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Assessment of Impacts and Sustainable Practices in Sediment Management via the Verbois Dam

T. Rubin[1]
[1]University of Applied Sciences Geneva HES-SO
Corresponding authors: T. Rubin (e-mail: rubint@gmail.com).

Abstract This research thoroughly investigates the multifaceted challenges of sediment management at the Verbois Dam, a project that intersects technical, financial, social, and environmental dimensions. Recognizing the intricate nature of this task, the Services Industriels de Genève (SIG) adopted a holistic approach that transcends traditional hydraulic methodologies. The primary aim was to develop a comprehensive decision support tool that encompasses two integral components: an analysis grid for assessing effects and a grid for evaluating durability. These elements work in tandem to facilitate a detailed scrutiny and assessment of current sediment evacuation tactics. Additionally, the tool's adaptable architecture permits the exploration and refinement of novel management strategies. The findings of this study endeavor to make a substantial contribution to the sustainable handling of sediment in dam operations, effectively marrying technical efficacy with wider environmental and social considerations.

Index Terms dam, sediment management, analysis tool, impacts, durability

I. Introduction

This expansive study, initiated by Geneva Industrial Services (SIG) in partnership with the Territorial Department, represents a collaborative endeavor spearheaded by the Office of Works and Environmental Studies (BTEE) and B+C Engineers SA. It brought together a multidisciplinary team of six entities, including engineers and specialists in various fields. The study's primary objective was to establish a comprehensive decision-making framework for sediment management at the Verbois Dam. This framework was designed to facilitate informed decision-making by systematically identifying and evaluating key components of sediment management strategies [1].

Emphasizing a holistic approach, the study incorporated a detailed impact analysis and assessment module (illustrated in Figure 1). This module integrates various evaluation tools, including quantified evaluation grids complemented by informative graphical representations such as fever and radar curves. These tools provide a nuanced understanding of the environmental, technical, and socio-economic implications of sediment management practices.

Notably, the study abstains from endorsing specific strategies or providing weighted conclusions. Instead, it presents a transparent and objective analysis, offering a range of scenarios through meticulously commented and quantified data. This approach ensures that decision-makers are equipped with unbiased, comprehensive information, enabling them to consider a spectrum of possibilities and implications before arriving at sustainable and effective sediment management strategies [2].

Denominationas part of the study	Operation	Periodicity
Scenario 1 Triennial hunt	Flush drain (current management)	3 years
Scenario 1 bis Hunting every 6 years	Flush flushing in the fall (optimized current scenario, period, frequency)	6 years for example
Scenario 2 Passive	Liability without support measure	-
Scenario 2 bis Passive with intervention	Passive with maintenance of the Arve and/or Rhône (dredging, damming)	10-20 years?
Scenario 3Raw active	Lowering of 2 meters per flow rate > 620 m3/s (preliminary proposal from AquaVision)	~ 5 to 10 times / year
Scenario 3 bis Planned assets	Programmed lowering of 4 meters	1 year

Figure 1: Sediment removal scenarios from the Verbois dam (Services Industriels de Genève GIS basic data).

The outcome of this study is expected to significantly contribute to the field of sediment management, particularly in the context of dam operations. It provides a replicable model for addressing complex environmental challenges, balancing technical feasibility with ecological and societal considerations.

Traditional scientific and technical research focusing on flushing in the Geneva Rhône has predominantly concentrated on specific aspects such as fish survival and sediment quality. While these studies have been instrumental in deepening understanding of critical parameters and advancing sediment management techniques, they often fell short in providing an integrated perspective that encapsulates economic, societal, and environmental dimensions. Addressing this gap, our study undertakes a holistic analysis of various flushing-emptying

scenarios in the context of sustainable development. This approach emphasizes early risk detection and conflict identification, thereby enhancing strategies for sustainable progress [3].

To tackle the multifaceted nature of this challenge, a specialized expert group was convened. This group, comprised of seasoned professionals, undertook an objective evaluation of data and insights provided by the Services Industriels de Genève (SIG) and the Territorial Department. Their collective expertise facilitated a nuanced and comprehensive understanding of the intersecting factors influencing sediment management and its broader implications [4].

II. Material and Methods

The study progression follows distinct steps

Presentation of variants describing the main characteristics of sediment management methods. The methodology employed in this study involved a meticulous selection of domains and identifying key components, each influenced by various factors. This process entailed the careful selection of sustainability criteria, drawing upon the Swiss Federal Council's 2002 guidelines for sustainable development, while tailoring these criteria specifically to the nuances of flushing-emptying processes [5].

The study then proceeded with an in-depth analysis of effects, which offered valuable insights into the impacts and potential enhancements associated with different scenarios. This step was crucial in understanding the various implications of each variant under consideration.

Finally, the study conducted a comprehensive sustainability evaluation. This involved correlating the observed effects and identifying any conflicts, all within the tripartite framework of sustainable development. This evaluation aimed to discern the pros and cons of each project variant, while also pinpointing areas for potential improvement. By doing so, the study strived to present a balanced view, encompassing the intricate interplay of environmental, economic, and social factors integral to sustainable development.

III. Scenarios

The study encompasses six sediment management scenarios, with a detailed focus on three "main scenarios" subject to study and hydraulic modeling during Aquavision 2005 and Aquavision 2006. The remaining "bis" scenarios are interpreted by the interdisciplinary group [1], [2].

IV. State Reference, Limits, and Assumptions

The baseline for evaluation in this study is established using the post-emptying conditions of 2003, as primarily recorded in the 2003 Rhône monitoring report by Services Industriels de Genève [6]. The geographic and temporal scope of the research encompasses the segment of the Rhône in Geneva, stretching from the Junction to the Chancy-Pougny dam, with a focus on the post-2003 drainage conditions extending up to the year 2050. The hydraulic and morphological assumptions

Hydraulics, solid transport and sediments	Operation, maintenance and safety related to hydr exploitation
Deposits, useful volumes	Energy production (including production losses)
Bottom erosion	Equipment and maintenance
Bathymetry (maintaining flow template)	Equipment safety
Landslides and instability	Administrative synchronization with downstream works
Groundwater	Dam stability
River overflow	Operating costs
Sedimentary impact on French Rhône	
Nature, landscape and leisure	**Industry and shipping**
Riparian and aquatic flora	Operation of waterways and access to docks
Avifauna	Water intakes and discharges
Pisces	
Beavers	
Sites of special interest	
Water quality and MES	
Landscape perception and ecomorphology	
Fishing	
Hobbies	
Safety of the Rhône and its banks	

Figure 2: Determining components retained for the analysis of effects.

employed in this study are derived from documentation provided by AquaVision Engineering Sàrl. This includes insights from the AquaVision 2005 study, as well as findings from their summary report released in 2006 [6]. It is important to note that this study did not involve any new field investigations, as it was confined to the parameters of the given mandate.

V. Areas and Components Determining Factors

The study inventories elements potentially influenced by flushing scenarios, categorized into four main areas: Hydraulics, Solid Transport, and Sediments; Operation, Maintenance, and Safety; Industry and Navigation; Nature, Landscape, and Leisure. The consortium and steering group identified key points known as "determining components" (Figure 2), which are analyzed, evaluated, and commented upon during the effects analysis of different operating methods.

The chosen scale within this work is a homogeneous cardinal scale with an increment of 1 (or 0.5 when necessary) ranging from "-2" for the most negative effects to "+2" for the most positive effects. This scale is applied uniformly to all determining components, regardless of quantifiability.

For efficiency, a general analysis was chosen in this study due to time constraints, as it is impractical to present all elements systematically and rigorously in their quantitative and/or qualitative forms. Similarly, their transposition onto the cardinal scale involves indicators, standards, and benchmarks currently absent. It was also considered reasonable to justify the results of the expertise using key elements of the project and the context that strongly influence the criterion in question.

VI. Appreciation Value, Analysis, and Evaluation Methodology for Effects Analysis

The adopted rating scale is relative, accounting for the difference of one scenario compared to the others. The score magnitude reflects the change's magnitude, with a score of 0 corresponding to the 2003 post-emptying reference state, well-documented by the 2003 Rh'ne monitoring [6].

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Sustainability criteria	Scenario 1	Scenario 2	Scenario 3	Comments
Biodiversity	-1.5	+2	-2	The interval between three-yearly hunts does not allow the population to rebuild. Strong impact on piscivorous birds the following flushing. Preservation or even extension of reed beds with the abandonme hunting, as well as development of water-related bird populations. Repetition of hunts during the year (scenario 3) is harmful for all w related birds and beavers (frequency of disturbances).
Investments	+2	-2	+1	The chosen operating mode, with programmed flush, with flush "natural" and without flushing, induces investments linked to ro maintenance of equipment (scenario 1), major modificatio installations (scenario 2) and maintenance limited to the upper (scenario 3).

Figure 3: Extract from the sustainability analysis table.

	scenario 1 "three-year hunt"		scenario 2 "passive"		scenario 3 "active flood	
	Effects	Comments	Effects	Comments	Effects	Comments
Operation of waterways and access to docks	-0.5	Long-term raising of the bottom of the bed and reduction in the width of the channel (max. 20 m on current width of 120 m). Generally speaking, no major disruption to navigation (including access to landing stages). Navigation still possible but less easy (e.g. visibility in fog) due to the reduction in the width of the channel and the higher flow speeds. Raising the water level by max. 40 cm at the Junction.	- 1.5	The waterway after 48 years without emptying maintains depths of around 4 to 5 m over widths of around 50 m minimum. Formation of a preferential flow channel. Navigation still possible, but less easy (e.g. visibility in fog) due to the reduction in the width of the channel (60%) and the higher flow speeds. Access to landing stages potentially reduced (filling and raising the water line locally).	- 0.5	Long-term raising of the bottom and reduction in width of the channel, les significant than for scen 2. Navigation still possil but less easy (e.g. visib case of fog) due to the reduction in the width of channel and higher flow velocities. Generally speaking, no major atta on the navigation (including ac to landing stages).

Figure 4: Extract from the effects analysis table.

VII. Criteria Sustainability

The sustainability assessment utilized criteria based on the 2002 Strategy of the Federal Council, Central Indicators for the sustainable development of cities and cantons [5], and the thematic fields and indicators of the Bernese Compass for sustainable development [3]. Twelve sustainability criteria (4 per sustainable development dimension) were employed, each described in Figure 3.

VIII. Results and Analysis of the Effects of the 3 Scenarios

The analysis of effects presents results summarized in tables and an overall qualitative synthesis with fever curves (Figure 1). Due to space constraints, only an extract from the effects analysis table (Figure 4) is presented here to demonstrate the approach and form of analysis.

IX. Synthesis

Scenario 1 "Three-year Hunt"

Positive aspects include easier management of the Rhone and effective solid transport management, but with very negative impacts on wildlife.

Scenario 2 "Passive"

Environmental equilibrium is quickly reached, promoting biodiversity and leisure activities. Negative aspects involve operational and maintenance challenges and increased flood risks.

Scenario 3 "Active Flood"

Favorable for still water fish species, it limits flood risks but poses challenges to wildlife. Planning and safety during floods may cause coordination issues with Rh'ne users [4].

X. Scenario Optimization Track

Three optimization avenues for each scenario are defined post-analysis, aiming to resolve identified problems but necessitating additional studies and simulations for precise control of implications. This involves optimizing flushing, avoiding sensitive wildlife periods, and studying the implications of modifying the reservoir's flushing water tipping point.

XI. Conclusion

This exploratory study represents an initial phase in identifying key elements for optimizing sediment management from the Verbois dam. Utilizing current data, simulations, and expert opinions, the study tested the tool through analysis of three scenarios. While providing valuable insights, refinement of the scenarios is essential, incorporating alternative scenarios to approach an optimal and sustainable sediment management solution for the Rhône.

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