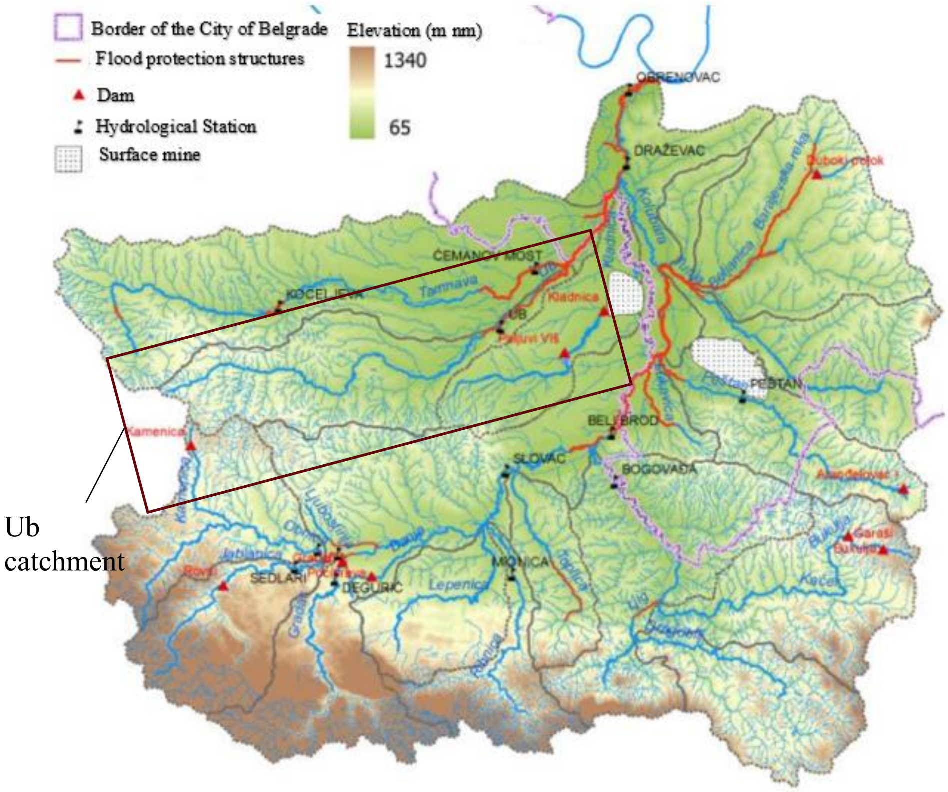


Figure 5-29 The Kolubara River Basin, with Ub River identified in the black box

Erosion across the sub-basin is moderate to slight, with upper reaches having greater levels of erosion (Figure 5-30). Historically anti-erosion measures have been applied in the sub-basin since 1991. This led to significant reduction of the average erosion intensity. The investment in new anti-erosion works and maintenance were significantly reduced in the last decades and, as a consequence, frequent torrential floods have occurred. Erosion prevention is integrated into the water management strategy for the Republic of Serbia through 3 main goals: Establish the legal framework for improving the protection against erosion and torrents; Improve the conditions of protection against erosion and torrents; and Monitor the situation and maintain structures and works.

Category of erosion	I - Excessive	II - Heavy	III - Moderate	IV - Slight	V - Very slight
Participation	0.34%	3.39%	38.05%	49.69%	8.53%

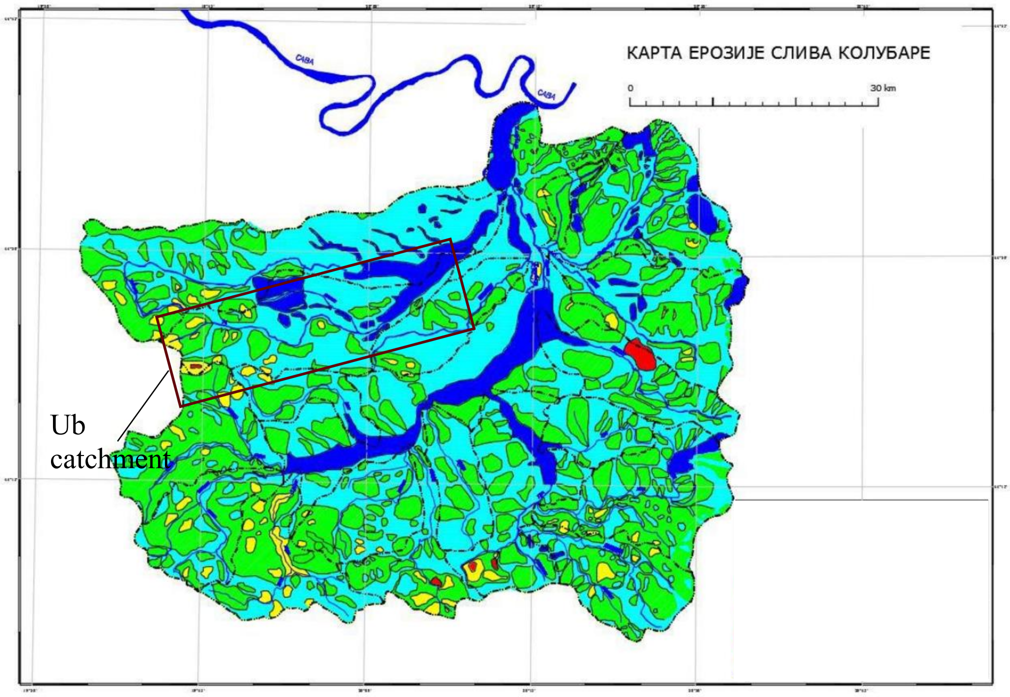


Figure 5-30 Categories of erosion for the Kolubara Basin, with Ub River identified in the black box (Source: UNDP, 2016)

The RHMSS conducted suspended sediment monitoring at Slovac (1958-1992), Beli Brod (1986-2001), Drazevac (1958-2002) and Stuborovni (1983-1993) on the Kolubara River. Studies in the short-term period since 2010 indicate that frequent discharge variation, flooding, and rapid change in extreme values due to climate change has caused more intensive bank erosion than in longer term periods (since the 1960s). The 2014 flood left a significant impact on the vulnerability of the riverbank, and subsequent bank-overtopping events have created changes to the meander structure of the river and eroded and transported considerable sediment amounts.

5.7.3 Sava River Basin

The Sava River is formed by two mountain streams: the Sava Dolinka (left) and Sava Bohinjka (right) in Slovenia. It flows through Slovenia, Croatia, forming the border with Bosnia and Hercegovina, and on the lower stretch runs through Serbia. The river network in the Sava River Basin is well developed with 18 tributaries of the basin. The Kolubara River is one of the important right tributaries. Annual erosion estimates from the global HydroSHEDS tool, using the outputs from GloSem v1.2, indicates that the Kolubara has moderate erosion potential (Figure 5-31). Common feature of almost all right tributaries of the Sava River is their torrential behaviour, particularly in their upper sections. River channels are often deeply cut into the hard rocks, with very violent flow through gorges.

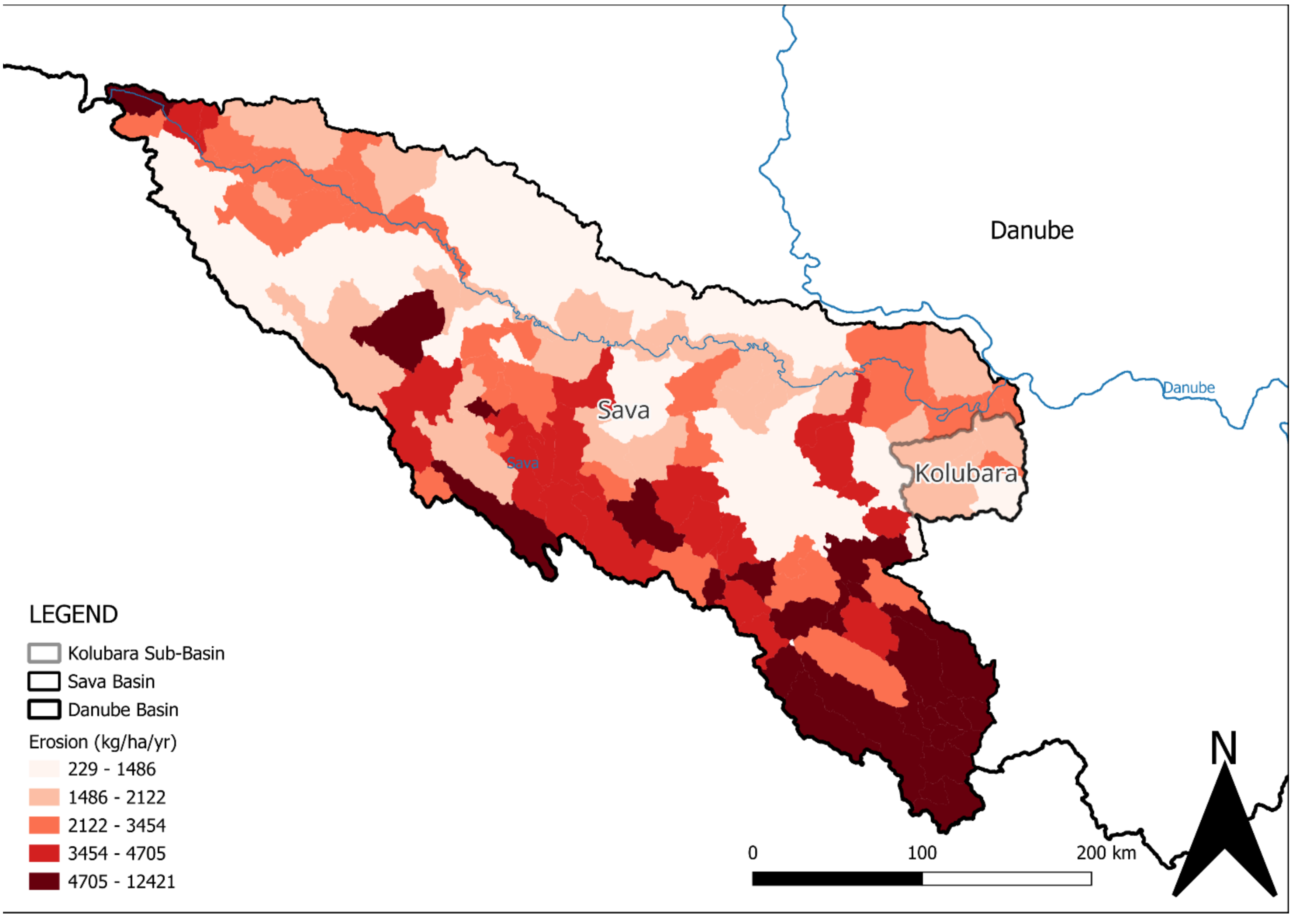


Figure 5-31 Annual erosion estimates for the Sava Basin (Source: HydroSHEDS)

The longitudinal profile of the Sava River from the Danube River in Belgrade (410 m a.s.l., river km 890) is shown in Figure 5-32. The average longitudinal slope in the Sava River between Rugvica (km 658) and Belgrade (km 0) is only ~0.05‰. Kolubara River discharges to the Sava River at about km 28. Riverbed material on the Middle and Lower Sava is finer (sand and find gravel), having D50% mainly below 12 mm. The main right tributaries (Vrbas, Bosna and Drina Rivers) bring coarse gravel material into the Sava riverbed, forming large and visible gravel bars at the mouths. The natural reference condition of the Sava River would mainly be a large meandering river in almost its entire course. However, the Sava and its tributaries have been experiencing major hydromorphological changes in the last two centuries. The Sava River downstream of Zagreb and lower parts of its tributaries are typical alluvial watercourses with river channel formed by their own sediments.

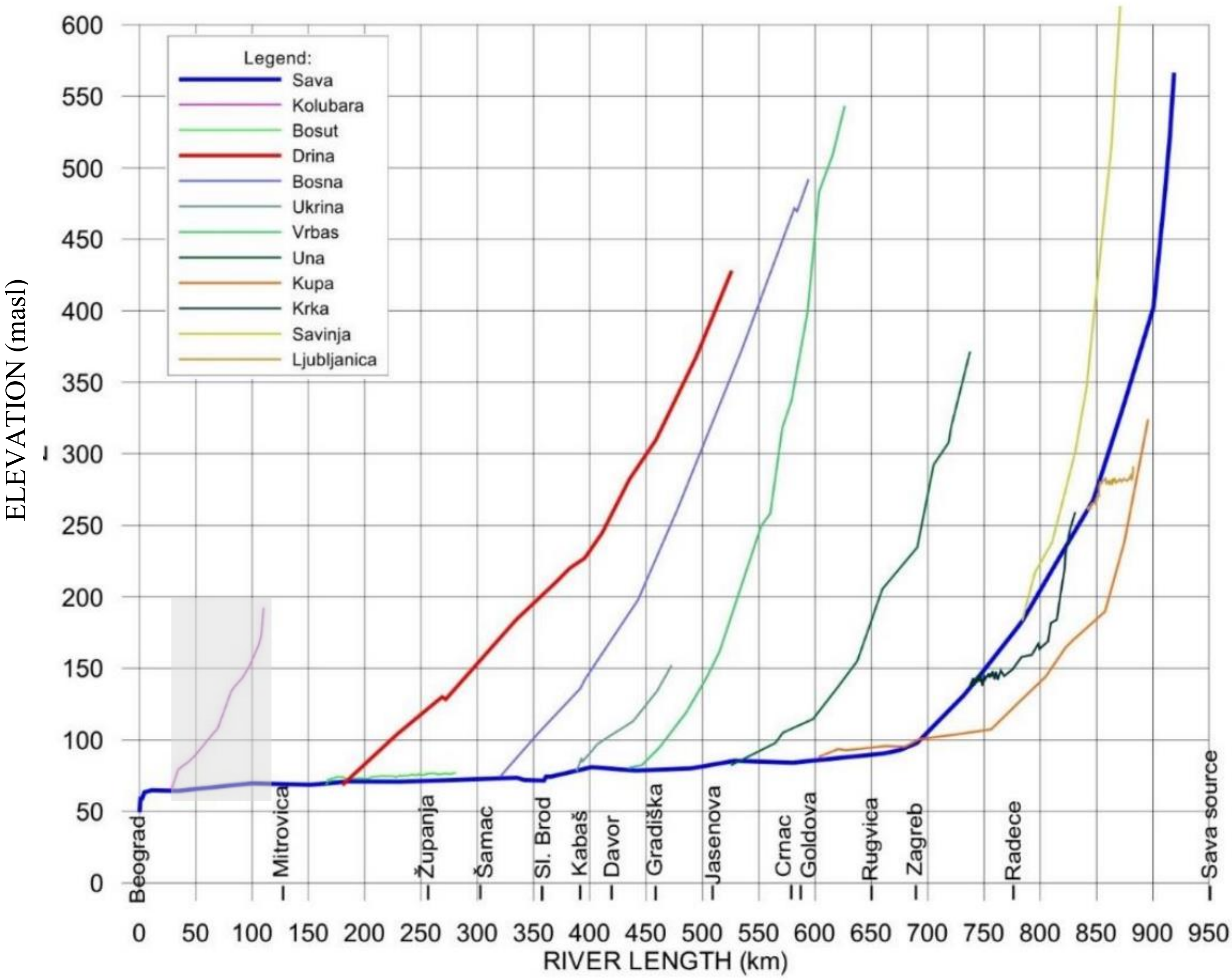


Figure 5-32 Schematic longitudinal profiles of the Sava River and its main tributaries (Source: ISRBC, 2021)

5.7.4 Danube River Basin

The delineation of large-scale units on the Danube takes into account the river channel's morphological characteristics and divides the basin into the Upper, Middle and Lower Danube sections (Figure 5-33). The middle Danube occurs within Serbia. This middle stretch is characterised by erosion and deposition processes that form larger river bends and/or meanders in partly confined and/or unconfined stretches of the middle river course (Figure 5-34). Alternating areas of deep water (pools) and areas of shallow water (riffles) are formed along the sinuous or meandering stretches of gravel bed rivers in the middle course. Sediments eroded during floods are deposited across wider floodplains, the coarser sediments are deposited close to the river channel, or they build up on the riverbanks and form natural levees. The spatial boundaries of the longitudinal section of the Danube are defined as: Upper Danube: rkm 2,600–1,790, Middle Danube: rkm 1,790–943 and Lower Danube rkm 943–0 (Figure 5-35).

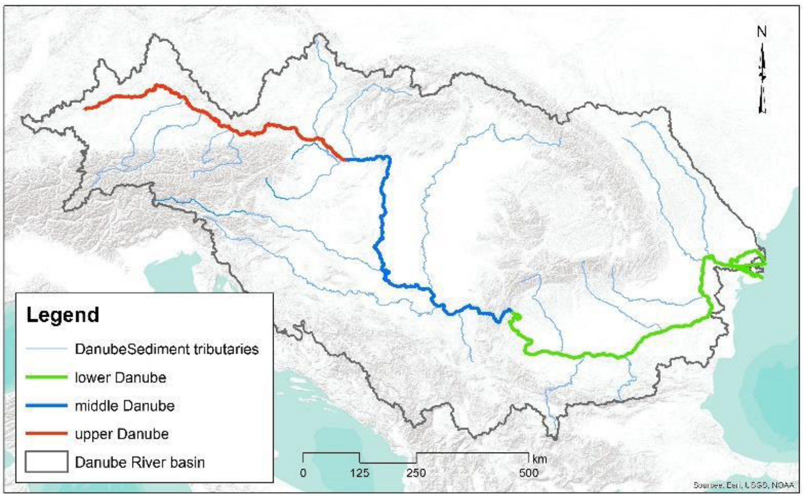


Figure 5-33 The three sections of the Danube River considered for analysis (Source: ICPDR, 2019)

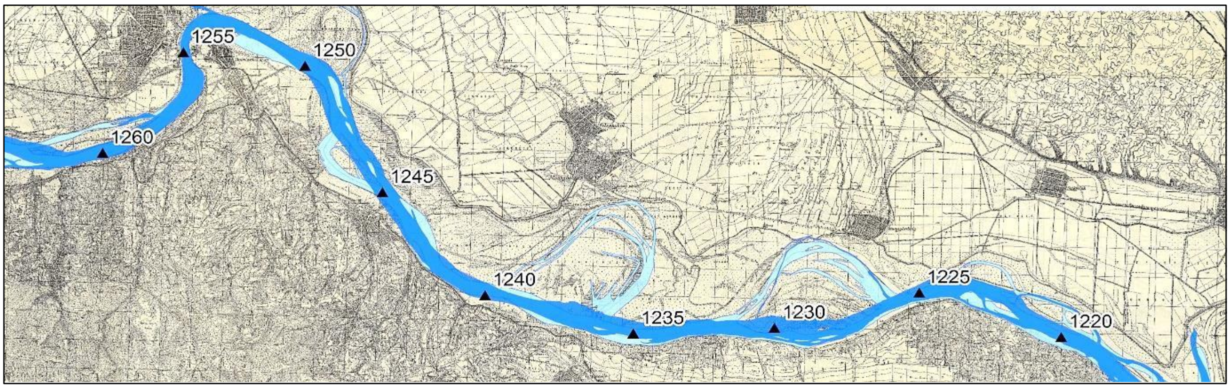


Figure 5-34 The present (dark blue) and reference state (light blue) of the Serbian Danube in the background of a historical map (Source: ICPDR, 2019)

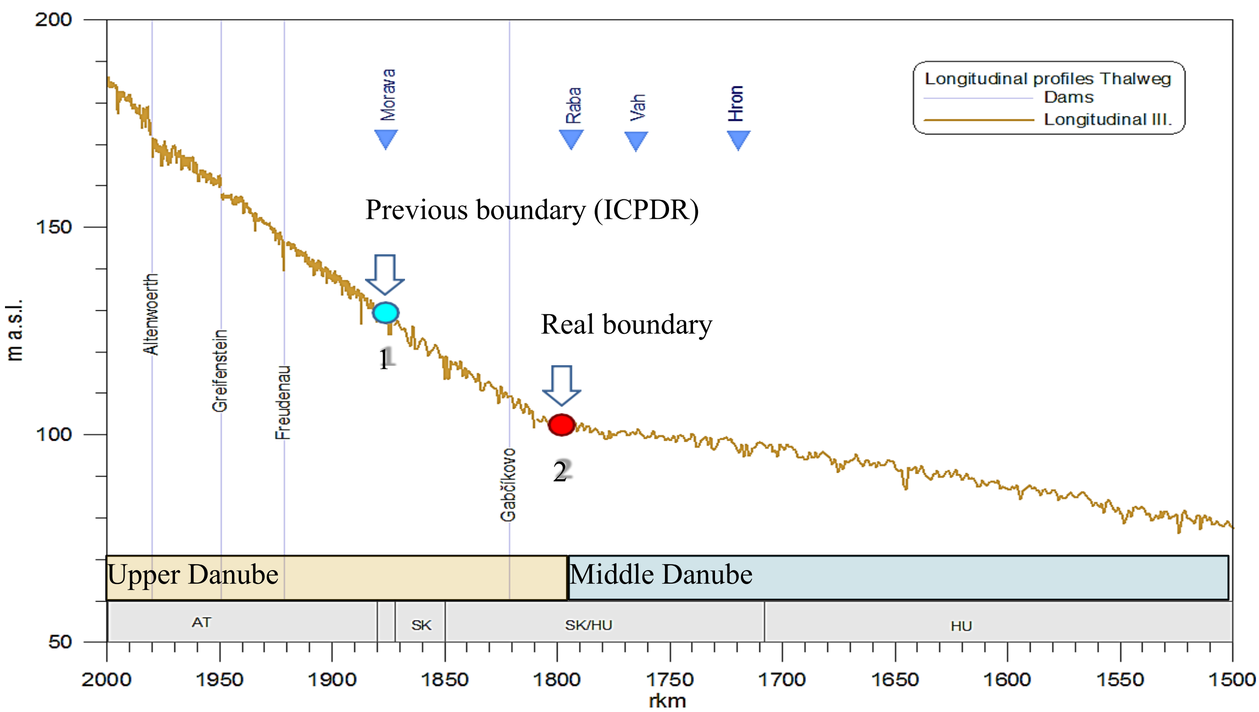


Figure 5-35 The longitudinal profile of the Danube River between rkm 2,600 and rkm 80 and the boundaries between Upper and Middle Danube (Source: ICPDR, 2019)

The chain of HPPs on the Upper Danube and especially the large reservoirs of Gabčikovo and Iron Gate I in the Middle Danube have an impact on the suspended sediment balance (Figure 5-36**Error! Reference source not found.**). Up to 60% of the sediment is deposited in the HPP Gabčikovo reservoir and 60-80% of the sediment input in the HPP Iron Gate I reservoir. As a consequence, the mean annual suspended sediment input to the Danube Delta and the Black Sea decreased by more than 60%, from former amounts of about 60 Mt/yr (into the Danube Delta) and 40 Mt/yr (into the Black Sea) to approximately 20 Mt/yr and 15 Mt/yr currently.

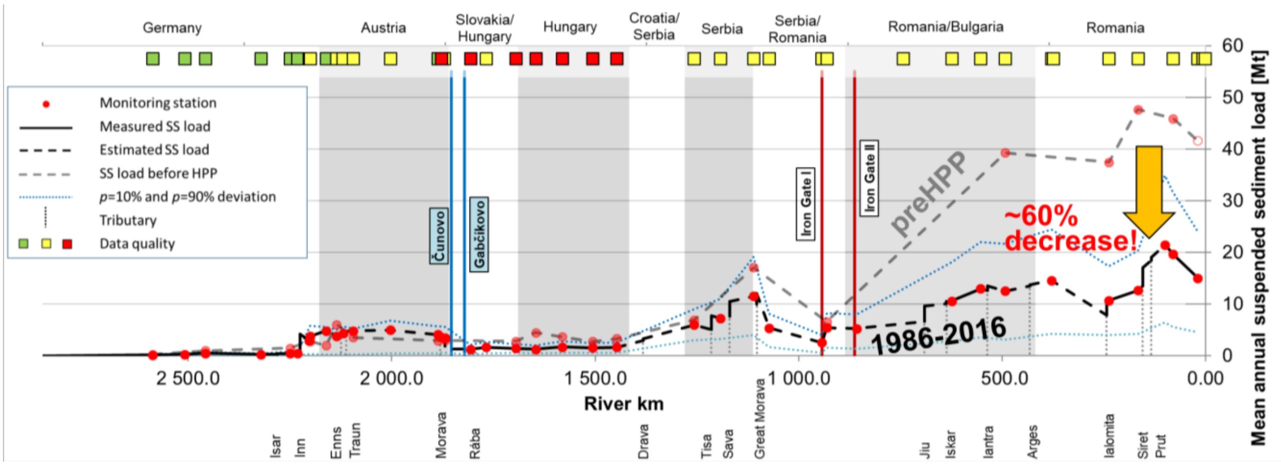


Figure 5-36 The suspended sediment load for the Danube Basin (Source: ICPDR, 2019)

5.8 Impact of Proposed Project on fluvial geomorphology

The potential impacts of direct habitat loss/change have been assessed pre and post mitigation in Section 8. The general considerations for fluvial geomorphology are as follows:

5.8.1 Change to longitudinal connectivity

The impact to longitudinal sediment connectivity was assessed for the Ub Catchment, Kolubara Sub-basin, Sava Basin and Danube Basin.

- **Ub catchment (118 km^2)**

  Zone 0 and Zone 1 are the main source of sediments for downstream ecosystems for the Ub Catchment. Although current landuse practices have likely increased erosion above natural, the torrential nature of flow and the steep slopes have meant that the upper Ub Catchment is prone to erosion. Zone 2 and Zone 3 have had significant transformation of the floodplain for agriculture and urban development. At the confluence of zone 2 with zone 3 there is an existing weir which is likely trapping sediments. Within Ub town there is limited capacity for deposition of sediments due to the canalisation of the river. The transformed nature of the lower Ub indicates that there are limited downstream ecosystems within Ub Catchment that are reliant on sediment from upstream sources.

- **Kolubara Sub-Basin (3,650 km^2)**

  The upper Kolubara Sub-Basin is the main source of sediments for downstream ecosystems. There is limited capacity for sediment storage in the lower Kolubara Sub-Basin are there are two significant mining operations which are mobilising sediments. The contribution of sediments from the Ub River is considered to be lower than the contribution from the Kolubara River therefore the Proposed Project is not likely to have a significant impact on the sediment dynamics of the Kolubara Sub-Basin.

- **Sava Basin (97,200 km^2)**

  The upper Sava Basin is the main source of sediments for downstream ecosystems. There have been morphological changes in the Sava Basin to allow for agricultural development. This has reduced the sediment storage potential of floodplains. The Kolubara River is an important right-tributary of the

Sava Basin that has the potential to contribute moderate levels of sediment. The scale of sediment delivery in comparison to the tributaries in the upper Sava Basin indicates that the Kolubara River is not a main contributor of sediment in the Sava Basin.

- **Danube Basin (801,463 km^2)**

  The upper Danube Basin is the main source of sediments for downstream ecosystems. The presence of hydropower stations along the upper and middle Danube Basin has reduced the longitudinal sediment connectivity to the Black Sea by up to 60%. The Sava Basin occurs within the middle Danube Basin. The Sava is an important source of sediment for the Danube Basin, although directly below its confluence with the Danube Basin the large reservoirs store sediment.

5.8.2 Change to channel morphology

The impact to channel morphology was assessed for the Ub Catchment up to Zone 2. The zone of influence for change to channel morphology will mainly be within the inundation area and downstream of the proposed dam.

- **Ub River (Zone 0)**

  The upper Ub catchment is prone to erosion therefore erosion mitigation measures have been proposed to reduce siltation of the Pambukovica Dam. The sediment traps on Jasenovac Stream, Medednjak Stream, Yosheve River and Ogladjenovayka River will have a direct impact on channel morphology during construction. Sediment will need to be removed from traps, which could cause localised erosion of banks.

- **Ub River (Zone 1)**

  The construction of the Pambukovica Dam is expected to have a direct impact on channel morphology of the Ub River within the reservoir inundation area. The site will need to be excavated to build the dam wall. The upstream side of the dam will be founded on degraded rock mass. The sediment traps on Babinic Stream will have a direct impact on channel morphology during construction and through the operation of the sediment traps storing sediment in tributaries upstream of the Pambukovica Dam.

- **Ub River (Zone 2)**

  The construction of the Pambukovica Dam is expected to have a direct impact on channel morphology of the Ub River directly downstream through erosion of banks.

5.8.3 Change to stream bed morphology

The baseline longitudinal connectivity was assessed from the Ub Catchment up to Zone 2.

- **Ub River (Zone 0)**

  The main bed sediment type in Zone 0 is gravel. Freshwater habitat mapping indicated that freshwater dependent species such as fish, aquatic macroinvertebrates and mussels are dependent on the gravel substrate in the Ub River. Upstream tributaries have more organic matter, with freshwater species accustomed to low-flowing habitat types. The sediment traps on Jasenovac Stream, Medednjak Stream, Yosheve River and Ogladjenovayka River will have a direct impact on streambed morphology during construction and through the operation of the sediment traps storing sediment in tributaries upstream of the Pambukovica Dam. Sediment will need to be removed from traps, which will impact the stream bed morphology.

- **Ub River (Zone 1)**

  Freshwater habitat mapping indicated that freshwater dependent species such as fish, aquatic macroinvertebrates and mussels are dependent on the gravel substrate in the Ub River. The construction of the Pambukovica Dam is expected to have a direct impact on stream bed morphology of the Ub River within the inundation area. The site will need to be excavated to build the dam wall.

- **Ub River (Zone 2)**

  Freshwater habitat mapping indicated that freshwater dependent species such as fish, aquatic macroinvertebrates and mussels are dependent on the gravel substrate in the Ub River. The construction of the Pambukovica Dam is expected to have a direct impact on bed morphology of the Ub River directly downstream during construction and operation. The downstream side of the dam will have a drainage blanket 2m thick, consisting of two layers of sandy filter material and a layer of coarse filter material. The downstream side of the dam will be founded on degraded rock mass.

6. Water Environment Impact Assessment

6.1 Impact Assessment Methodology

This chapter outlines the methodology used to assess the potential impacts of the future dam construction on water quality and quantity within the project area. The methodology aligns with international standards for environmental and social impact assessments (ESIA) and incorporates field data, expert evaluations, and best practices in water science.

6.1.1 Definitions

Direct vs Indirect Impacts – a direct impact is any change to the environment, whether adverse or beneficial, wholly or partially, resulting directly from an environmental aspect related to the project. An indirect impact may affect an environmental, social or economic component through a second order impact resulting from a direct impact.

Magnitude Criteria - the assessment of impact magnitude was undertaken by categorising identified impacts of the Project as beneficial or adverse. Then impacts are categorised as 'major', 'moderate', 'minor' or 'negligible' based on consideration of parameters such as:

Duration of the impact – ranging from 'well into operation' to 'temporary with no detectable impact'.

Spatial extent of the impact – for instance, within the site boundary, within district, regionally, nationally, and internationally.

Reversibility – ranging from 'permanent thus requiring significant intervention to return to baseline' to 'no change'.

Likelihood – ranging from 'occurring regularly under typical conditions' to 'unlikely to occur'.
Table below presents generic criteria for determining impact magnitude (for adverse impacts)

Table 6-1 General criteria for determining impact magnitude

Impact	Criteria
Major	Fundamental change to the specific conditions assessed resulting in long term or permanent change, typically widespread in nature and requiring significant intervention to return to baseline; would violate national standards or Good International Industry Practice (GIIP) without mitigation.
Moderate	Detectable change to the specific conditions assessed resulting in non-fundamental temporary or permanent change
Minor	Detectable but small change to the specific conditions assessed.
Negligible	No perceptible change to the specific conditions assessed

6.1.2 Sensitivity criteria

Sensitivity is specific to each aspect and the environmental resource or population affected, with criteria developed from baseline information. Using the baseline information, the sensitivity of the receptor is determined factoring in proximity, number exposed, vulnerability and the presence of receptors on site or the surrounding area. Generic criteria used to determine sensitivity of receptors are outlined in Table below.

Table 6-2 Generic criteria used to determine sensitivity of receptors

Impact Sensitivity	Criteria
High	Receptor (human, physical or biological) with little or no capacity to absorb proposed changes
Medium	Receptor with little capacity to absorb proposed changes
Low	Receptor with some capacity to absorb proposed changes
Negligible	Receptor with good capacity to absorb proposed changes

6.1.3 Impact Evaluation

The significance of impacts was evaluated taking into account the interaction between the magnitude and sensitivity criteria as presented in the impact evaluation matrix in Table 6-3. Potential impacts evaluated as Major and Moderate were considered to be 'significant', and Minor and Negligible as 'not significant'.

Table 6-3 Impact Significance Matrix

		Magnitude			
		Major	Moderate	Minor	Negligible
Sensitivity	High	**Major**	**Major**	**Moderate**	**Negligible**
	Medium	**Major**	**Moderate**	**Minor**	**Negligible**
	Low	**Moderate**	**Minor**	**Negligible**	**Negligible**
	Negligible	**Minor**	**Negligible**	**Negligible**	**Negligible**

6.2 Screening of Potential Impacts

The screening of potential impacts for the Pambukovica Dam project aims to identify and assess key water quality and quantity effects that may arise during both the construction and operation phases. This process ensures that potential risks to water resources, and surrounding ecosystems are understood and appropriately assessed and managed through targeted mitigation measures.

In addition to the dam construction, the Project will involve development of an irrigation network of approximately 2,225ha. The Project can therefore be split into two phases:

- **Phase 1 - Construction and operation of Pambukovica dam for flood prevention purposes.**

  For construction of the dam, and before impoundment, a 900m long section of the State Road No.21 will need to be raised above the maximum water level of the reservoir, and additional services located in the reservoir footprint relocated. Phase 1 will complete with the impoundment of the river and formation of the reservoir. Design of the dam has been prepared up to the level of Design for the Construction Permit (PGD) as defined in national legislation.

- **Phase 1 – Operation of Pambukovica dam.**

  The detailed operating rules for the reservoir are detailed in Technical Assessment Report Appendix 7 – Operational Rules. Under Serbian legislation there is a requirement to deliver a seasonal environmental flow (Qe) which has been evaluated at 68 l/s for cold season (Oct-Mar) and 102 l/s for warm season (Apr-Sep). The maximum capacity of the environmental flow pipe is 200 l/s. However, operations phase flows downstream of the reservoir typically far exceed the presented Serbian minimum flow, as additional water is required to be released to maintain the Phase 1 target reservoir level of 138.5 masl. The release of additional water to maintain the target reservoir level will be delivered through the bottom gate outlet. Modelled operations-phase flows for a dry, normal and wet year are described in the Section 4.4. Periodic sediment flushing from the dam may be required. The frequency of sediment flushing activities will be dependent on sediment accretion levels which will be monitored using bathymetry during the operations phase. In years where sediment flushing is required, it will be timed to minimise impacts to downstream biodiversity. Sediment flushing would likely occur in winter/spring (Feb-April) making use of the high spring river levels to carry and dissipate the sediment effectively, whilst also avoiding excess sediment during the summer fish spawning and egg incubation periods.

- **Phase 2 - Construction and operation of an irrigation system within Ub Municipality is now planned to begin in parallel with finalisation of Phase 1 works.**

  This phase involves the dam and reservoir operating for both flood defence and irrigation purposes. Irrigation works will involve construction of the key facilities of the irrigation system distribution network which include pump stations, pressure pipelines and the tanks for daily balancing of the inflow. The rest of the distribution network infrastructure is planned to be developed to full capacity in the subsequent two years. Development of the secondary distribution network is planned concurrently with the primary distribution network.

- **Phase 2 – Operation of Pambukovica dam.**

  The operations-phase flow releases, considering irrigation demands, are described in Section 3.5.2. Potential impact pathways associated with the Phase 2 regime is screened in Section 6.2.2.

Construction of upstream sediment traps is planned as part of the overall Pambukovica Dam Project, as part of Phase 1. PWMC Srbijavode confirmed that the plan is to construct sediment traps in parallel with the construction of the dam. Completion is planned before start of reservoir operation.

The screening of potential impacts for the Pambukovica Dam project aims to identify and assess key environmental effects that may arise during both the construction and operation phases. This process ensures that potential risks to water resources, surrounding river linked ecosystems, are understood and appropriately assessed and managed through targeted mitigation measures.

6.2.1 Construction-phase Impacts

During the construction phase, the primary water quality and quantity impacts are associated with activities such as land clearing, excavation, and material transport, which may lead to habitat loss, soil erosion, and changes in hydrology (Table 6-4). Additionally, construction-related emissions and accidental spills pose risks to water.

Change of flow regime

Although during the construction of the Pambukovica Dam a concrete gallery will maintain Ub River flow, with associated support structures like a control building and power connection point, it is likely that working in a watercourse may still impact the natural flow regime. Water for construction may be sourced from the Ub River which may reduce flow in the river.

Water pollution

The construction of the Pambukovica Dam is expected to result in various forms of pollution. Excavation, land clearing, and earthworks could lead to soil erosion and increased sedimentation in nearby water bodies, potentially altering aquatic habitats and reducing water quality. Additionally, the use of heavy machinery and construction materials poses a significant risk of chemical spills and leaks, which could contaminate freshwater ecosystems. In-stream construction works can disturb sediment deposits, leading to increased turbidity and a reduction in light penetration, which is crucial for aquatic life.

Change in longitudinal sediment connectivity

As mentioned above the construction of the proposed Pambukovica Dam will allow for flow of Ub River during construction. Sediment will not be disconnected from downstream ecosystems but there is potential for the excavation, land clearing and earthworks to increase sediment loads and cause unnatural siltation of downstream freshwater ecosystems.

Change to channel and stream bed morphology

The construction of the Pambukovica Dam is expected to have a direct impact on channel morphology and stream bed morphology of the Ub River within the inundation area as well as directly downstream. The site will need to be excavated to build the dam wall. The downstream side of the dam will have a drainage blanket 2m thick, consisting of two layers of sandy filter material and a layer of coarse filter material. The upstream and downstream sides of the dam will be founded on degraded rock mass. There will also be upstream flood barriers to trap sediments in tributaries of the Ub River.

6.2.2 Operations-phase Impacts

The operational phase of the dam presents long-term environmental changes, particularly due to altered river hydrology and flow regimes, habitat fragmentation, and changes in water quality (Table 6-5). Changes in sediment transport, water temperature, dissolved oxygen levels and nutrients can significantly impact aquatic ecosystems and downstream habitats. Additionally, ongoing maintenance and water management practices, such as the introduction of non-native species, may further affect local biodiversity. The potential for associated impacts (adverse and beneficial) on ecological receptors have been assessed pre- and post-mitigation in **Book 4 Biodiversity Impact Assessment**.

Change of flow regime

The creation of the reservoir will lead to changes in the hydrological regime for zone 2-3, potentially disrupting the ecological balance of downstream freshwater habitats and riparian vegetation. The magnitude of these changes, some of which may be beneficial to the river's ecosystem, depends on the degree of alteration to natural hydrological and geomorphological processes. Ensuring the Serbian minimum flow will provide drought resilience for downstream ecosystems.

From a hydrological perspective, the analysis in Section 4.5 demonstrates the following for Phase 1 of operation:

- A minor reduction in monthly average flows during winter (i.e. cold season: October to March) and spring (i.e. start of warm season: March to May), associated with storage in the reservoir.
- Monthly flows will mimic that of the baseline (albeit reduced) maintaining a natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream.
- In both the modelled 'average' and 'dry' year scenarios the operations phase flow will be higher than that under the baseline scenario in dryer months, as a result of the Serbian minimum flow, delivering drought resilience for the zone 2-3.

From a hydrological perspective, the analysis in Section 4.5 demonstrates the following for Phase 2 of operation:

- For the representative **average year (2007)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir (indicated by the blue line). The E Flow to the River Ub downstream of the dam (purple line: outflow to river) matches the natural baseline regime (red line: inflow to dam), other than for a short period in October / December where reservoir filling occurs. With the exception of this period of filling, daily flows will maintain a natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream.
- For the representative **wet year (2005)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir (indicated by the blue line). The E Flow to the River Ub downstream of the dam (purple line: outflow to river) matches the natural baseline regime (red line: inflow to dam), other than for a short periods in June to September where reservoir filling occurs. With the exception of this period of filling, daily flows will maintain a

natural hydrological regime, consisting of high flows and low flows in the required seasons. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream

- For the representative **dry year (2020)** both the irrigation demand and downstream Serbian minimum flow will be met through drawdown of the reservoir. However, the reservoir storage would not fully recover to target level during Autumn / winter and further recharge in January February of the following year would be required. However, water availability is high at this time of year (indicated by the peaks on the lefthand side of the graph) and recharge to target is expected to be quick. Once the reservoir target level is achieved E flows would again mimic the natural regime. This is crucial to support and maintain the lifecycle of sensitive aquatic and riparian ecology downstream.
- In dry years the E Flow will be higher than that under the baseline scenario as a result of delivery of the Serbian minimum flow, delivering drought resilience for ecosystems along the Ub, Tamnava and Kolubara Rivers downstream. This can be seen in Figure 3-10 (2020 - representative dry year) where the operations-phase flows downstream of the dam (purple line: outflow to river) is higher than the natural baseline regime (red line: inflow to dam) between the months June and October.

In addition, the storage in the reservoir for the retention of flood water will also result in a reduction in the magnitude of downstream flood events in the River Ub. Stored water will be released at a slower rate following a storm event which change the flood hydrology of the river downstream of the proposed dam.

Change of water quality within inundation area

Immediately upstream of the dam wall (zone 1) the river will change from a flowing river environment to a near static reservoir. The potential for eutrophication of the reservoir was assessed in Section 5.5. Nutrient loading from upstream sources is low in the Ub River, although further analysis is necessary, it seems that there is a low risk of eutrophication during operation of the reservoir.

Change of water quality downstream of dam

Change in water quality downstream of the dam is mainly at risk of decreased oxygenation levels due to formation of an oxycline within the reservoir due to stratification of the reservoir over prolonged periods. This process is mainly a risk for phase II operations as discussed in Section 4

Change in longitudinal sediment connectivity

More than 60% of suspended sediment in the Danube River is trapped in reservoirs and does not make it to the delta or Black Sea. The contribution of Ub River to the Kolubara and Sava Basin sediment budget is low, and the proposed Project will have a limited impact to basin-wide sediment dynamics.

At the local level the current condition of the Ub River is highly active at moving sediments during high flow events but the canalisation and physical structures have transformed downstream sections of the Ub River. This has reduced the natural capacity of the Ub River to deposit sediments along floodplains.

The design of the Pambukovica Dam has accounted for sediment retention in the active zones of the catchment. Although the upper reaches of the Ub River catchment are prone to erosion, there are a range of sediment retention measures proposed to reduce sediment reaching the reservoir (zone 0 and zone 1). These measures will improve the landscape resilience and have a beneficial effect on terrestrial and freshwater habitats through reduced erosion and sedimentation.

Downstream of the proposed dam the current condition of the Ub River does not allow for natural sediment dynamics. In its current condition there is limited deposition along riparian edges or floodplains therefore it is not expected that current ecosystems are reliant on sediment.

Directly downstream of the dam there will be a reduction of suspended sediment and bedload. This will directly impact the availability of substrate for biota (i.e. fish, invertebrates, mussels and macrophytes).

Change to channel and stream bed morphology

The operation of the Pambukovica Dam is expected to have a direct impact on channel morphology and stream bed morphology of the Ub River within the inundation area as well as directly downstream.

Immediately upstream of the dam wall (zone 1) the river will change from a flowing river environment to a more stagnant reservoir. Directly below the dam wall (zone 2) there will likely be scour during peak flow.

6.3 Mitigation and Monitoring

6.3.1 Construction

Mitigation would be implemented in order to mitigate for potential impacts of the construction phase as described in Table 6-4and the Actions in Biodiversity Management Plan in Book 4 Biodiversity Impact Assessment.

6.3.2 Operation

Mitigation and embedded / design mitigation would be implemented in order to mitigate for potential impacts of the operation phase as described in Table 6-5 and the Actions in Biodiversity Management Plan in Book 4 Biodiversity Impact Assessment

Table 6-4 – Water Environment Impact Assessment – Construction

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
Hydrology	Changes in flow regime (zone 1-3)	**Major**	Although flow will be maintained during construction through a concrete gallery the natural flow regime will likely still be impacted. To mitigate these impacts, it is needed to: - **Monitoring and adjustments** to ensure flow is as close to natural as possible, in terms of low flow and high flows (depending on the season of construction).	Moderate
Water quality	Change to downstream water quality (zone 1-3)	**Major**	The construction of the dam and associated activities may result in downstream water pollution. To mitigate these impacts, it is needed to: - **River diversion -** the river is planned to be diverted, creating dry conditions for dam construction. This will reduce the risk of water pollution through physical separation. **- Sediment control measures** such as silt curtains, sediment ponds, or diversion channels to minimize the impacts of construction on water quality and aquatic habitats (WEMMP Action 4). - **Long-term water quality monitoring** to assess the success of water quality measures.	Moderate
Fluvial geomorphology	Change to longitudinal connectivity (zone 0-3)	Moderate	Although flow will be maintained during construction through a concrete gallery the sediment regime will likely still be impacted. To mitigate these impacts, it is needed to: **- River diversion -** the river is planned to be diverted, maintaining a degree of longitudinal connectivity **- Monitoring and adjustments** to ensure flow of sediment is as close to natural as possible, in terms of low flow and high flows (depending on the season of construction). **- Long-term sediment monitoring** to assess the success of sediment control measures.	Minor

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
Fluvial geomorphology	Change to channel and stream bed morphology (zone 0)	Moderate	The construction of sediment traps in tributaries upstream of Ub River will have a direct impact on channel and stream bed morphology (Jasenovac Stream, Medednjak Stream, Yosheve River, Ogladjenovayka River). To mitigate these impacts, it is needed to: - **Sediment control measures** such as silt curtains, sediment ponds, or diversion channels to minimize the impacts of construction on water quality and aquatic habitats.	Minor
Fluvial geomorphology	Change to channel and stream bed morphology (zone 1)	**Major**	The construction of sediment traps in tributaries upstream of Ub River will have a direct impact on channel and stream bed morphology of Babinic Stream. Construction of the dam wall will have a direct impact on channel and stream bed morphology of Ub River. To mitigate these impacts, it is needed to: - **Sediment control measures** such as silt curtains, sediment ponds, or diversion channels to minimize the impacts of construction on water quality and aquatic habitats.	Moderate

Table 6-5 - Water Environment Impact Assessment – Operation

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
Hydrology	Changes in flow regime (zone 0-3)	**Major**	Phase 1 operation will result in a minor reduction in monthly average flows during winter and spring, associated with storage in the reservoir. Monthly flows will mimic that of the baseline (albeit reduced) maintaining a natural hydrological regime, consisting of high flows and low flows in the required seasons. In both the modelled ‘average’ and ‘dry’ year scenarios the operations phase flow will be higher than that under the baseline scenario in the drier months of some years (see Section 3.5), delivering drought resilience for the Ub River downstream. Phase 2 operation will need to balance irrigation demand against the requirement to release the Serbian minimum flow and EFlow. This will be met through operation of the reservoir over the year requiring a period of filling. As presented, under all representative scenarios (average, wet and dry years) the operational E Flow is	Moderate

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
			similar to that of the baseline scenario and mimics the natural regime. In addition, in dry years the E Flow will be higher than that under the baseline scenario for some drier months as a result of delivery of the Serbian minimum flow, delivering drought resilience. To mitigate these impacts, it is needed to: - **Flow management strategies** to maintain environmental flows that support aquatic life, including seasonal variability in flow to mimic natural conditions. - **Operations phase flow reporting –** public disclosure of reservoir releases. Refer to Action 2 of the WEMMP.	
Water quality	Change to inundated area water quality (zone 1)	**Moderate**	The damming of the Ub River may result in eutrophication of the inundated area within the reservoir. The release of eutrophic water may be harmful to downstream biodiversity. To mitigate these impacts, it is needed to: - **Water quality monitoring** to assess impacts on aquatic species and riparian habitats, ensuring that water parameters such as chlorophyl, temperature, oxygenation, conductivity, pH, and nutrients levels remain within acceptable thresholds according to the Surface Water Quality regulations of Serbia (No. 50/2012). - **Adaptive Water Quality management** - eutrophication of the reservoir will need to be monitored through applying the OECD limits for trophic state. In the event that the reservoir is eutrophic then adaptive management principles should apply to improve water quality of flows prior to downstream release. If required, adaptive management could include the use of an artificial mixer in the reservoir. Reservoir mixers offer a cost-efficient way to reduce stratification of the reservoir water column resulting in more uniform temperature and dissolved oxygen throughout a water column. This minimises or eliminates incidence of Blue Green Algae and oxidising metallic ions. https://www.wears.com.au/resmix-product-range/resmix-5000/ Refer to Action 3 of the WEMMP.	Minor
Water quality	Change to downstream water quality (zone 2)	**Moderate**	The release of water from the reservoir during Phase 2 may result in downstream water quality changes in terms of higher water temperatures, lower DO and increased nutrients. Temperature changes are considered likely to be minimal due to	Minor

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
			the short residency times of water within the impoundment area. Water temperature will be similar to inflowing river water. Downstream water quality may be affected by the potential release of water that has formed an oxycline or has high nutrients. To mitigate these impacts, it is needed to: - **Water quality monitoring** to assess impacts on aquatic species and riparian habitats, ensuring that water parameters such as temperature, oxygenation and nutrients levels remain within acceptable thresholds according to the Surface Water Quality regulations of Serbia (No. 50/2012). - **Reservoir Water Quality management** - Proper mixing or aeration of the water for Phase 2 would ensure larger amounts of oxygenated flow entering the river downstream of the dam. It is recommended to install hypolimnetic aeration or oxygenation or alternatively a mechanical mixer to increase the potential for reoxygenation. Reduction of nutrient sources within the reservoir may also help to mitigate oxycline formation. Refer to Action 3 of the WEMMP.	
Fluvial geomorphology	Change to sediment longitudinal connectivity (zone 0-3)	**Major**	The damming of the Ub River will retain suspended sediment and bedload from the surrounding catchment within Zone 0 and Zone 1, which would normally travel to downstream ecosystems. Downstream of the proposed dam there are two tributaries (Bukovica and Dokmirica Rivers) which provide additional suspended sediment and bedload to the Ub River within Zone 2. At the point where these two tributaries join the Ub River there is a weir which acts to trap a proportion of Zone 0-2 sediments. Beyond the weir within Zone 3 the channel has been significantly modified within Ub town into a trapezoidal concrete channel which does not promote sediment deposition. As the Ub River has existing weirs and river transformation it is unlikely that wetland ecosystems are currently reliant on suspended sediment and bedload sourced from the upper catchment. To mitigate these impacts, it is needed to: **- Long-term sediment monitoring** - as part of the management and monitoring measures for the Ub River suspended sediment and bedload should be monitored annually at strategic locations within zone 0-3 (pre-construction through to operations). Turbidity is also to be monitored following a high flow event and sediment flushing. - **Barrier removal / fish passage improvements –** if possible additional measures should be taken to improve river connectivity for biodiversity and sediment by	Moderate

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
			removing, or improving passability (for fish) at the weir at zone 2. This will improve the longitudinal sediment connectivity of Ub River and promote natural sediment dynamics. The relative benefits of weir removal, or provision of fish passage, at the weir should consider the needs of fish and Thick-Shelled Mussel (see Chapter X: Biodiversity). Refer to Action 5 of the WEMMP.	
Fluvial geomorphology	Change to channel and stream-bed morphology (zone 0)	**Major**	The sediment traps in tributaries upstream of Ub River (Jasenovac Stream, Medednjak Stream, Yosheve River, Ogladjenovayka River) will retain sediment and reach full capacity in a shorter period then what is to be expected for the lifespan of the dam. To mitigate these impacts, it is needed to: - **Long-term sediment monitoring** at zone 0. Long-term adaptive management is required for the management response for accumulated sediment. **- Sediment management** – as part of the management and monitoring measures for the catchments upstream of the dam within Zone 0 there is a requirement to remove sediment trapped behind sediment traps. In accordance with sediment connectivity management measures accumulated sediment should be translocated to the mainstem Ub River within Zone 2. Refer to Action 6 of WEMMP.	Minor
Fluvial geomorphology	Change to channel and stream-bed morphology (zone 1)	**Major**	The inundated area of the reservoir will accumulate suspended sediment and bedload (i.e. gravel). This will result in a change in channel and stream-bed morphology within the inundated area of Zone 1. Bed The construction of sediment traps in tributaries upstream of Ub River on Babinic Stream will retain sediment and reach capacity in a shorter period then the proposed dam. To mitigate these impacts, it is needed to: - **Long-term sediment monitoring** at zone 1. Long-term adaptive management is required for the management response for accumulated sediment. **- Sediment management** – as part of the management and monitoring measures for the reservoir there is a need to consider sediment management options (i.e. sediment flushing or dredging) for the long-term sustainable maintenance of the reservoir.	Moderate

Receptor	Potential Impact Description	Impact Significance (pre-mitigation)	Assessment (mitigation)	Residual Impact Significance
			- **Sediment management** – as part of the management and monitoring measures for the catchments upstream of the dam within Zone 1 there is a requirement to remove sediment trapped behind flood barriers. In accordance with sediment connectivity management measures accumulated sediment (i.e. sediment that may have been transported downstream under baseline pre-dam conditions) should be translocated to the mainstem Ub River within Zone 2. Refer to Action 6 of WEMMP.	
Fluvial geomorphology	Change to channel and stream-bed morphology (zone 2)	**Major**	The operation of the dam may result in scour directly below the spillway. To mitigate these impacts, it is needed to: - **Monitoring of scour** at spillway. Refer to Action 6 of WEMMP.	Moderate

7. Water Environment Monitoring and Mitigation Plan (WEMMP)

The Project Water Environment Monitoring and Mitigation Plan (WEMMP) will be an iterative document that will be updated and amended as the project proceeds from loan approval, through pre-construction and into operation. The WEMMP covers action pertaining water quantity, water quality and fluvial geomorphology and is a publicly disclosed document. This WEMMP has been designed to be implemented in conjunction the aquatic elements of the Biodiversity Management Plan (BMP); these documents should continue to be developed and delivered together as evidence gathered as part of the WEMMP will underpin the BMP.

Site specific monitoring will relate to the activity relevant to the Water Study Area as defined below.

- **Zone 0**: Sub-catchment above reservoir area inclusive of Ub, Joseva, Ogladenovacka Rivers and Jasenovac and Medveniak Streams
- **Zone 1**: Sub-catchment of reservoir / inundation area, inclusive of Ub River and Babinac Stream
- **Zone 2:** Sub-catchment of Ub River downstream of proposed dam up to the confluence of two tributaries (Dokmirca and Bukovica Rivers)
- **Zone 3:** Sub-catchments of Ub River inclusive of town of Ub, up to the confluence with Tamnava River

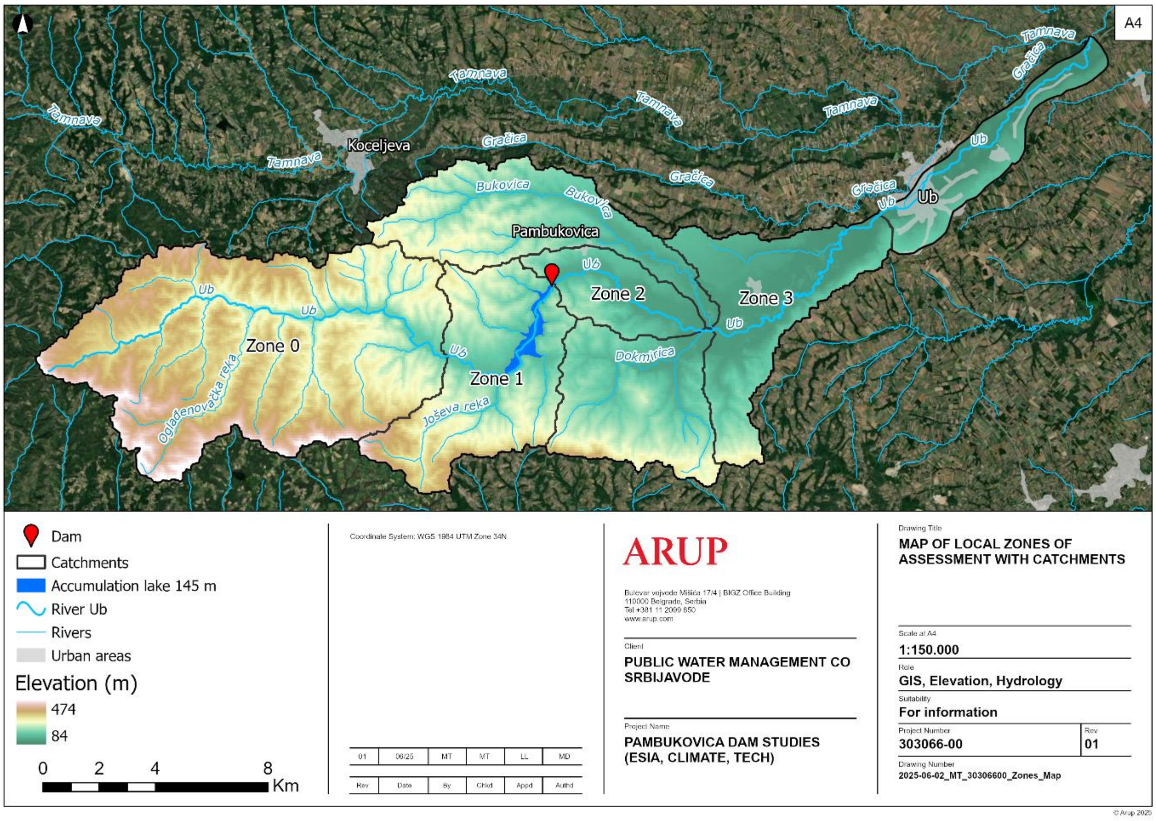


Figure 7-1 Study area inclusive of the zones of analysis for the impact on surface water resources from the proposed Project (Elevation in meters above sea level)

In order to implement the WEMMP preceding studies are required to collect an adequate baseline for water quality and fluvial geomorphology prior to construction. Measurements for water quality will need to account for cold and warm months; whilst the fluvial geomorphology will need to consider appropriate timing (i.e. low flow) for river cross-sections as well as timing (i.e. high flow) for sediment grab samples/turbidity sampling. Appropriately qualified water quality and fluvial geomorphology specialists should be experienced in the site collection methods required.

Other specific responsibilities for the specialist will involve ongoing monitoring of specific reaches identified through the baseline assessment. The site-specific monitoring will allow for a comparison with baseline over time and will relate to specific activities (i.e. after releases, high flows, after sediment flushing).

7.1 Action 1: Develop and implement a Pollution Control Strategy

7.1.1 Identified impact

Degradation / pollution of habitats

7.1.2 Timeframe

During construction phase to manage pollution during construction.

7.1.3 Location

Project-wide across site upstream of the reservoir at Zone 0, at the reservoir site in Zone 1 and downstream of the dam in Zone 2.

7.1.4 Mitigation, Management or Monitoring Measure

Implement a Water Quality Management Strategy (as part of the WEMMP) to prevent pollution from construction runoff, accidental spills, and operational discharges. Measures will include sediment traps, silt fences, and regular water quality monitoring for parameters such as temperature, dissolved oxygen, and turbidity. During operation, special attention will be given to managing water releases to prevent thermal pollution from dam discharge, ensuring temperature regulation to match natural river conditions and protect aquatic life. Develop and enforce best practices for handling hazardous materials, including proper storage, transportation, and disposal to minimize the risk of accidental spills. Training programs will be conducted for construction and operational staff to ensure compliance with environmental standards and emergency response procedures. Implement erosion and sediment control measures, such as vegetative buffers and soil stabilization techniques, to prevent sedimentation that can degrade water quality and aquatic habitats.

Establish a continuous monitoring and reporting system to track potential sources of pollution and habitat degradation, allowing for timely intervention and adaptive management strategies.

7.2 Action 2: Water quantity disclosure and hydrograph monitoring

7.2.1 Identified impact

Reduction in flows

7.2.2 Timeframe

During operation phase to disclose the operational flows for downstream ecosystems.

7.2.3 Location

At the dam. Flowmeter located on the discharge pipework.

7.2.4 Mitigation, Management or Monitoring Measure

To demonstrate that the environmental flow commitments are met, the flow monitoring will be disclosed publicly (for example, on the Project website). The operations phase minimum flow is to be monitored through a flowmeter located on the discharge pipework. Flow release data will be made public and logged providing a minimum flow audit trail. Operations phase flows can be compared to Ub River flows upstream of the dam allowing the deviation from 'natural' pre-dam conditions to be calculated and disclosed.

7.3 Action 3: Develop and monitor reservoir and downstream water quality

7.3.1 Identified impact

Water quality

7.3.2 Timeframe

Pre-construction phase requires baseline water quality monitoring. Further monitoring required during construction up to operational phase to monitor changes to water quality during construction and operations.

7.3.3 Location

Additional baseline monitoring is required prior to construction. The previous sites for water quality monitoring are defined in section 4. Baseline monitoring to define an upstream and downstream location for follow-up trend monitoring during the operational phase of the reservoir.

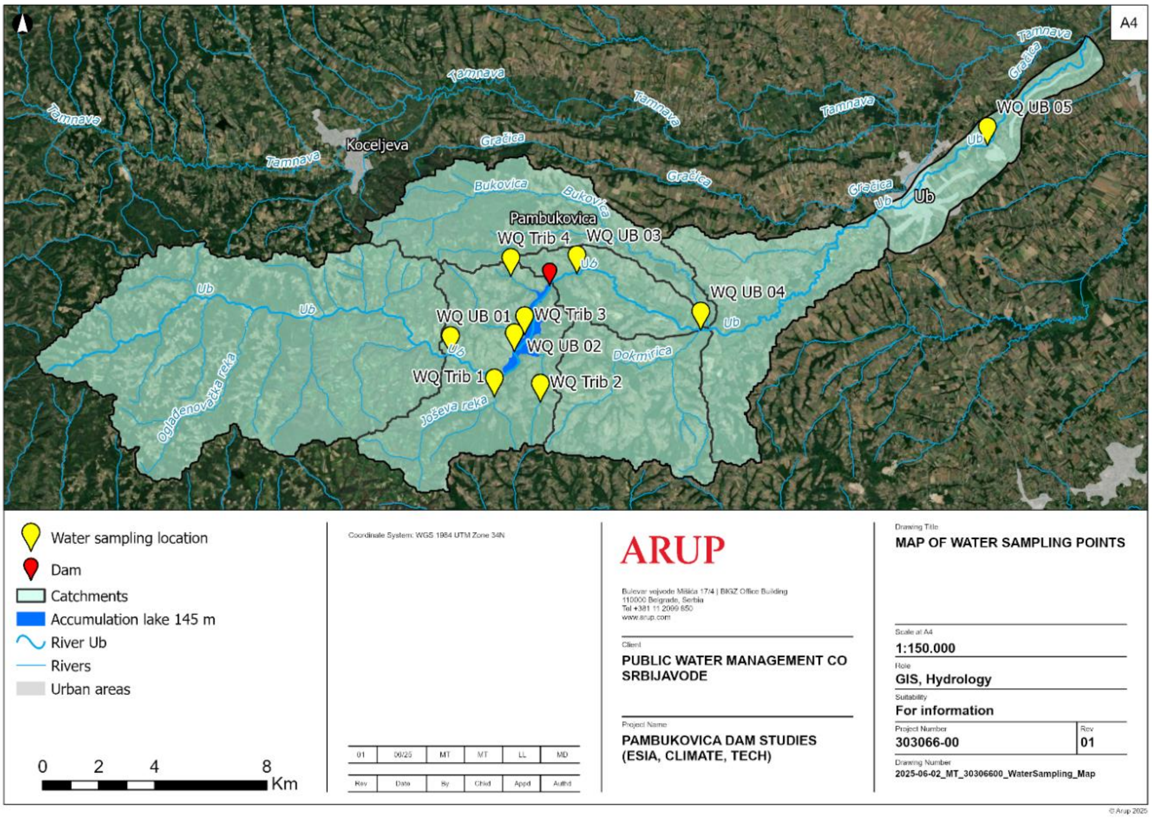


Figure 7-2 Location of baseline water quality sampling sites within Ub Catchment

7.3.4 Mitigation, Management or Monitoring Measure

The reservoir water quality will need to be monitored at the reservoir, within Zone 1, and downstream of the reservoir, within Zone 2, to ensure that the water quality does not vary significantly from baseline. The annual trends should also be compared against the Serbian Surface Water Quality standards. Water quality monitoring during construction should be carried out by the Contractor and parameters and monitoring locations documented in the CEMP. Should water quality exceed limits then identification of the source of pollution and preventative action will be required.

7.3.5 Reservoir water quality modelling

The water quality assessment (Section 4.5.1 and 4.5.2) has identified an increased risk of both de-oxygenated and nutrient enrichment water (from the reservoir) entering the downstream ecosystems during Phase 2. Further detailed analysis/modelling of reservoir water quality is needed to rule out the de-oxygenation and eutrophication risk, considering the operations of Phase 2, and/or develop suitable mitigation (e.g. reservoir mixers). Reservoir water quality data, including data collected at 1m intervals (probe readings) and surface and bottom water (laboratory samples), will form a crucial input parameter to future modelling (see Table 7-1).

Table 7-1 Site specific water quality monitoring

Location	Method	Parameter	Operation[23]
Zone 1 physio-chemical	Water quality monitoring of the reservoir conducted by contractor during construction and operational monitoring to be determined. Surface and bottom water samples will be required in addition to probe readings as 1m interval from surface to bottom	Temperature	Monthly during the first 4 years following reservoir filling and every quarter during operation.
		Oxygenation (DO)	
		Conductivity	
		Acidification (Total alkalinity, pH)	
		Nutrients (Total phosphorus, Phosphates, Ammonia, Nitrate, Nitrite, Chlorophyll a)	
		Turbidity	
		Suspended solids	
Zone 2 physio-chemical	Water quality monitoring of the downstream river conducted by contractor during construction and operational monitoring to be determined.	Temperature	Monthly during the first 4 years following reservoir filling and every quarter during operation.
		Oxygenation (DO)	
		Conductivity	
		Acidification (Total alkalinity, pH)	
		Nutrients (Total phosphorus, Phosphates, Ammonia, Nitrate, Nitrite, Chlorophyll a)	
		Turbidity	
		Suspended solids	

[23] From four years after construction.

7.4 Action 4: Develop and monitor sediment yield reduction activities

7.4.1 Identified impact

Erosion

7.4.2 Timeframe

During construction up to operation.

7.4.3 Location

Upstream restoration measures in Zone 0 and Zone 1 are defined in Figure 7-3.

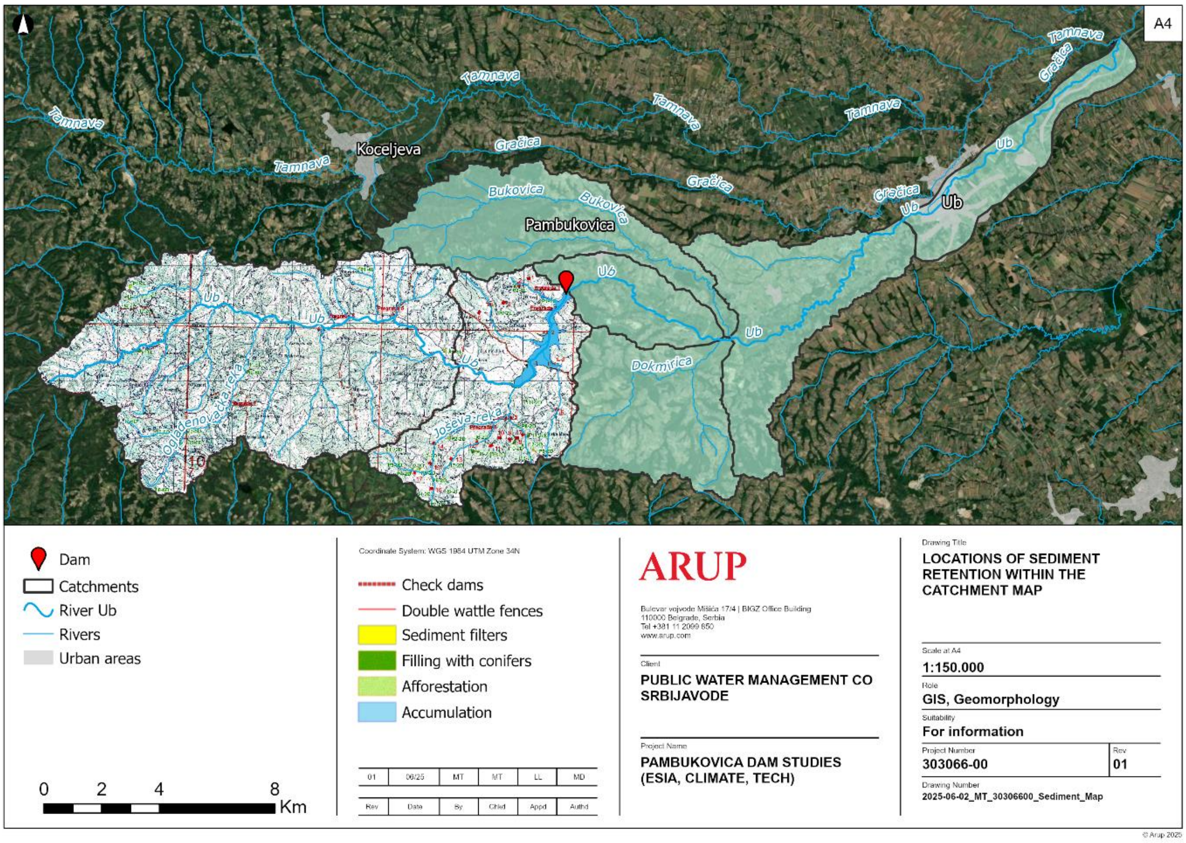


Figure 7-3 Locations of erosion mitigation within the catchment of proposed Project (Source: Project of anti-erosion works in the watershed (Ref: 16018-PV-11))

7.4.4 Mitigation, Management or Monitoring Measure

Most of the upper Ub Catchment is under arable landuse with patches of forest. The areas at risk of erosion will have both biological (afforestation) and biotechnical (double living braids) measures implemented in parallel to the construction of the dam to reduce erosion of sediment which could reduce the life span of the dam. Each of the erosion mitigation measures will also have a maintenance requirement. The owner of the dam will be required to continue the follow up maintenance for biological, biotechnical, Ilofilters and farmer improved management practices during the operational life of the dam.

Table 7-2 Site specific erosion and sedimentation monitoring

Location	Method	Parameter	Operation[24]
Zone 0 biological	Monitor forest growth and erosion. Mostly within Joseva sub-catchment and areas of erosion.	Vegetation growth	Annual
		Erosion	Annual
Zone 0 biotechnical	Monitor braid and bank stability. Planted in the upper reaches of the direct tributaries of future reservoir. Babinac Stream, Sigraye Stream, Kokanovac Stream, Yosheva River	Braid stability	Annual
		Bank stability	Annual
Zone 1 Ilofilters	Forest grass belts planted in the narrow accumulation zone of the proposed reservoir	Sediment accumulation	Annual
Zone 0-1	Monitor improved agricultural practices.	Improved agricultural land	Annual

7.5 Action 5: Develop and implement an Ub River Connectivity Strategy

7.5.1 Identified impact

Habitat fragmentation and species displacement

7.5.2 Timeframe

From pre-construction up to Operation.

7.5.3 Location

Zone 2

7.5.4 Mitigation, Management or Monitoring Measure

Construction activities will be phased to minimize disruption. The construction of the dam will result in the physical separation of the river, leading to population fragmentation of aquatic species. Similarly, the formation of a larger water body will alter habitats for terrestrial species, potentially causing displacement and fragmentation of their populations. One of the proposed management measures to mitigate these impacts includes the removal of downstream barriers to enhance connectivity along the remaining river length. Additionally, ensuring a suitable minimum flow of the Ub River throughout the year—something that has been previously hindered by climate change and extreme droughts—will help maintain continuous flow and favourable conditions over a longer stretch downstream of the dam. Given the significant rise in pollution levels from the city of Ub, maintaining a minimum flow will also contribute to improving the ecological status of the river until it reaches the urban area.

Monitoring programs will assess species movement and habitat use, adjusting mitigation measures as needed to optimize connectivity and minimize displacement effects.

7.6 Action 6: Develop and implement a Sediment Monitoring and Management Strategy

7.6.1 Identified impact

Downstream change in lateral and longitudinal sediment dynamics

[24] From four years after construction.

7.6.2 Timeframe

From pre-construction (i.e. baseline) and up to four years of operation to assess the changes to sediment dynamics.

7.6.3 Location

Refer to Figure 7-3 above. During baseline fluvial geomorphology assessment upstream and downstream sampling sites to be considered.

7.6.4 Mitigation, Management or Monitoring Measure

A baseline fluvial geomorphology survey is required in Zone 0-3 prior to construction. This will need to consider bedload (i.e. gravel) and suspended sediment sampling at the location of the sediment traps in the tributaries upstream of the proposed Project (zone 0 and 1), at the inundation area (zone 1) and downstream of the proposed dam wall (zone 2).

Annual sediment monitoring along the river in Zone 0-3 during the initial four years of project operation will be particularly important to build an understanding of the reaction and behaviour of the river morphology and fish habitat to the new flow regime. Longterm options for sediment management involve either *minimizing sediment deposition* through sediment flushing during operation or *increasing reservoir volume* through in-situ mechanical techniques such as dredging (Kondolf et al. 2014[25]). Disposal and use of removed sediment will require additional assessment and should be in accordance with national regulations for River Sediment Extraction.

When periodic sediment flushing or a large release is made then an event-based site inspection will be required. Sediment flushing would likely occur in winter/spring (Feb-April) making use of the high spring river levels to carry and dissipate suspended sediment effectively, whilst also avoiding excess sediment during the summer fish spawning and egg incubation periods. If monitoring shows that flushing has predictable results and does not cause significant issues for fish habitat then additional mitigation activities may not be required over the long term. If, however, monitoring shows that flushing negatively impacts fish habitat or connectivity, and mitigation is needed, then ongoing monitoring and management of the river channel may be required over a longer duration guided by the specialists.

When removing suspended sediments or bedload from upstream sediment traps or within the reservoir then consideration sediment augmentation techniques can be employed to effectively reallocate sediment from the sediment traps to downstream reaches in Zone 2. As no guidance exists for placement of the sediment along the channel bed or banks, guidance by specialists will be required. Placement may consider an in-channel stockpile, high-flow stockpile, point-bar stockpile or high-flow point injection (Figure 7-4). Decisions about placement must be site-specific and will depend on the volume and grain-size of the sediment removed the downstream sediment transport capacity, hydrograph characteristics, and local ecological considerations (Morris and Fan, 1998[26]). As this catchment is gravel dominated siltation of habitats is less of a concern and mechanical distribution of sediment can be undertaken to improve the stability of the channel bed and promote fluvial landforms.

[25] Kondolf, G. M., Gao, Y., Annandale, G. W., Morris, G. L., Jiang, E., Zhang, J., ... & Yang, C. T. (2014). Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents. Earth's Future, 2, 256-280

[26] Morris, G.L., & Fan, J. (1998). Reservoir sedimentation handbook: design and management of dams, reservoirs, and watersheds for sustainable use. McGraw Hill Professional

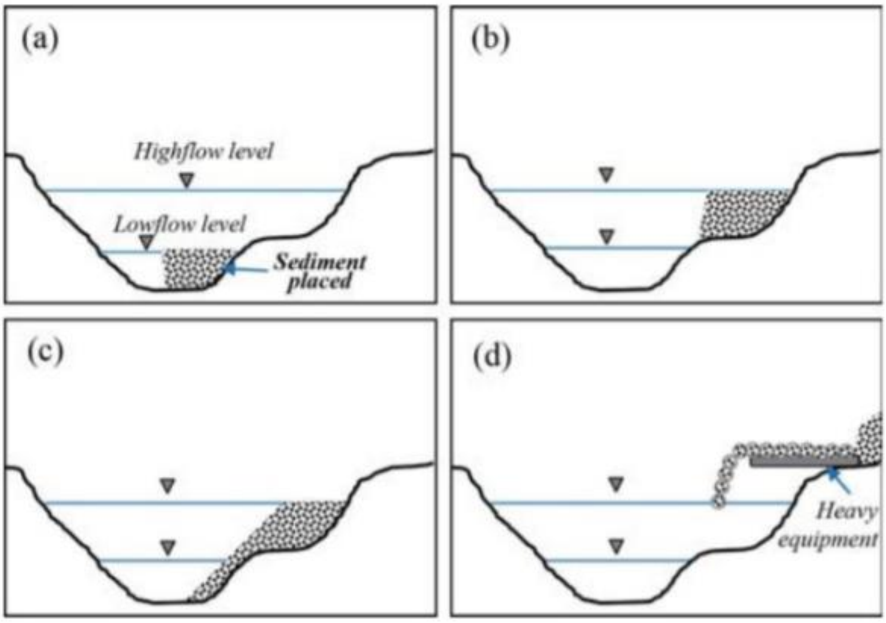


Figure 7-4 Sediment replenishment methods according to sediment placement or injection types (Source: Ock et al. 2013)

Site-specific monitoring of morphological change during the construction and operational phase is identified in Table 7-3.

Table 7-3 Site-specific sediment monitoring

Location	Method	Parameter	Frequency	
			Construction[27]	Operation[28]
Zone 0 sediment traps	Cross section survey to capture sediment accumulation within the streams	Morphology	Annual	Annual
		Turbidity	Daily following a flood event until measurements constant value	N/A
Zone 1 sediment traps	Cross section survey to capture sediment accumulation within the streams	Morphology	Annual	Annual
		Turbidity	Daily following a flood event until measurements constant value	N/A
Zone 1 reservoir	Bathymetry survey of sediment accumulation in reservoir	Bathymetry	Annual	Annual
		Suspended sediment	Immediately after flood event	Annual
		Bedload	Immediately after flood event	Annual
		Turbidity	Daily following a flood event until measurements constant value	N/A

[27] From the start of construction and up to 4 years after.

[28] From four years after construction.

Location	Method	Parameter	Frequency	
			Construction[27]	Operation[28]
Zone 2 Ub River	Downstream bedload and suspended sediment sampling	Suspended sediment	Annual	Annual
		Bedload	Annual	Annual
		Turbidity	Daily following a flood event until measurements constant value	N/A
	Site inspection after major events (i.e. spill from dam or sediment flushing release)	Morphology	N/A	Immediately after flood event
		Suspended sediment	N/A	Immediately after flood event
		Bedload	N/A	Immediately after flood event
		Turbidity	N/A	Daily following a flood event until measurements constant value

8. Summary of E Flow assessment

Baseline studies and modelling were conducted to assess current and predicted future (post-dam development) water quantity and quality of the Ub Catchment. This included assessing the change in water quantity and quality upstream and downstream of the proposed dam, which informed the Biodiversity Impact Assessment (**Book 4 Biodiversity Impact Assessment)**. The project has been screened against the World Bank EFlows decision tree, and it was concluded that a high-resolution assessment was required, that considers the assessment of water quality and quantity, connectivity, sediment and biodiversity. This chapter considers changes in water quantity / hydrology (Section 3), water quality (Section 4), and fluvial geomorphology / sediment (Sediment 5). The potential effects of these physical and physico-chemical changes are then assessed pre and post avoidance and/or mitigation measures in **Book 4 Biodiversity Impact Assessment**.

An important consideration was the assurance of the Serbian minimum flow (Qe) for downstream ecosystems during Phase 1 and Phase 2 of the dam operation, which is a legal requirement, and the predicted E Flow that will present in the River Ub based on the management of the reservoir during each phase.

Phase 1 of the Project involves the operation of Pambukovica dam for flood mitigation. The design and operation of the dam is such that there will be an 'environmental flow' pipe to deliver an EFlow beyond the Serbian minimum flow throughout the year. Phase 2 of the Project involves operation of Pambukovica for the dual purposed of flood mitigation and irrigation. The increased demand on stored water will be balanced against the Serbian minimum flow requirements. The residence time of stored water will be longer then for Phase 1, with implications for dam siltation and water quality.

The Impact Assessment and Mitigation included a screening of potential impacts during both construction and operation phases, as defined in the WEMMP. Key mitigation and monitoring actions were outlined, including:

- Pollution control strategies

- Water quantity disclosure and hydrograph monitoring
- Reservoir and downstream water quality monitoring
- Sediment yield reduction activities
- River connectivity and sediment management strategies

Biodiversity monitoring and mitigation are set out in the Biodiversity Management Plan (BMP) in **Book 4 Biodiversity Impact Assessment**.

It is considered that this chapter provides a holistic evaluation of the potential environmental and social impacts of the Pambukovica Dam project. It identifies key risks and proposes robust mitigation and monitoring plans to ensure compliance with national and international standards. The project is expected to deliver significant benefits in terms of flood risk reduction and water resource management / drought resilience.

9. Implications of the Project in relation to EU Directives and Transboundary Agreements and Management Plans

9.1 EU Directives

The Project has been assessed in alignment with the principles and objectives of key EU Directives, including the Water Framework Directive (WFD), Floods Directive, Environmental Impact Assessment (EIA) Directive, and Strategic Environmental Assessment (SEA) Directive. Although Serbia is not yet an EU Member State, it is a candidate country and has committed to harmonizing its national legislation with EU environmental standards.

The implications of the Project on these directives are as follows:

Water Framework Directive (WFD): The Project is not considered to preclude the achievement of good ecological or chemical status (or potential) of water bodies. The Project includes mitigation measures to avoid deterioration of water status. These include environmental flow releases, sediment management, and water quality monitoring. However, Article 4.7 of the WFD has been considered in light of the scale of change in the River Ub. Article 4.7 of the WFD makes provision for exemptions to the achievement of certain WFD objectives under certain circumstances. Exemptions may be invoked where there is a failure to prevent deterioration of status arising from new modifications or new sustainable human development activities where there are reasons of over-riding public interest, or where the benefits of achieving WFD objectives are outweighed by the benefits to human health, human safety or sustainable development. The Project is designed to ensure that any modifications are justified by overriding public interest (flood protection and irrigation), and no better environmental alternatives exist. It is considered that should such a be development be progressed in the EU, the requirements of Article 4.7 could be met.

Floods Directive: The Project directly supports the objectives of the Floods Directive by reducing downstream flood risk through controlled water retention and attenuation of high flows.

EIA Directive: The ESIA process has been conducted in accordance with EBRD PR1 and PR10, which incorporate the principles of the EIA Directive. Public consultation and disclosure have been integrated into the assessment process.

SEA Directive: While not directly applicable to project-level assessments, the Project aligns with the broader strategic planning objectives under Serbia’s Water Management Strategy and River Basin Management Plans, which are informed by SEA processes.

9.2 Transboundary Agreements and Management Plans

The Project is located within the Danube River Basin and the Sava River sub-basin, both of which are governed by international transboundary agreements:

Danube River Protection Convention (DRPC) and Danube River Basin Management Plan (DRBMP): Serbia is a contracting party to the DRPC and a member of the International Commission for the Protection of the Danube River (ICPDR). The Project aligns with DRBMP objectives by incorporating sediment management, ecological flow releases, and water quality protection measures. The Project is not considered to compromise the achievement of good status in other water bodies within the basin.

Framework Agreement on the Sava River Basin (FASRB) and Sava River Basin Management Plan (Sava RBMP): The Project supports the FASRB’s goals of integrated water management and sustainable use. The 2nd Sava RBMP (2022–2027) emphasizes sediment balance and hydromorphological restoration, both of which are addressed in the Project through sediment traps, erosion control, and adaptive reservoir operations.

Sava Sediment Management Plan: The Project contributes to the objectives of the ISRBC's sediment management protocol by reducing upstream erosion and managing sediment transport in a controlled manner, thereby minimizing downstream impacts.

The Project is not expected to undermine these agreements and is not considered to have significant adverse transboundary impacts. The ESIA has addressed this through hydrological and sediment modelling, biodiversity assessments, and mitigation strategies. The Project's design and operational rules are consistent with the principles of equitable and sustainable water use promoted by these agreements.