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River energy potential in the Swiss part of NWE

SHINES

**Showcasing Hydrokinetic energy Innovations
for Northwest European Energy Sovereignty**



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SHINES – Turning tidal and rivers into tomorrow's energy.

As Europe searches for local, sustainable alternatives to fossil fuels, SHINES (Showcasing Hydrokinetic Energy Innovations for Northwest European Energy Sovereignty) focuses on a powerful yet untapped natural force: tidal and river currents. Unlike wind and solar, these water flows are highly predictable and reliable making them the perfect complement to existing renewable energy sources.

This ambitious €10 million project, co-funded by the European Union through Interreg NWE, brings together 14 partners from 6 countries to test three innovative technologies in real-world conditions: RivGen, Hydro Wing, and TidalKite. Tests will take place in France and the Netherlands, with a clear goal: to prove that hydrokinetic energy can play a key role in Europe's energy transition.

Beyond demonstration, **SHINES will identify and de-risk the most promising sites in each partner country**, working hand in hand with local stakeholders to pave the way for the large-scale deployment of hydrokinetic solutions.

SHINES is about an entire region coming together to harness the steady power of water—turning rivers and tides into a clean, local, and shared source of energy for the future, efficiently using space and grid.

INTRODUCTION / EXECUTIVE SUMMARY

Hydrokinetic energy technologies convert the kinetic energy of flowing water into electricity without requiring significant civil infrastructure such as dams or large hydraulic head differences. In recent years, these technologies have reached an important level of technological maturity and are increasingly considered as a promising complement to conventional renewable energy sources. Unlike solar and wind power, river and tidal currents offer highly predictable generation profiles, which can contribute to improving grid stability and supporting Europe's long-term decarbonisation objectives.

Within this context, the SHINES project (Showcasing Hydrokinetic Energy Innovations for Northwest European Energy Sovereignty) aims to accelerate the deployment of hydrokinetic technologies across Northwest Europe by demonstrating innovative solutions, identifying high-potential sites, and reducing technical, regulatory and market barriers. The project brings together 14 partners from six countries and focuses on both tidal and river applications.

As part of Work Package 2 (Market development and business case validation), HES-SO Valais-Wallis / HEI is responsible for assessing the hydrokinetic potential of the Swiss part of the North-West Europe area, with a specific focus on the cantons of Valais and Geneva. Particular attention is given to both:

- Natural river sections with sufficient flow velocity, and
- Artificial waterways such as headrace channels, tailrace channels and other hydraulic infrastructures associated with hydropower schemes.

This approach is particularly relevant in Switzerland, where the dense hydropower infrastructure network may offer favourable conditions for hydrokinetic deployment while limiting environmental impacts compared to installations in natural river sections.

The present deliverable focuses on the first stage of this assessment: identifying the theoretical hydrokinetic resource available in Swiss rivers and artificial channels. Historical hydrological datasets, hydraulic characteristics and geographical information are combined to estimate flow velocities and associated kinetic energy potential.

Following this first screening phase, the most promising sites will be selected for further analysis in subsequent project tasks. These additional investigations will include:

- Technical feasibility assessments,
- Estimation of mechanical and electrical production potential.

The final objective is to contribute to the development of a regional hydrokinetic resource atlas for Northwest Europe and support future deployment strategies for hydrokinetic technologies in Switzerland.

The results of this work package show that the theoretical hydrokinetic resource in the Western part of Switzerland, and particularly within the Canton of Valais, is predominantly concentrated in the Rhône River. In addition, several artificial waterways associated with existing hydropower schemes exhibit relatively significant hydrokinetic potential, confirming their interest as promising locations for a future deployment. Overall, the total theoretical hydrokinetic energy potential identified in the investigated

Swiss river sections and hydraulic infrastructures of the Cantons of Geneva and Valais is estimated at approximately 200 GWh/year, providing a solid basis for the subsequent techno-economic assessment and the development of the Swiss contribution to the SHINES hydrokinetic resource atlas.

TABLE OF CONTENT

1	Background	7
1.1	General aspects of the hydrokinetic energy.....	7
1.2	State of the art of hydrokinetic potential assessment	8
1.3	Hydrokinetic turbines performance, operation and limitations.....	9
2	Methodology	12
2.1	Identification of main river stretches and tributaries.....	12
2.2	Global methodology	14
2.3	Input data description	15
2.4	Model HEC-RAS	17
2.4.1	River Model	17
2.4.2	Rating curves database	18
2.5	Discharge model.....	19
2.5.1	Year-long discharge profile	19
2.5.2	Estimation of the tributary contributions.....	19
2.5.3	Discharge model calibration.....	20
2.6	Potential Energies.....	22
2.6.1	Theoretical potential energy.....	22
2.6.2	Technical potential energy.....	22
2.7	Resulting outputs.....	23
3	Results and analysis.....	24
3.1	Hydrokinetic potential of the Canton of Valais	24
3.1.1	Global hydrographic maps	24
3.1.2	Numerical model calibration and validation	26
3.1.3	Estimation of the yearly discharge distribution	29
3.1.4	Resulting estimated hydrokinetic energy of natural rivers.....	31
3.1.5	Resulting estimated hydrokinetic energy of artificial channels.....	37
3.2	Hydrokinetic potential of the Canton of Geneva	45
3.2.1	Global hydrographic maps	45
3.2.2	Numerical model calibration and validation	45

3.2.3	Estimation of the yearly discharge distribution	47
3.2.4	Resulting estimated hydrokinetic energy of natural rivers.....	48
3.2.5	Resulting estimated hydrokinetic energy of artificial channels.....	53
3.3	Atlas rendering.....	54
3.3.1	Canton of Valais	54
3.3.2	Canton of Geneva	54
3.4	Discussions.....	56
4	Conclusions and perspectives.....	58
4.1	Conclusions	58
4.2	Perspectives	59
	Acknowledgements	60
	References	61
	Appendix.....	63

1 Background

1.1 General aspects of the hydrokinetic energy

Hydrokinetic energy consists in converting the kinetic energy of flowing water into electricity without requiring significant hydraulic head or major civil infrastructure. Unlike conventional hydropower plants, hydrokinetic systems extract energy directly from water currents using submerged turbines installed in rivers, tidal streams, canals or other hydraulic infrastructures.

The theoretical kinetic power available in a water flow can be expressed as:

$$P_h = \frac{1}{2} \rho \cdot A \cdot C_{ref}^3 \quad (1)$$

where:

P_h is the theoretical kinetic power available in the flow

ρ is the water density

A is the cross-section of the river or artificial channel

C_{ref} is the reference water velocity.

This relationship highlights the major influence of flow velocity, as the available power increases with the cube of velocity. Consequently, hydrokinetic projects require locations with sufficiently high and stable flow velocities to become technically and economically viable.

Compared with conventional hydropower, hydrokinetic systems offer several potential advantages:

- Limited civil engineering works
- Reduced environmental footprint
- Modular deployment possibilities
- Valorisation of existing hydraulic infrastructures
- Suitability for isolated or distributed electricity generation.

However, hydrokinetic technologies also face several challenges:

- Relatively low energy density compared with conventional hydropower
- Sensitivity to seasonal flow variations
- Debris transport issues
- Maintenance accessibility constraints
- Uncertainties regarding long-term economic profitability.

Hydrokinetic technologies have mainly been developed for tidal applications in countries such as the United Kingdom, France and Canada, but river applications are increasingly being investigated, particularly in artificial channels where hydraulic conditions are more stable and predictable.

1.2 State of the art of hydrokinetic potential assessment

Assessing hydrokinetic potential requires identifying locations where sufficient kinetic energy can be extracted while considering hydraulic, technical, environmental and economic constraints. Most hydrokinetic resource assessments are typically conducted through successive evaluation levels:

- Theoretical potential, corresponding to the total kinetic energy available in flowing water;
- Technical potential, considering turbine operational constraints and installation feasibility;
- Economic potential, considering investment costs, maintenance requirements and expected revenues.

Different methodologies have been developed in the literature to estimate hydrokinetic resources, including GIS-based screening tools, hydrological database analysis, field measurements, hydraulic modelling and multi-criteria approaches.

While many international studies focus on tidal currents or large river systems, Switzerland presents a specific context where hydrokinetic opportunities are more likely to be found in artificial hydraulic infrastructures connected to conventional hydropower schemes.

A first important contribution was made by Münch-Alligné et al. in Water (2018) [1] where the feasibility of hydrokinetic deployment in Switzerland was investigated through experimental tests performed at the Lavey hydropower plant. The study evaluated the integration of a hydrokinetic turbine installed in the tailrace channel of a hydropower plant under real operating conditions. The objective was to assess whether residual kinetic energy downstream of existing hydropower facilities could be valorised. The experimental campaign highlighted several important findings:

- Artificial channels provide relatively stable and predictable flow conditions;
- Existing electrical infrastructure facilitates grid connection;
- Installation and maintenance accessibility is generally better than in natural rivers;
- Residual kinetic energy can be exploited without modifying the primary hydropower operation.

However, the study also identified important limitations:

- Relatively low flow velocities in certain operating conditions;
- Economic profitability remains highly dependent on turbine costs;
- Debris management remains an operational concern;
- Site-specific hydraulic constraints strongly influence feasibility.

The conclusions of this work showed that artificial channels associated with hydropower infrastructures represent one of the most promising hydrokinetic opportunities in Switzerland.

This work was further extended through the bachelor thesis of Damien Pettinaroli [2], which investigated hydrokinetic deployment opportunities downstream to the Chancy-Pougny hydropower scheme, operated by Services Industriels de Genève.

This project focused on evaluating the installation of multiple hydrokinetic turbines in the outlet channel through numerical simulations. The study analysed:

- Velocity distributions;
- Turbine positioning;
- Wake interactions between turbines;
- Energy production optimisation;
- Operational constraints related to existing infrastructure.

The numerical simulations demonstrated that turbine positioning has a significant impact on overall energy production due to wake effects between machines. The study also confirmed that artificial channels may offer attractive deployment opportunities when hydraulic conditions are sufficiently favourable. These previous studies provided strong technical foundations for hydrokinetic development in Switzerland. However, they remained focused on individual infrastructures and local case studies.

A comprehensive regional assessment methodology capable of identifying hydrokinetic opportunities across a wider territory was still missing.

The SHINES project addresses this gap by scaling up previous local investigations to the regional level through a systematic assessment of hydrokinetic resources across the Cantons of Valais and Geneva.

1.3 Hydrokinetic turbines performance, operation and limitations

Although hydrokinetic resources can be estimated from hydraulic conditions, the actual energy production of a hydrokinetic installation strongly depends on turbine performance, operational constraints and site-specific limitations. The mechanical and electrical power effectively produced by a hydrokinetic turbine can be expressed as:

$$P_{mec} = C_p \frac{1}{2} \rho \cdot A_t \cdot C_{ref}^3 \quad (2)$$

$$P_{elec} = \eta_{e-m} \cdot P_{mec} = \eta_{e-h} \cdot P_h \quad (3)$$

where:

C_p is the turbine power coefficient

A_t is the cross-section of the turbine

η_{e-m} & η_{e-h} represents the generator electromechanical efficiency and the global hydroelectrical efficiency respectively.

While the theoretical resource depends only on flow conditions, the actual power output is significantly lower due to technological and operational losses.

Turbine performance factors

Hydrokinetic turbine performance is strongly influenced by:

- flow velocity magnitude
- turbulence intensity
- flow uniformity
- turbine design
- rotor diameter
- blade profile
- control strategy

Because available power increases with the cube of velocity, even small variations in flow velocity can significantly affect production. Turbines also operate within specific velocity ranges:

- below cut-in velocity → no production
- nominal velocity range → optimal production
- above maximum velocity → shutdown may be required for safety reasons

Operational constraints

Several operational challenges affect hydrokinetic systems:

- Debris and sediment transport

Floating debris, vegetation and sediment transport may:

- damage turbine blades
- reduce efficiency
- increase maintenance frequency
- require additional protection systems.

This issue is particularly relevant in natural rivers but may also occur in artificial channels.

- Cavitation risks

High rotational speeds or local pressure drops may generate cavitation phenomena, leading to:

- blade erosion
- vibration issues
- reduced turbine lifespan.

Maintenance accessibility

Submerged systems often require:

- difficult interventions
- shutdown periods
- lifting equipment
- increased operational costs

Artificial channels generally offer better accessibility than natural river installations.

➤ Seasonal variability

River discharge variations may strongly affect annual production. Low-flow periods may reduce profitability, while flood events may require turbine shutdown.

➤ Multi-turbine interactions

When multiple turbines are installed in the same site, wake effects may reduce downstream turbine performance. Previous simulations conducted in the work of Damien Pettinaroli demonstrated that turbine spacing and positioning significantly influence overall farm efficiency. These interactions must be considered when evaluating large deployment opportunities.

➤ Economic limitations

Despite promising technical opportunities, hydrokinetic technologies remain less mature than conventional hydropower, solar or wind power. Current limitations include:

- high installation costs
- relatively low unit power output
- uncertain maintenance costs
- limited industrial standardisation.

These limitations explain why hydrokinetic potential assessments generally move progressively from theoretical potential to technical potential and finally economic potential, which is precisely the approach followed in the SHINES project.

2 Methodology

2.1 Identification of main river stretches and tributaries

The identification of the hydrokinetic potential focuses on two of the 26 cantons in Switzerland: Geneva and Valais. Their locations are highlighted in red in **Figure 1**.



Figure 1. Main Swiss hydrographic network with indication of the Geneva (left red zone) and Valais (right red zone) Cantons retained for the identification of hydrokinetic potential, Swiss Federal Statistical Office [3].

The main river stretches and tributaries in the Canton of Valais are shown in **Figure 2**. The Rhône River is the principal watercourse, flowing from the Rhône Glacier to the Geneva Lake. Its main tributaries are torrents from the Alps mountains. In addition, the locations of the 6 hydrological gauging stations of the Swiss Federal Office for the Environment (FOEN) are shown. Measurements of discharge and water depth are available and used to calibrate the river numerical model.

Similarly, **Figure 3** shows the main river stretches and tributaries for the Canton of Geneva. The main rivers are the Rhône and the Arve Rivers. The tributaries are creeks with discharges much smaller than the Rhône and the Arve Rivers.



Figure 2. Main river stretches and tributaries (cyan lines) in the Canton of Valais [4]. The main lakes are shown by a filled cyan colour and a black contour line. The locations of the FOEN hydrological gauging stations are shown by a circle filled by a green colour and a red colour contour line. The names of the 6 stations, starting from the lightest colour representing the beginning of the Rhône River to the Geneva Lake, are: Gletsch, Reckingen, Brig, Sion, Branson and Porte du Scex. The black line represents the boundary of the Canton of Valais.

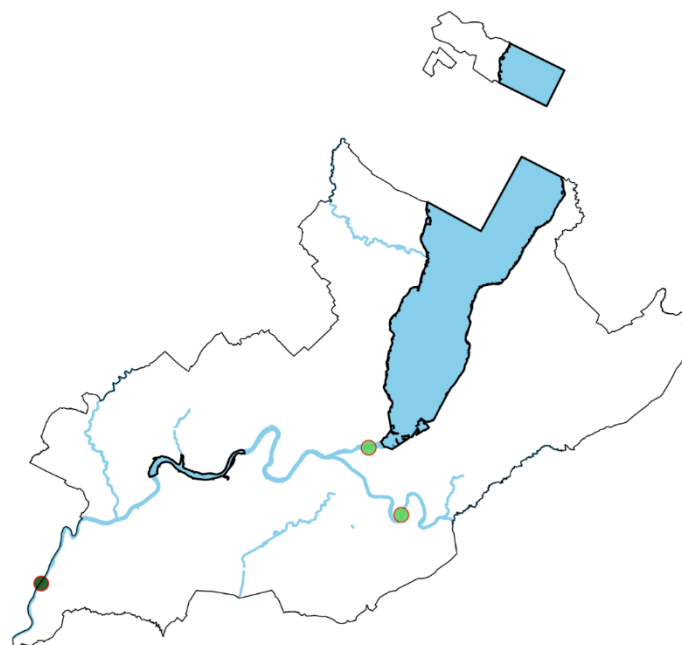


Figure 3. Main river stretches and tributaries (cyan lines) in the canton of Geneva [4]. The locations of the FOEN hydrological gauging stations are shown by a circle filled by a green colour and a red colour contour line. The canton has 3 stations. The first is at the Halle de l'île located downstream the Geneva Lake. Another one is located on Arve River (bottom right) and called Bout du Monde, the last one (bottom left), is near the end of the Rhône River in the canton and is called Aux Ripes. The black line represents the boundary of the Canton of Geneva.

2.2 Global methodology

The methodology developed in this study is illustrated by a flowchart shown in **Figure 4**. This methodology can be decomposed into four parts.

- The first stage involves collecting all the data required for the analysis. The diverse types of data and their respective sources are described in Section 2.3.
- The second stage focuses on modelling the river using the HEC-RAS software [5]. The process begins with the development of hydraulic model, see Section 2.4.1, which is subsequently used to generate a database of rating curve, see Section 2.4.2.
- The third stage consists of establishing a representative year-long discharge model for the river, its tributaries and any artificial channels considered in the study. The methodology used to construct this discharge model is presented in Section 2.5.
- Finally, the fourth stage combines the outputs of the hydraulic model and the discharge model to estimate the theoretical and technical potential energy available within the studied river system, as described in Section 2.6.

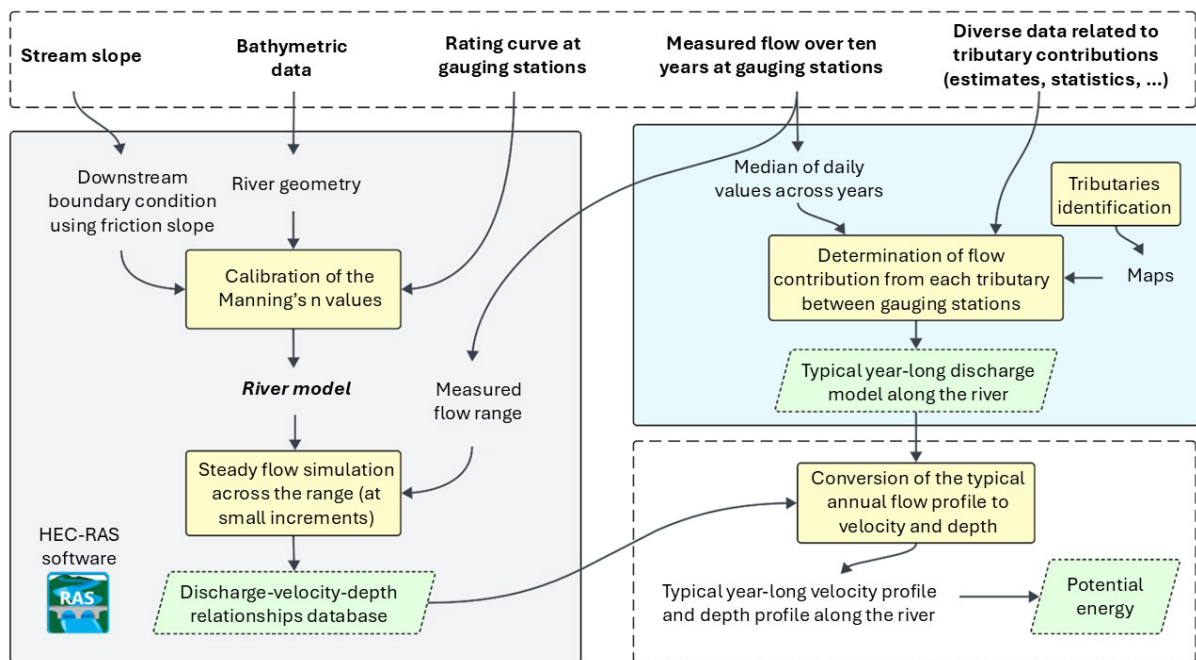


Figure 4. Methodology flowchart to assess the theoretical energy of river.

2.3 Input data description

For each of the two case studies (the Cantons of Valais and Geneva respectively) retained for Switzerland, a considerable effort has been made to collect several datasets, indispensable for characterizing the flow in the natural rivers and artificial channels. The list of the main input data collected for the Valais case study is provided in [Table 1](#), whereas for the Geneva test case it is provided in [Table 2](#).

Table 1. List of available input data used for the analysis on the Wallis case study.

Variable	Location	Time period	Data type	Source
Spatial coordinates (latitude, longitude, altitude)	Rhône River axis and confluences	Mars 2025	swissTLM3D	swisstopo, [6]
Bathymetry of cross sections, average riverbed width and altitude	Multiple sections from Reckingen to Léman lake	06.11.2018 15.04.2025	-	Swiss FOEN – Hazard prevention division
Discharge	Hydrometric stations	01.01.2014 23.06.2025	Daily values	Swiss FOEN – Hydrology division, [7]
Water level	Hydrometric stations	01.01.2014 23.06.2025	Daily values	Swiss FOEN – Hydrology division, [7]
Tributary regulatory extracted discharge	Tributary catchments	-	Average monthly values	Swiss FOEN, [9]
Tributary discharge	Different Rhône tributaries	1981-2000	Average monthly values	Swiss FOEN, [10]
Turbined annual volumes	Different tributary powerplants	2017-2025	Average yearly values	Swiss SFOE, [11]

As illustrated in [Figure 2](#) and [Figure 3](#), the main watercourse flowing through these two Swiss cantons is the Rhône River. Several natural and artificial tributaries were also identified. However, due to their relatively small average depth, which generally makes them unsuitable even for small hydrokinetic turbines, only their downstream contribution to the Rhône River was considered in the study. In addition, the Rhône River reach between Reckingen and Brig was excluded from the analysis because its average water depth is typically less than 1 m, primarily due to the combined effects of the river morphology and water diversions associated with several run-of-river hydropower plants. Finally, the Arve River was also included in the analysis within the Canton of Geneva.

Focusing on the Valais case study, the spatial coordinates of the Rhône River axis and confluences were extracted from the open swisstopo [6] platform in swissTLM3D format. The bathymetry of the cross sections, as well as the average riverbed width and altitude, were then obtained from the Hazard Prevention Division of the Swiss Federal Office for the Environment (FOEN) for no fewer than 1'050 sections distributed along the river from Oberwald (close to the Rhône source) to the Geneva Lake, at intervals of 200 to 300 m.

The daily discharge and water-level values from 2014 to 2025 at five hydrometric stations were obtained from the Hydrology Division of FOEN.

The legally prescribed extracted average monthly discharges ((i.e., the volumes of water diverted from the Rhône River) and the average monthly discharges of each tributary for the period 1981–2000 were also obtained from the Swiss Federal Office for the Environment (FOEN). Finally, the annual turbinated volumes of the main tributary hydropower plants from 2017 to 2025 were obtained from the Swiss Federal Office of Energy (SFOE).

Table 2. List of available input data used for the analysis on the Geneva case study.

Variable	Location	Time period	Data type	Source
Spatial coordinates (latitude, longitude, altitude)	Rhône river axis and confluences	Mars 2025	swissTLM3D	swisstopo, [6]
Bathymetry of cross sections	Integral scanned riverbed of the Rhône River from Halle de l'Île to the French border	-	-	Services Industriels de Genève
Bathymetry of cross sections	Multiple sections on the Arve River	29.02.2024	Lidar	Office cantonal de l'eau, Genève
Discharge	Hydrometric stations	01.01.2014 23.06.2025	Daily values	Swiss FOEN – Hydrology division, [7]
Water level	Hydrometric stations	01.01.2014 23.06.2025	Daily values	Swiss FOEN – Hydrology division, [7]

For the Geneva test case, the spatial coordinates of the Rhône River centreline and confluences were again extracted from the open access swisstopo [6] platform. The bathymetry of the Rhône River from Geneva Lake to the French border was obtained from Services Industriels de Genève, while bathymetric data for 18 cross sections of the Arve River were obtained from the Office cantonal de l'eau of Geneva. Finally, the daily discharge and water-level values from 2014 to 2025 at two hydrometric stations were obtained from the Hydrology Division of FOEN.

Regarding the final techno-economical assessment of the hydrokinetic potential estimation, the specifications of the smallest hydrokinetic turbine adapted to rivers developed by ORPC Ireland (see recent towing tank test results in Falchi et al. [12]) as well as the hydrokinetic turbine prototype developed by HES-SO VS in 2018 (see Münch-Alligné et al. [1]) are considered.

2.4 Model HEC-RAS

2.4.1 River Model

River modelling was performed using the HEC-RAS software, which provides several components for hydraulic river analysis. In this study, the steady flow water surface profiles component was selected, as it can simulate water surface profiles under subcritical, supercritical and mixed flow regimes [8].

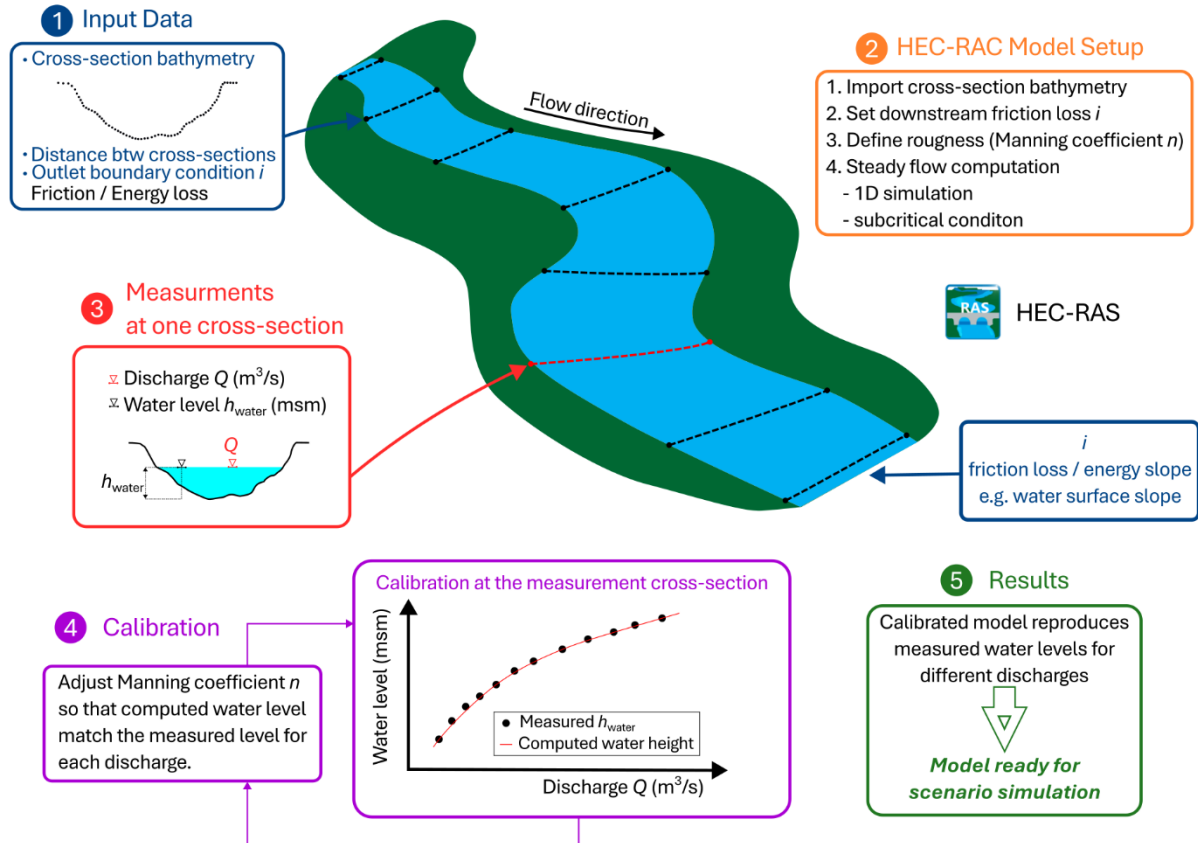


Figure 5. Setup of the HEC-RAS river model using the one-dimensional steady flow water surface profile computations component.

The methodology to build the river model is illustrated in **Figure 5** and requires the following inputs:

- the cross-section bathymetry,
- the longitudinal distance between each bathymetry,
- the Manning coefficient,
- the friction loss at the outlet boundary, i.e. at the last bathymetry location.

To simulate the flow behaviour of a river or artificial channel, the software solves the one-dimensional energy equation [8]. The energy losses due to friction are evaluated using the Manning's equation stating that:

$$C = \frac{1}{n} R_h^{2/3} \sqrt{i}, \quad (4)$$

where C (m/s) is the cross-sectional average velocity, n (s/m^{1/3}) is the Manning coefficient, R_h (m) is the hydraulic radius and i (m/m) is the stream slope.

Based on Eq. (4), the hydraulic model requires two user-defined parameters. One is the channel bed slope i which was estimated using the swisstopo swissALTI3D model [13]. The second one is the Manning roughness coefficient n . This coefficient was calibrated using discharge and water-level measurements collected at one reference cross-section. For each measured discharge, the Manning coefficient was manually adjusted until the computed water level matched the corresponding measured value. Once this calibration procedure was completed, the hydraulic model was ready to simulate the different operating scenarios.

2.4.2 Rating curves database

Once the river model validated, it can be used to generate the database providing the relationship between the cross-sectional average velocity or water height with regards to the discharge. An example of the HEC-RAS model with its expected output is given in **Figure 6**. It shows the model in the Canton of Valais between Sierre and Geneva Lake.

The model solved the steady subcritical flow behaviour for the expected range of discharge occurring in this river. These simulations generate the required database providing at each cross-section bathymetry the two rating curves as shown on the two left graphs in **Figure 6**.

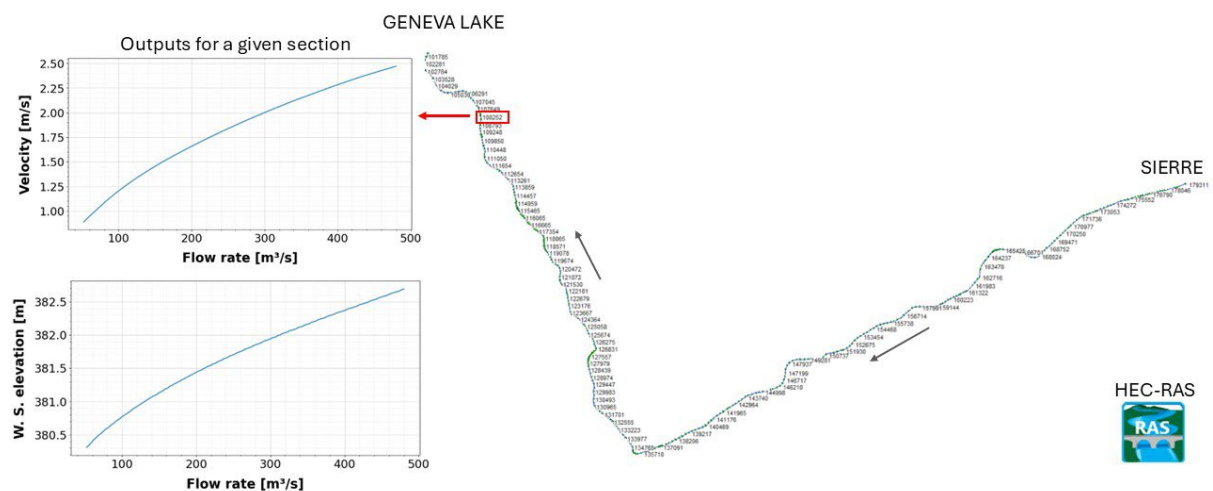


Figure 6. Example showing the model HEC-RAS between Sierre and Geneva Lake – Valais case study. Each green dot with its identification number represents a cross-section bathymetry of the Rhône River. The graphs show, for a given cross-section, the resulting relationship between velocity and flow rate, and between water level and flow rate.

2.5 Discharge model

2.5.1 Year-long discharge profile

The objective of the discharge model is to estimate the flowrate expected in the modelled river throughout a typical year-long. For main rivers, long-term discharge records are generally available, as there are routinely monitored for hydrological and flood management purposes. When such data are available, a representative year-long daily discharge profile is constructed by grouping the historical flowrate records according to the day of the year. For each calendar day, the discharge values from all available years are sorted, and the median value is selected as the representative daily discharge. This approach preserves the seasonal evolution of the river discharge while reducing the influence of extreme hydrological events. Such extreme events should be considered when designing a machine or establishing its operating range. However, since the objective of this study is to estimate the hydrokinetic potential under typical operating conditions, they are intentionally excluded from the analysis.

To estimate the discharge evolution between hydrological gauging stations, the contributions of the tributaries must also be modelled. The methodology adopted for this purpose is presented in the following subsections.

2.5.2 Estimation of the tributary contributions

2.5.2.1 Methodology overview

The methodology employed to model the tributaries daily discharge contribution relied on the estimation of the annual volume of water flowed in the tributary, see [Figure 7](#).

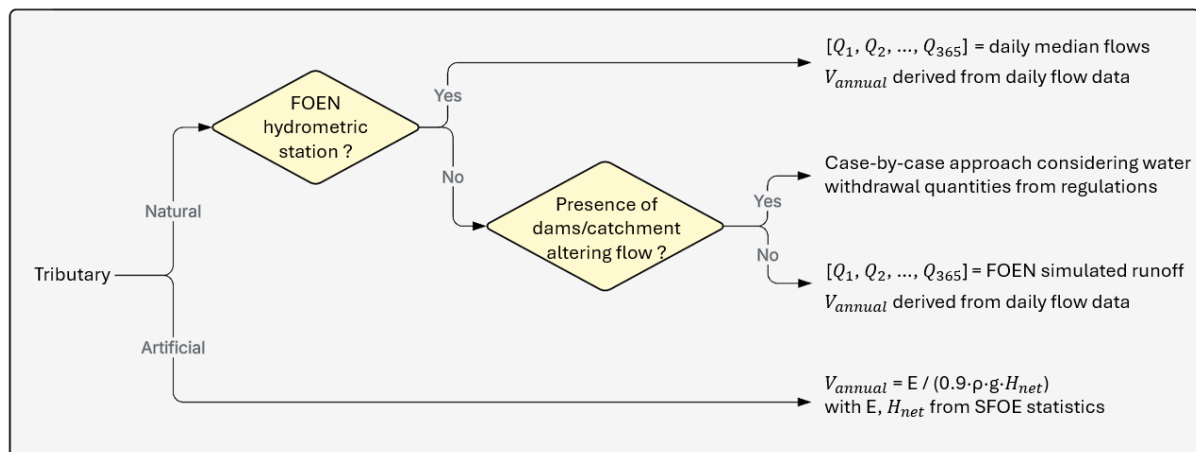


Figure 7. Methodology flowchart for estimating tributary contributions.

2.5.2.2 Natural tributary flow with a hydrometric station

The first step consists of identifying all tributaries equipped with a hydrometric station. For these tributaries, the typical yearly discharge profile can easily be estimated using the time history of the daily discharge. Using 10 years of historical data, the typical discharge for each day was constructed by taking the median discharge for that specific day. Then, the annual volume of water was obtained by integrating these median daily discharges.

2.5.2.3 Natural tributary flow without a hydrometric station

The second step consists of identifying the tributaries that are not equipped with a hydrometric station, which are separated into two categories. These two categories are used to separate catchment basin with and without dams or catchment altering the flow.

For catchment basin unaffected by dams or flow-regulating structures, the simulated data provided by FOEN [10] are used. These simulated data are monthly natural discharge within a catchment basin. As a first approximation, these monthly volumes are linearly divided into daily volume, representing the simulated monthly volume evolution.

In the opposite, for catchments influenced by dams or other flow-regulating structures, an additional analysis is carried out to identify how the water resources are utilized, in particular which hydropower plant receives the diverted water. Since most of the powerplant are located near the main river, i.e. the Rhône River, the contribution of the catchment basin with a dam or catchment altering the flow will be considered in the last step of this methodology, i.e. artificial tributaries.

2.5.2.4 Artificial tributary flow

The last step is the identification of artificial tributaries. These tributaries are tailrace channels of hydropower plants. To estimate the annual volume of water, the following equation is used:

$$V_{\text{annual}} = \frac{E}{\eta_{\text{glob}} \cdot \rho \cdot g \cdot H_{\text{net}}}, \quad (5)$$

with E (Wh) the annual energy production, ρ the water density (kg/m^3), g the gravitational acceleration (m/s^2), η_{glob} (-) the global efficiency of the hydropower plant and H_{net} (m) the net head of the hydropower plant. For this study, the global efficiency was assumed to be 90%. The annual energy production as well as the net head are obtained from the statistics given by the SFOE [11].

2.5.3 Discharge model calibration

2.5.3.1 Annual volume calibration

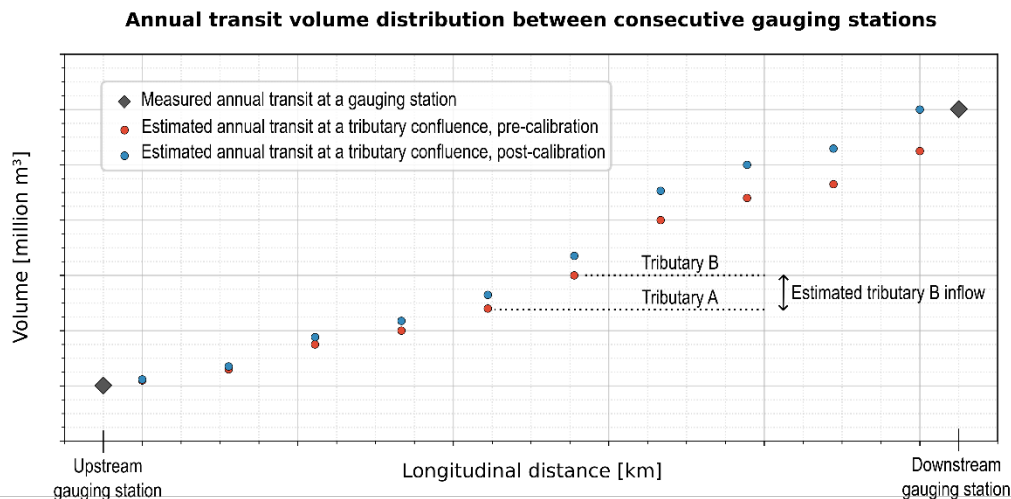


Figure 8. Example of the tributaries annual volume calibration to fit the measured volume along the river path.

The methodology introduced above is a first estimation of the evolution of the daily discharge during one typical year along the path of the river. However, as expected, this approach cannot accurately achieve it. As shown in **Figure 8**, if one look at the evolution of the annual volume flowing in the river between two hydrological gauging stations (see red points), the annual volume doesn't reach the one measured at the downstream hydrological gauging station. Therefore, since the measurements at the hydrological gauging stations are considered accurate, a proportional ratio is applied to all tributaries between the two hydrological gauging station to fit the main river measured data, see blue points in **Figure 8**.

2.5.3.2 Artificial tributaries daily discharge calibration

Based on the previous step, the annual volumes of natural and artificial tributaries are available. From the methodology flowchart introduced in **Figure 7**, an estimation of the daily discharge for the natural tributaries is already available. However, to fulfil the requirement of conservation of the mass shown in **Figure 8**, the ratio used to correct the annual volume is applied to the daily discharge. Therefore, it remains to estimate the daily contribution of the artificial tributaries, i.e. the contribution of the hydropower plants.

The approach selected to distribute the artificial tributaries annual volumes into daily discharge is shown in **Figure 9**. The studied river is decomposed into stretches bounded by hydrological gauging station, see the left most figure in **Figure 9**. The following figure on the right, shows the daily discharge measured between these two hydrological gauging stations. The observed daily discharge difference represents the contribution of the tributaries. Since, the daily discharge for natural tributaries is already known, their contributions are summed up as shown by the salmon-pink and blue colours shaded areas. The remaining area represents the contributions of the artificial tributaries. According to their annual volume contributions, the volume is distributed proportionally along the year, see the gold and purple colours areas.

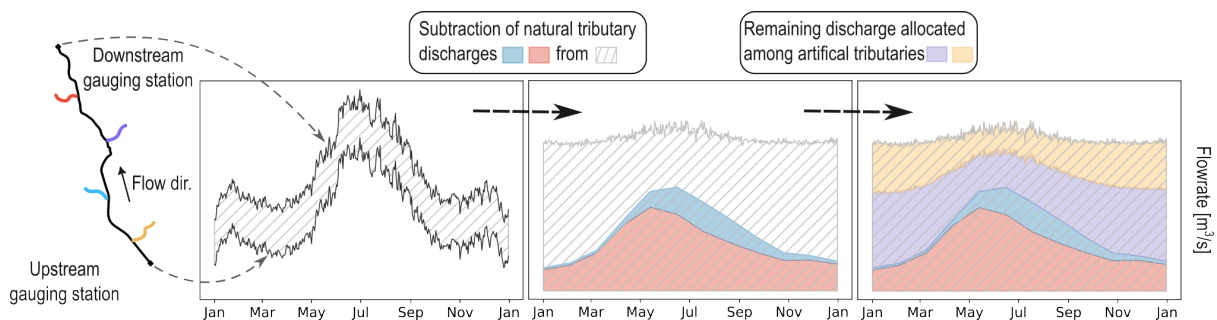


Figure 9. Methodology selected to distribute the artificial tributaries annual volume into daily volume.

2.6 Potential Energies

2.6.1 Theoretical potential energy

The assumptions adopted to estimate the theoretical hydrokinetic potential at a given river cross-section are summarized in **Figure 10** for both natural rivers and artificial channels. Accordingly, the full wetted cross-sectional area, denoted by A , is considered to calculate the average discharge velocity C (see Eq. (6)).

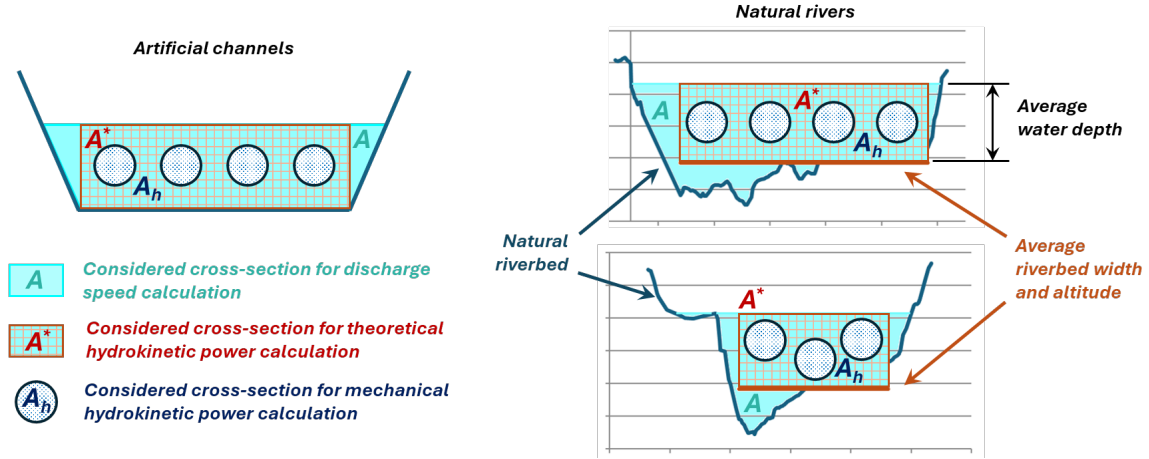


Figure 10. Definition of reference cross-sections for discharge speed and hydrokinetic power calculations.

Assuming that using the full cross-section to estimate the hydrokinetic energy is not feasible due to its complex geometrical shape, a simplified rectangular area A^* has been defined using the average riverbed width and water depth. This rectangular area A^* was used to calculate the annual theoretical hydrokinetic energy E_{kin} (eq. (7)), by integrating the available temporal data.

$$C = Q/A - \text{discharge speed (m/s)} \quad (6)$$

$$E_{kin} = \int_0^T \frac{\rho \cdot A^* \cdot C^3}{2} dt / 3.6 \cdot 10^6 - \text{theoretical hydrokinetic energy (kWh)} \quad (7)$$

The resulting theoretical average hydrokinetic power is then calculated as:

$$P_{kin} = E_{kin} / (24 \cdot 365) - \text{theoretical average hydrokinetic power (W)} \quad (8)$$

2.6.2 Technical potential energy

For a given number of hydrokinetic turbines installed within a section, the total recovered mechanical energy E_{mec} (see eq. (9)) can be derived from the theoretical energy by considering a blockage factor β (defined in eq. (10) as the ratio between the total inlet area of the considered hydrokinetic turbines, A_h , and the previously defined area A^*) and the power coefficient c_{p_max} provided by the turbine manufacturer.

$$E_{mec} = \beta \cdot c_{p_max} \cdot E_{kin} - \text{total recovered mechanical energy (kWh)}, \quad (9)$$

with $c_{p_max} < 0.59$ (-) the maximum power coefficient (according to Betz limit).

$$\beta = A_h / A_* - \text{hydrokinetic blockage factor (-)} \quad (10)$$

Finally, the resulting total recoverable electrical energy can be obtained as:

$$E_{elec} = \eta_{e-m} \cdot E_{mec} - \text{total recovered electrical energy (kWh)}, \quad (11)$$

with η_{e-m} (-) the electric-mechanical efficiency.

Regarding the distribution of turbines along the river/channel, a minimum spacing of $20 \cdot D$ is considered necessary (see Laws and Epps, 2016 [14]) to allow recovery of the flow velocity in the wake of a hydrokinetic turbine. For this study, the minimum spacing between two consecutive sections is thus considered as 20 times the average riverbed width, which, for the Rhône River, corresponds to approximately 1 km. For the analysed artificial channels (e.g., headrace or tailrace channels of existing run-of-river power plants), the resulting longitudinal spacing considered differs from case to case depending on the geometry of their cross-sections.

2.7 Resulting outputs

Following the described methodology, the main outputs consist, first, of a global hydrographic map of the Rhône River and its major natural and artificial tributaries, together with a numerical database containing all spatio-temporal values associated with each cross-section along the longitudinal profile of the river. The database is subsequently completed with statistical indicators (minimum, maximum, average, and median values) of discharge, flow velocity, water depth, and cross-sectional area, as well as estimates of the theoretical hydrokinetic energy and power potential. Secondly, these datasets are then used to analyse the evolution of the main hydraulic parameters along the river and to identify the sites with the highest hydrokinetic potential for further detailed analysis. For these sites, as well as for two artificial channels located in the Canton of Valais, summary datasheets of the theoretical hydrokinetic potential are generated. Finally, the main information is planned to be made publicly available through a multilayer hydrokinetic atlas in QGIS format.

3 Results and analysis

3.1 Hydrokinetic potential of the Canton of Valais

3.1.1 Global hydrographic maps

As shown in **Figure 2**, the hydrographic network of the Canton of Valais is dominated by the Rhône River, which takes its source at the Rhône Glacier and finishes its course in the Geneva Lake at Porte du Scex, being supplied all along the canton by many smaller or larger streams and rivers, as well as tailraces and other artificial channels. The main result of the hydrographic data analysis is presented in **Figure 11**, which provides the riverbed elevation profile of the Rhône River axis over almost its entire length, starting from the Reckingen station, where the river starts to have a relatively considerable cross-section, down to Geneva Lake at Porte du Scex, with a total elevation drop of almost 1000 m over a longitudinal distance of a little more than 160 km. The sections indicated in red in **Figure 11** are dominated only by the residual flow discharge, the main discharge being diverted through the different run-of-river hydropower plants distributed along the river. From its source to Geneva Lake, one may cite the Gletsch–Oberwald hydropower plant (located upstream of Reckingen), the Ernen–Mörel hydropower plant (situated between Reckingen and Brig), the Chippis–Rhône hydropower plant (on the Brig–Sion stretch), as well as the Lavey hydropower plant, located on the last stretch before Geneva Lake. The main natural and artificial tributaries (hydropower plant tailraces), together with the five hydrological gauging stations, are also indicated according to their longitudinal distance. Among a total of 70 identified natural tributaries, the most important ones are the Vispa, the Lonza, the Dranse, and the Grande Eau. In addition, a detailed plot of the Branson–Porte du Scex stretch is provided in **Figure 12**, whilst the complete information is summarised in a global database together with the rest of the collected input data and the resulting output data. For the hydrokinetic potential assessment of the Valais case study, the tributaries were considered only for estimating the discharge evolution of the Rhône River. Their own hydrokinetic potential was neglected because their average flow velocity and/or water depth were generally insufficient for the deployment of hydrokinetic turbines in the Canton of Valais.

Figure 13 provides an overview of the riverbed slope along the Brig–Geneva Lake reach (excluding residual flow sections). The reported values correspond to the slopes obtained from linear regressions of the average riverbed elevations, calculated for 1 km river segments. The median slope over the entire reach is 1.5 ‰. The highest slopes are observed at the upstream end of the reach, corresponding to the tailrace of the Bitsch hydropower plant and the river section through the city of Brig. Elevated slopes are also found downstream of the tailraces of the Chippis and Lavey hydropower plants. In fact, a new hydropower scheme is currently under development downstream of the Lavey tailrace to harness this available hydraulic potential [17].

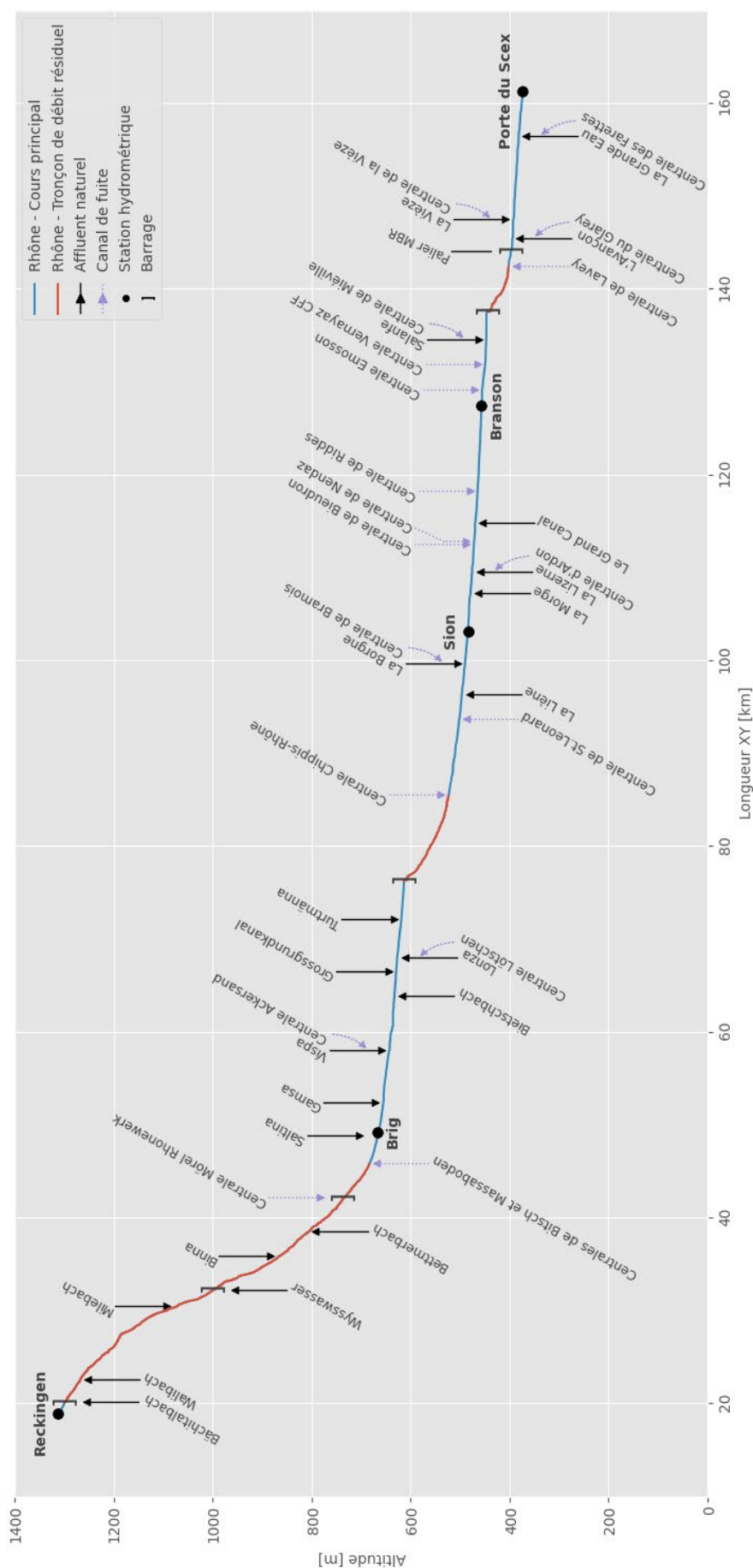


Figure 11. Elevation profile of the Rhône River along its path with its main tributaries on the territory of the Canton of Valais (see Appendix A).

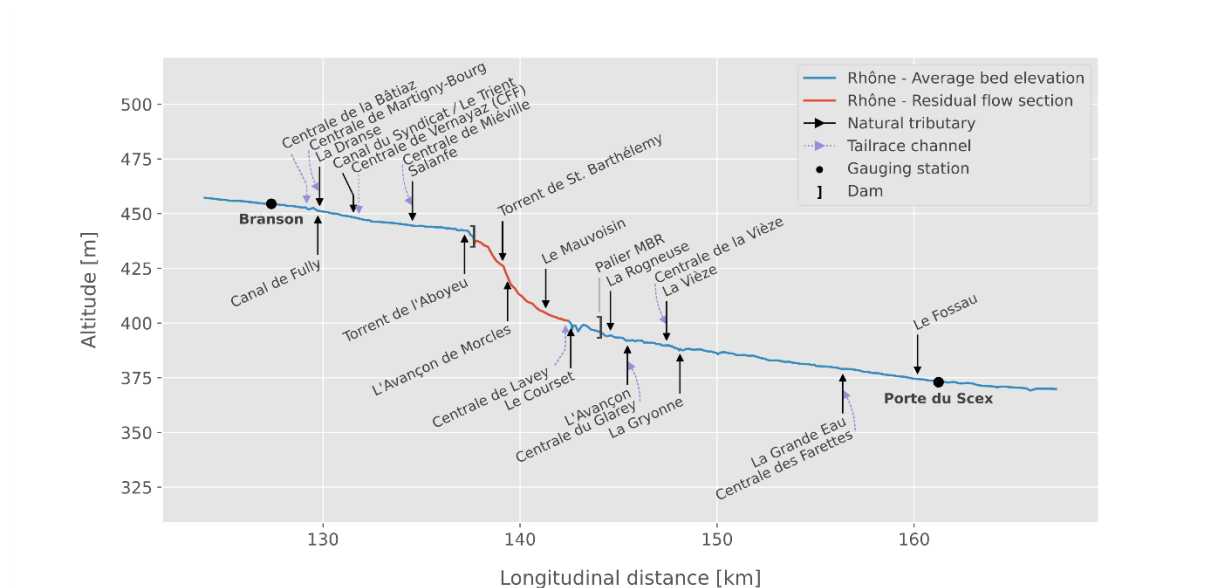


Figure 12. Detailed indication of the Rhône River axis elevation along with main tributaries on the Branson-Porte du Scex stretch.

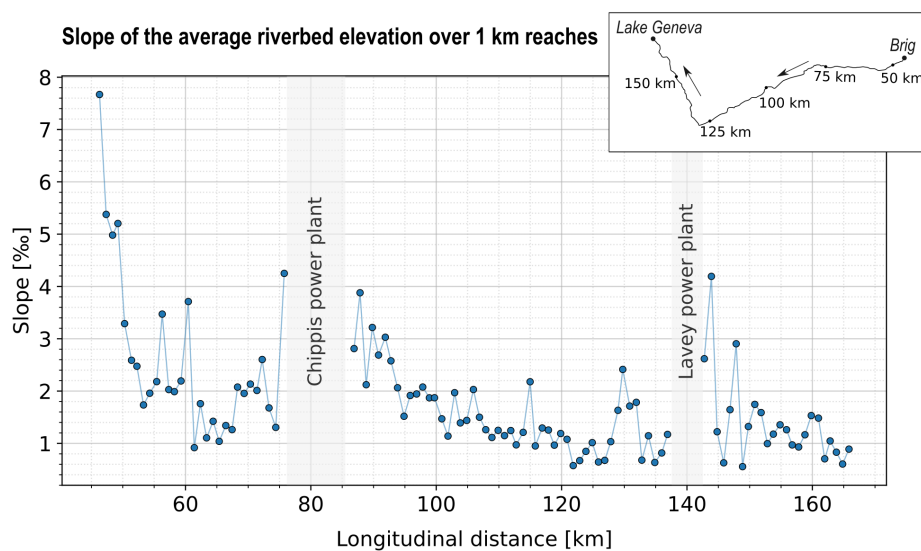


Figure 13. Evolution of riverbed slope along the longitudinal profile of the Chippis-Porte du Scex stretch of the Rhône River).

3.1.2 Numerical model calibration and validation

The setup of the HEC-RAS model followed the procedure introduced in section 2.4. The bathymetry resolution is shown in **Figure 14** with a quantitative overview given in **Table 3**.

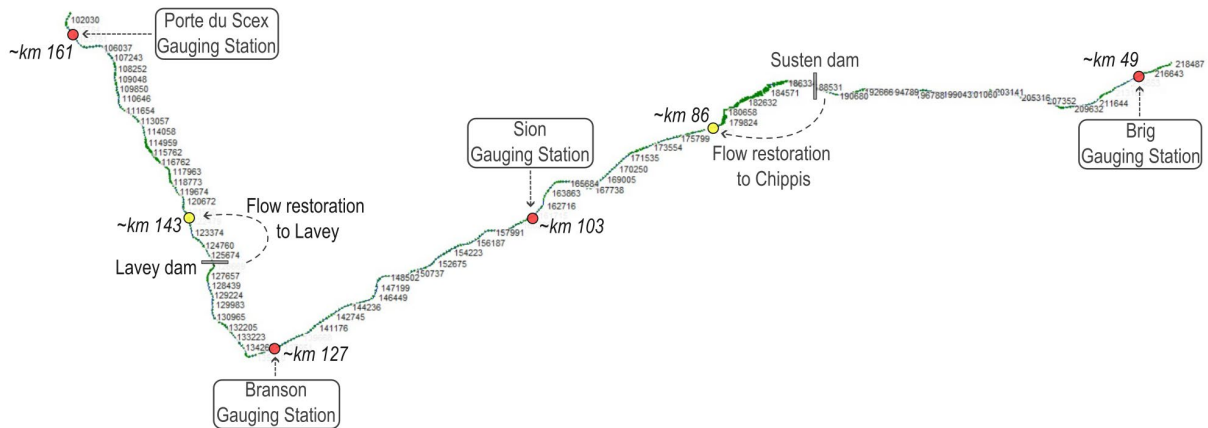


Figure 14. Model HEC-RAS between Brig and Geneva Lake – Valais case study.

Table 3. Description of the HEC-RAS model developed for the Rhône River in the Canton of Valais.

Rhône River: Number of bathymetries (Brig – Geneva Lake)	665
Rhône River: Mean distance between bathymetries	~200 m
Outlet friction loss	0.8933 ‰

This part of the Rhône River is equipped with 4 hydrological gauging stations with their location given in Figure 2 and Figure 14. Using the HEC-RAS model, the time history of the discharge as well as the water height, several calibration curves representing the Manning coefficient with regards to the discharge could be computed, see Figure 15. For visualisation purpose, the number of points on the right graph of Figure 15 was reduced from 365 to 30 points. It could be observed that among the curves, the “Brig” curve has a significant different behaviour compared to the others. One of the main reasons is that this station is the most upstream and, therefore, has a discharge range lower than the others.

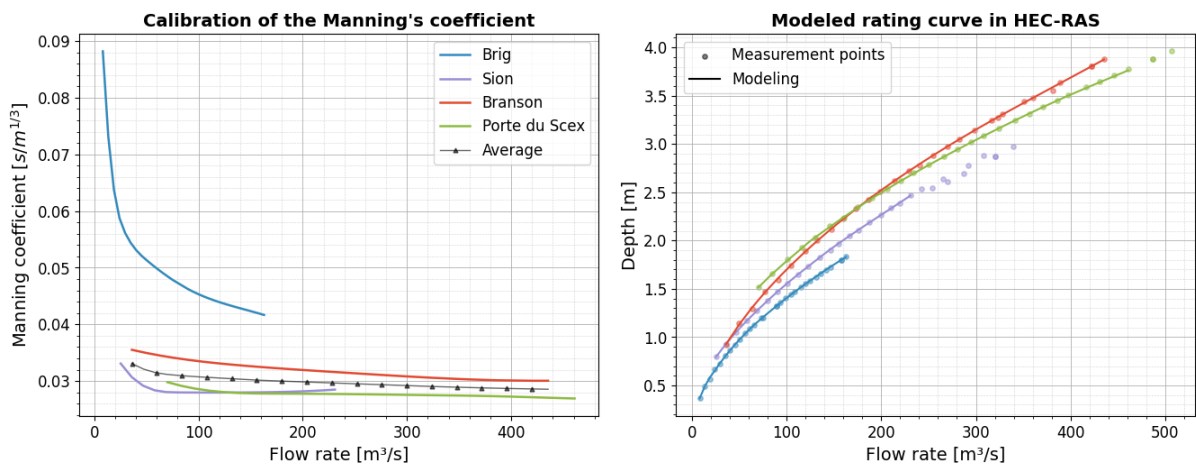


Figure 15. Detailed indication of the Rhône River axis elevation along with main tributaries on the Branson-Porte du Scex stretch. For visualisation purpose, the number of points on the right graph was reduced from 365 to 30 points.

To validate the HEC-RAS model, two simulations were performed to assess its ability to reproduce the longitudinal evolution of the water level for different discharge conditions. For this purpose, days exhibiting significant variations in river discharge were first identified. Two representative days were then selected, as they provided sufficiently distinct discharge conditions to enable a meaningful validation of the model.

For the stretch between the hydrological gauging stations of Sion and Branson, the data from the end of the day of May 22nd, 2023, were selected. These raw data are shown by the red curve (Sion station) and the blue curve (Branson station) in **Figure 16**. To evaluate the performance of the HEC-RAS model, the discharge at the Sion station was given to the model and the expected discharge at Branson was simulated and shown in **Figure 16** by the purple dash-line. As it can be seen, there is a good agreement between the measured and computed discharges.

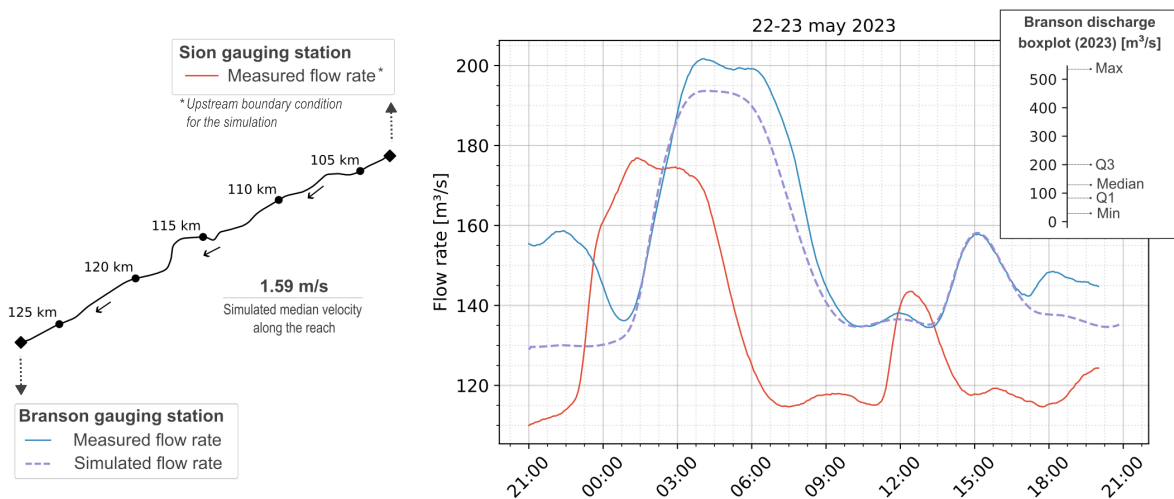


Figure 16. First validation of the HEC-RAS model using the hydrological gauging station of Sion and Branson.

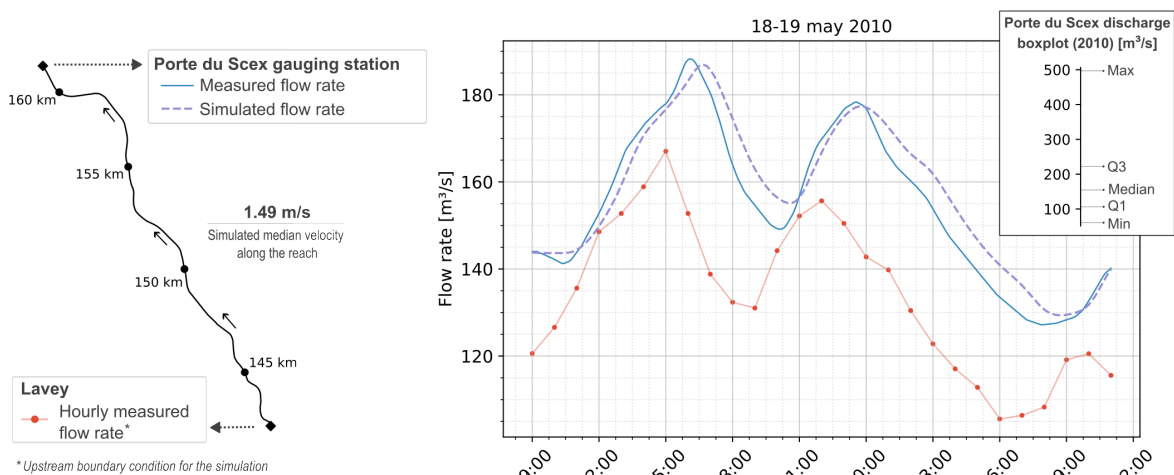


Figure 17. Second validation of the HEC-RAS model using the hydrological gauging stations of Lavey, proprietary of the Lavey hydropower plant, and Porte du Scex.

Performing the same approach for a second stretch is introduced in **Figure 17**. This Rhône stretch is between the hydrological gauging station of Lavey, which is proprietary of the Lavey hydropower plant, and the Porte du Scex station. Again, a good agreement

between the measured and computed discharges is obtained, confirming the proper setting of the present HEC-RAS model.

Once the model has been validated, the final step consists of generating, for each cross-section, a database of rating curves relating the average cross-section velocity and the water height with regards to the discharge. To this end, the HEC-RAS model is run for successive discharge values ranging from 20 to 480 m³/s with an increment of 1 m³/s, thereby generating the complete rating curve database.

3.1.3 Estimation of the yearly discharge distribution

Once the rating curve database has been created, the next step is to establish the expected year-long discharge along the modelled path. For this purpose, the time history discharge data at the four hydrological gauging stations are used. Following the methodology introduced in Section 2.5.3.1, the annual transit volumes were first calibrated for the three stretches, see [Figure 18](#), [Figure 20](#) and [Figure 22](#).

The second step was to establish the contributions from the natural and artificial tributaries using the methodology presented in Section 2.5.3.2. One graph on the left introduces the measured median daily discharges to show the variation along the stretch. A second graph on the right shows the daily distribution of the tributary's contributions. For visualisation purpose, all the tributaries were not listed, the smaller contribution being grouped into the category "Other tributaries". These graphs are presented in [Figure 19](#), [Figure 21](#) and [Figure 23](#).

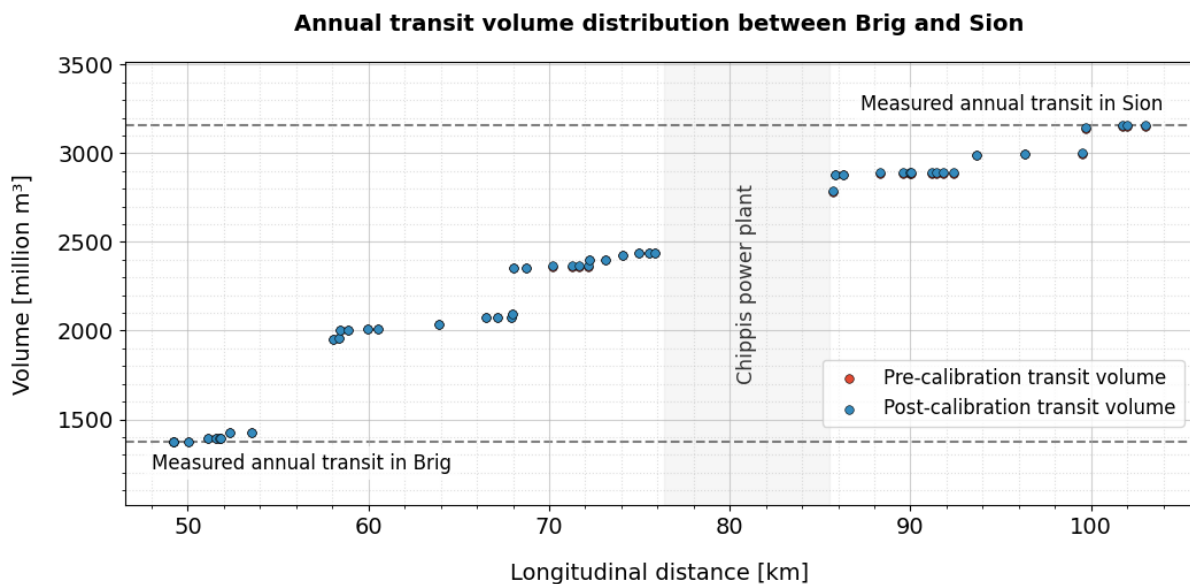


Figure 18. Repartition of the annual contribution between Brig and Sion, pre- and post-calibration.

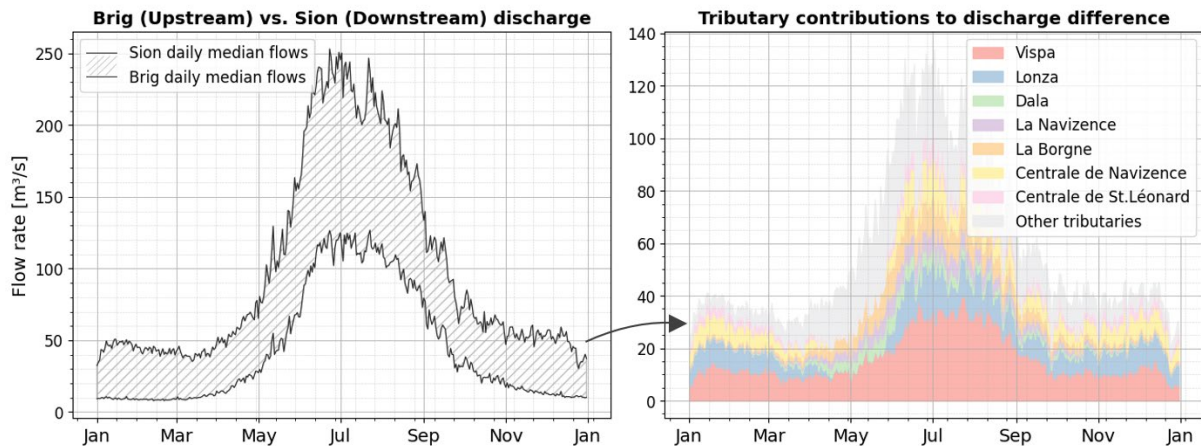


Figure 19. The left graph shows the difference between the daily median flows at Brig and Sion (consecutive stations). The right graph shows the distribution of daily discharge differences between the main tributaries.

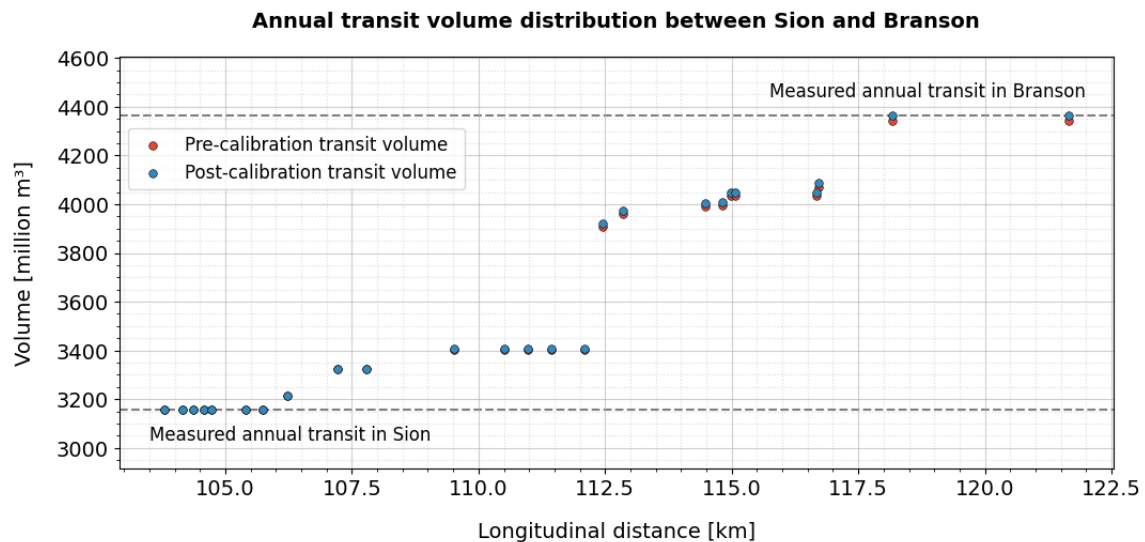


Figure 20. Repartition of the annual contribution between Sion (km ~103) and Branson (km ~122.5), pre- and post-calibration. Bieudron contribution can be seen around km 112.5.

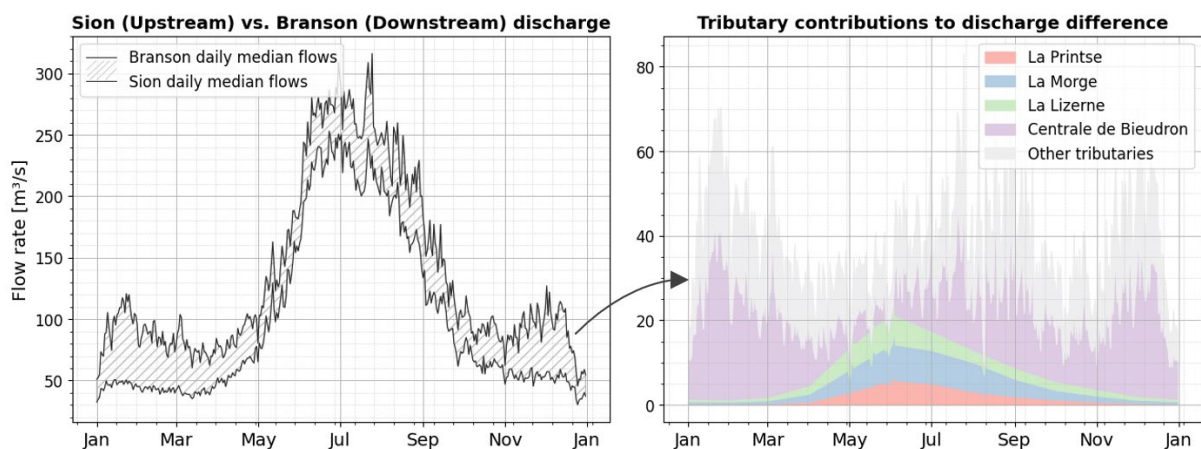


Figure 21. The left graph shows the difference between the daily median flows at Sion and Branson (consecutive stations). The right graph shows the distribution of discharge differences between the main tributaries.

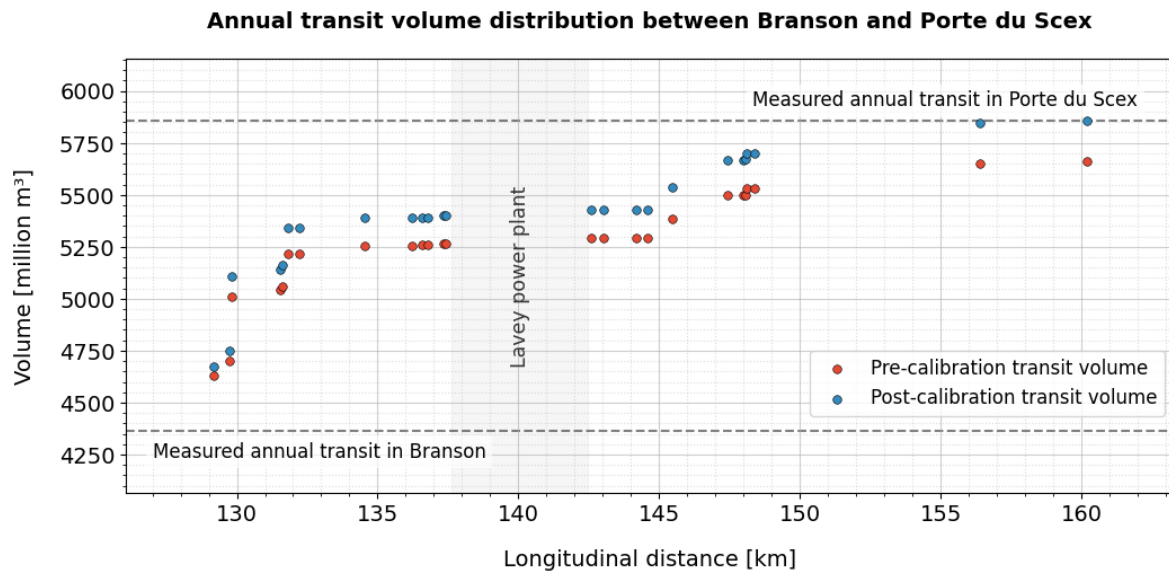


Figure 22. Repartition of the annual contribution between Branson and Porte du Scex, pre- and post-calibration.

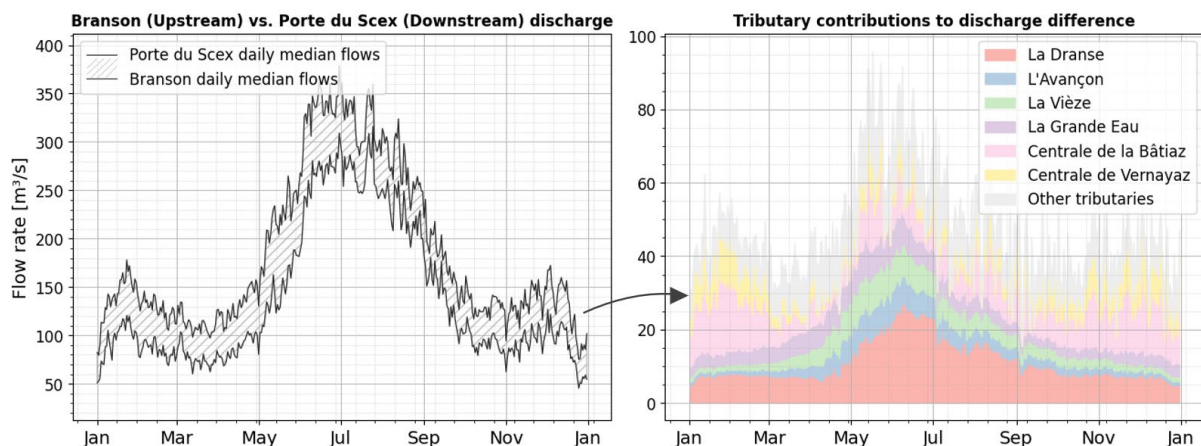


Figure 23. The left graph shows the difference between the daily median flows at Sion and Branson (consecutive stations). The right graph shows the distribution of discharge differences between the main tributaries.

3.1.4 Resulting estimated hydrokinetic energy of natural rivers

3.1.4.1 Reach length and riverbed width estimation

To compute the hydrokinetic energy of a reach, the length of the latter needs to be set and its riverbed width and altitude established. For the length, a distance of 20 times the riverbed width is used as presented in Section 2.6.2. **Figure 24** shows the estimated riverbed width along the path Chippis – Porte du Scex (see the employed procedure in [15]). The average value is 50.4 m; therefore, the length of the reach is set to 1 km.

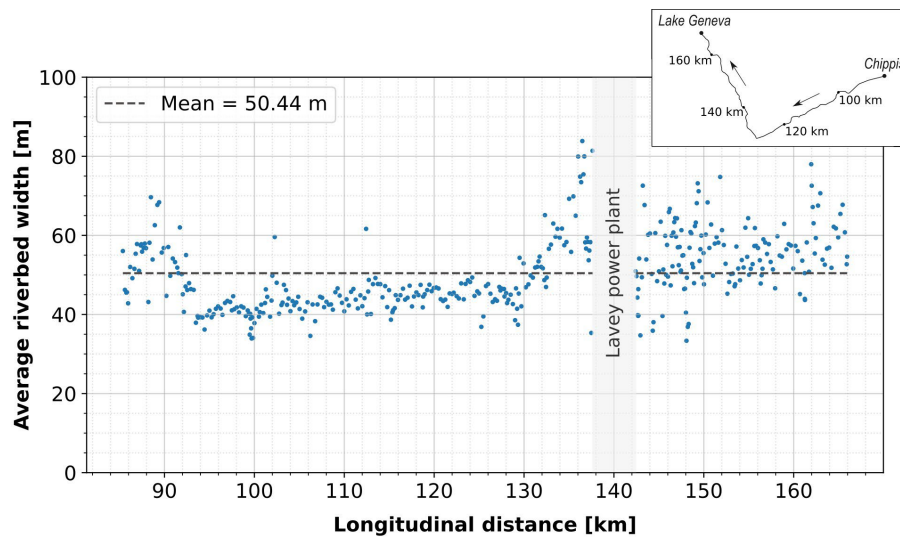


Figure 24. Resulting riverbed width along the longitudinal profile of the Chippis–Porte du Scex stretch of the Rhône River.

With the cross-section bathymetries, the averaged riverbed width and its elevation (obtained by weighted average, see the formulation in [15]) are available, as illustrated (horizontal red lines) for three locations in **Figure 25**. This width and altitude are used to compute the water depth and thus the area A^* as shown in **Figure 10**.

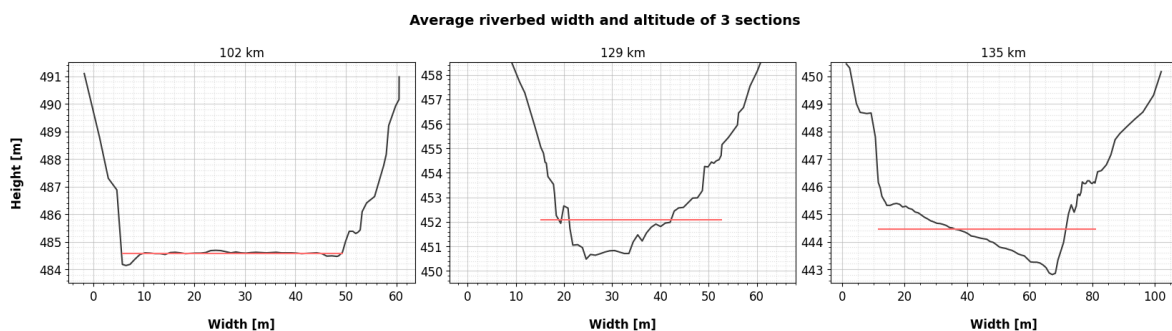


Figure 25. Example of cross-section bathymetries (black line) with their available averaged riverbed width and altitude (red line).

3.1.4.2 Velocity and water depth profiles, Brig–Susten dam stretch

Using the representative discharge along the Rhône path, the expected average cross-section velocity for the stretch Brig–Susten dam is shown in **Figure 26** and the expected water depth in **Figure 27**.

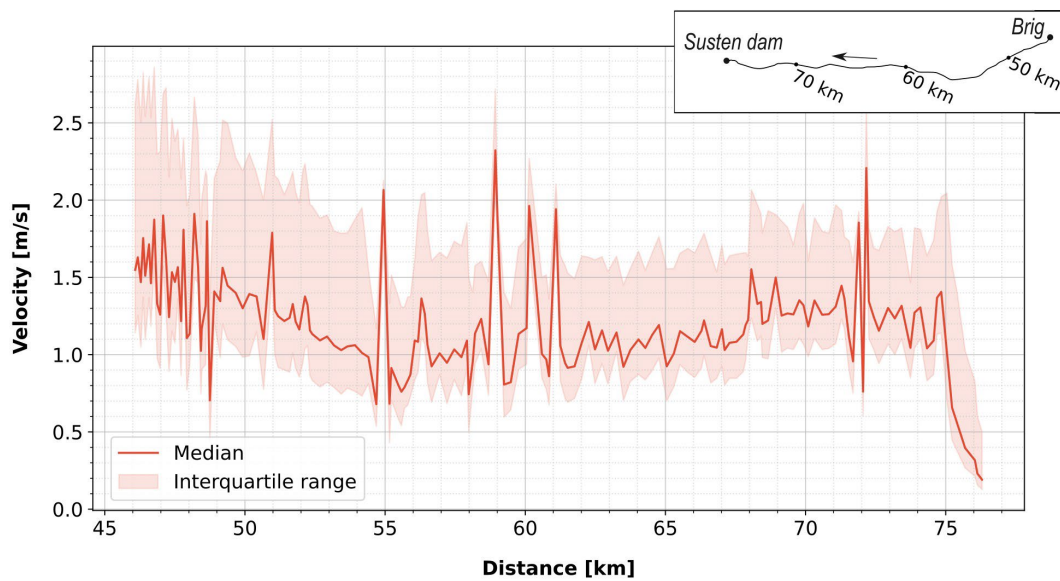


Figure 26. Resulting median discharge speed along the longitudinal profile of the Brig-Susten dam stretch of the Rhône River.

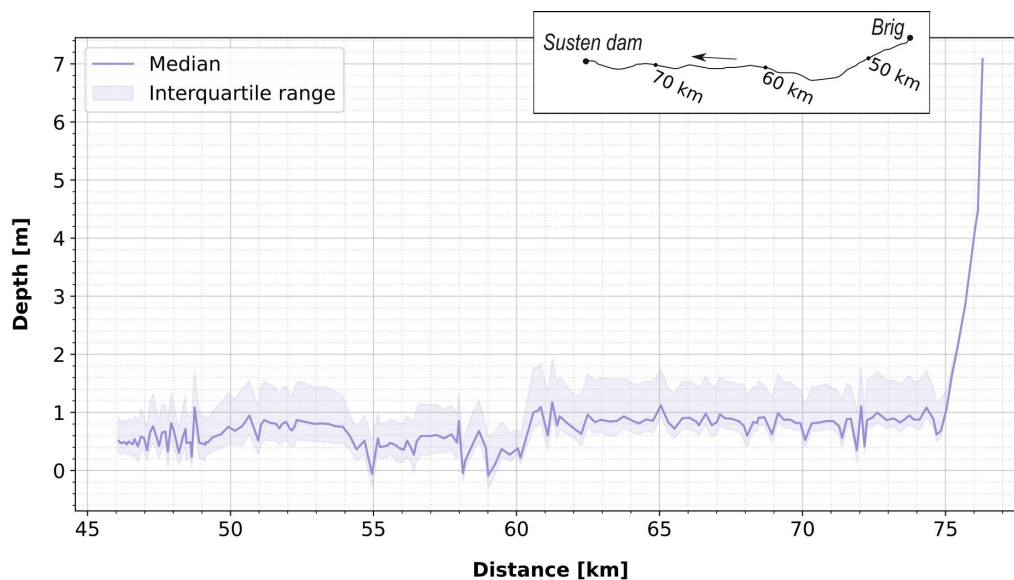


Figure 27. Resulting median water depth along the longitudinal profile of the Brig-Susten dam stretch of the Rhône River.

The discharge velocity is in average between 1.0 and 1.5 m/s. However, the water depth is shallow as it is often below 1 m depth. Therefore, this stretch won't be able to accommodate a hydrokinetic turbine. However, the potential theoretical hydrokinetic energy was estimated and shown in [Figure 28](#). In average, the annual theoretical potential energy per reach is around of 0.8 GWh with a total along the stretch reaching 24.34 GWh.

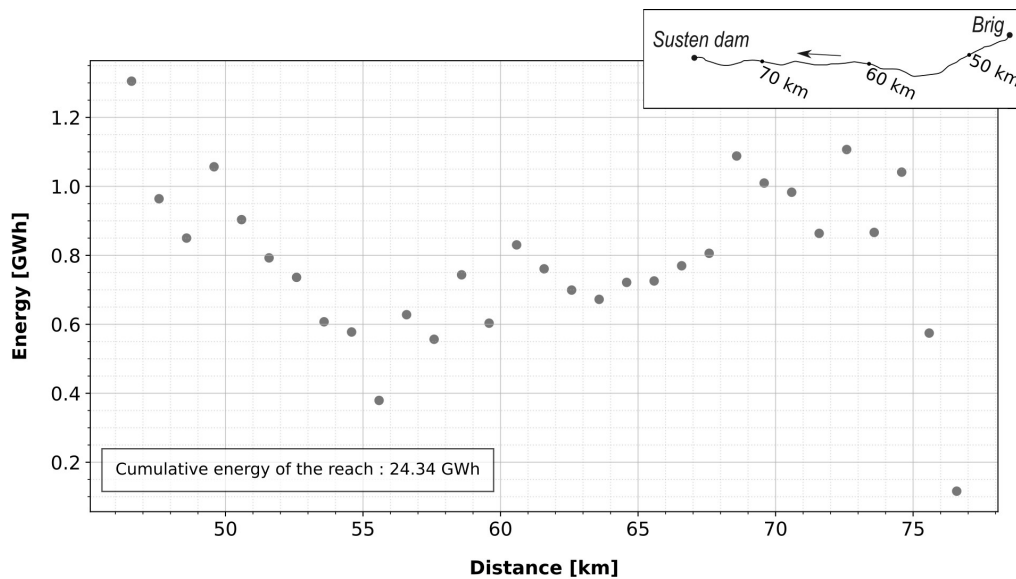


Figure 28. Resulting integrated yearly theoretical hydrokinetic energy along the longitudinal profile of the Brig-Susten dam stretch of the Rhône River.

3.1.4.3 Velocity and water depth profiles, Chippis-Porte du Scex stretch

The median discharge velocity and water depth along the longitudinal profile of the Rhône River on the Chippis-Porte du Scex reach (approximately 80 km long), obtained through numerical modelling and statistical analysis, are presented in **Figure 29** and **Figure 30**, respectively.

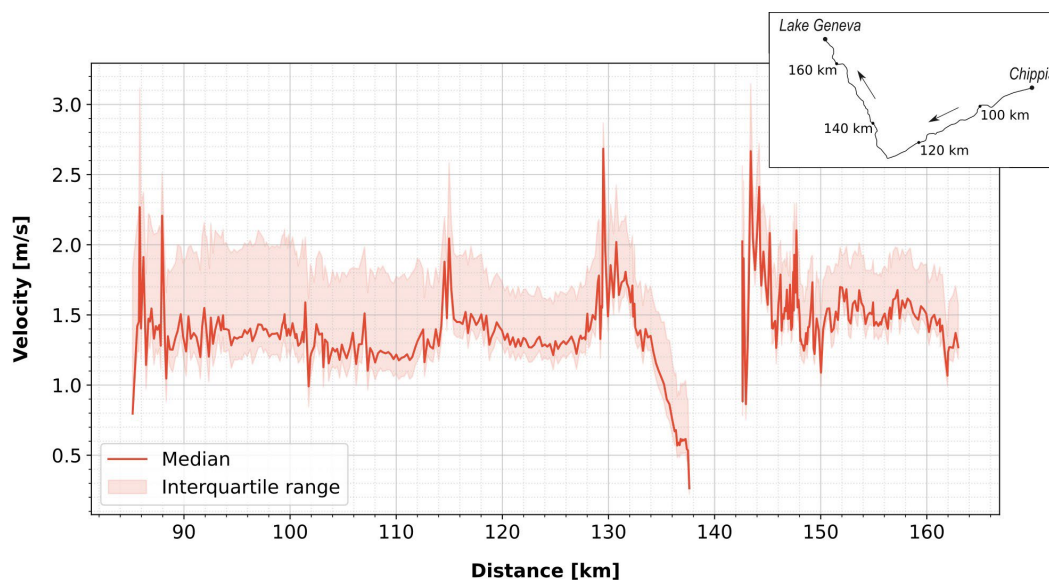


Figure 29. Resulting median discharge speed along the longitudinal profile of the Chippis-Porte du Scex stretch of the Rhône River.

Regarding the water depth, the median value increases from approximately 1 m to 2 m along the river between km ~85 and km ~125. The marked increase up to approximately 6 m at km ~138 is explained by the presence of the upstream dam of the Lavey hydropower plant. The reach between km ~138 and km ~142 is not considered, as it is only concerned by the residual discharge downstream of the hydropower plant. The high values observed at km ~142 result from the limitations of the numerical model in the

presence of local 3D flow patterns and sediment deposition zones, which are induced here by the confluence with the tailrace channel of the hydropower plant. Nevertheless, over this 80 km river reach, the average median water depth remains between 1 m and 2 m, which, depending on the turbine technology considered, may represent a limiting factor.

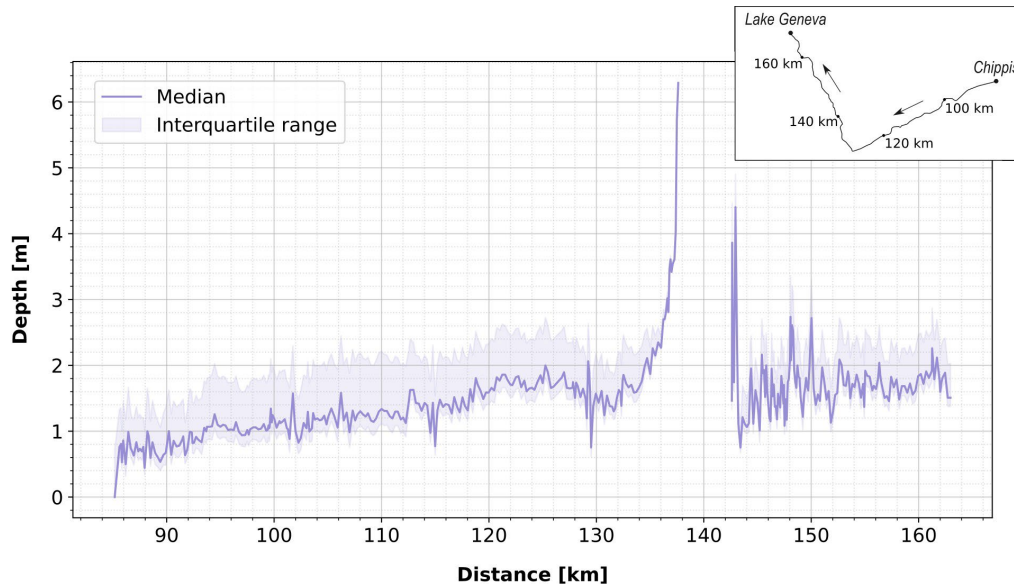


Figure 30. Resulting median water depth along the longitudinal profile of the Chippis–Porte du Scex stretch of the Rhône River.

Focusing on the discharge velocity, the average median value is approximately 1.4 m/s. On the one hand, the marked decrease observed along the reach between km ~132 and km ~142 is explained by the local effect of reaching the Lavey hydropower plant dam. On the other hand, the pronounced velocity spikes (see km ~86, km ~88, km ~115, km ~129, km ~143, and km ~148), exceeding 2 m/s, are more likely the result of numerical inaccuracies than representative of river sections with genuinely high flow velocities.

Considering the case of km ~115, located at the confluence with the Losentse River (see **Figure 31**), the high velocity is obtained in a section characterized by riverbed slope variations, significant changes in the cross-sectional geometry, sediment deposition, and complex 3D flow patterns that cannot be captured by the HEC-RAS model.

At km ~130, the anomalous result is also a consequence of the limitations of HEC-RAS employed setup in simulating supercritical flows ($Fr > 1$).

Finally, **Figure 32** presents an aerial view of the confluence between the Rhône River and the Lavey tailrace channel at km ~143. This area is again characterized by significant cross-sectional shape variations, sediment deposition, and complex 3D flow patterns, explaining the limitations of the numerical modelling in accurately representing the local hydraulic conditions.

The resulting integrated annual theoretical hydrokinetic energy along the longitudinal profile of the Chippis–Porte du Scex reach of the Rhône River is presented in **Figure 33**. Average values of approximately 1.5 GWh/km and 2.2 GWh/km are obtained for the river sections upstream and downstream of the Lavey hydropower plant, respectively. The

cumulative theoretical hydrokinetic energy potential of this natural river reach is estimated at 135.81 GWh/year. By adding the 24.34 GWh/year estimated for the upstream reach between Brig and Susten, the total theoretical hydrokinetic energy potential of the natural Rhône River in the Valais canton reaches 160.15 GWh/year.

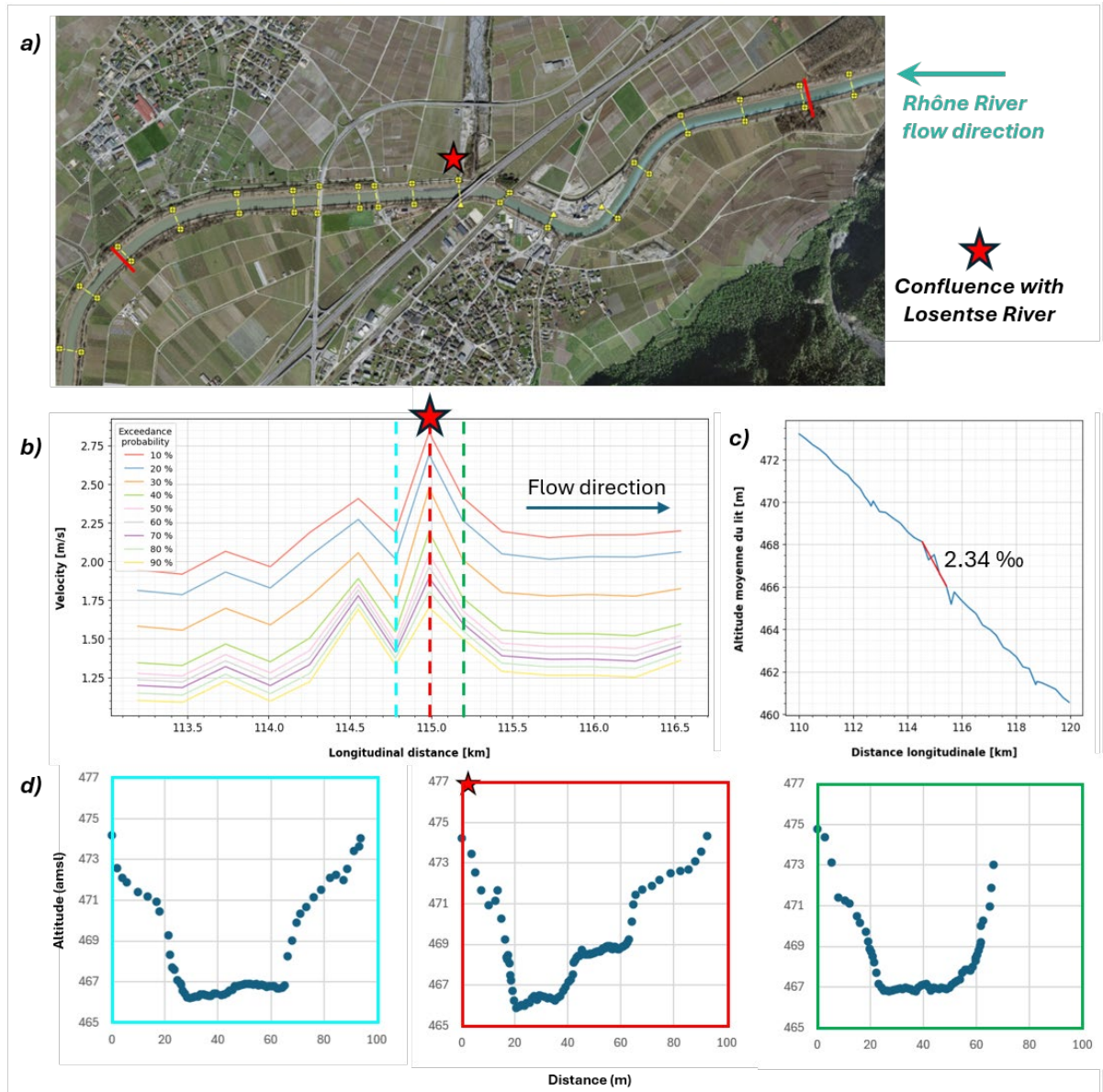


Figure 31. Zoom on the high velocity values observed at km ~115 from **Figure 30**. **a)** Aerial view with the two red lines showing the starting and ending location of the longitudinal velocity profiles shown under **b)**. **b)** Velocity profiles along the considered path for different probability of occurrence. **c)** Elevation profile along the considered path with a highlight shown by the red line of a local steeper slope. **d)** Cross-section bathymetries with their locations shown under **b)** by the vertical lines with corresponding colour.



Figure 32. Zoom on the high velocity values observed at km ~143 from **Figure 30**. Confluence between the natural Rhône River and the tailrace channel of Lavey powerplant.

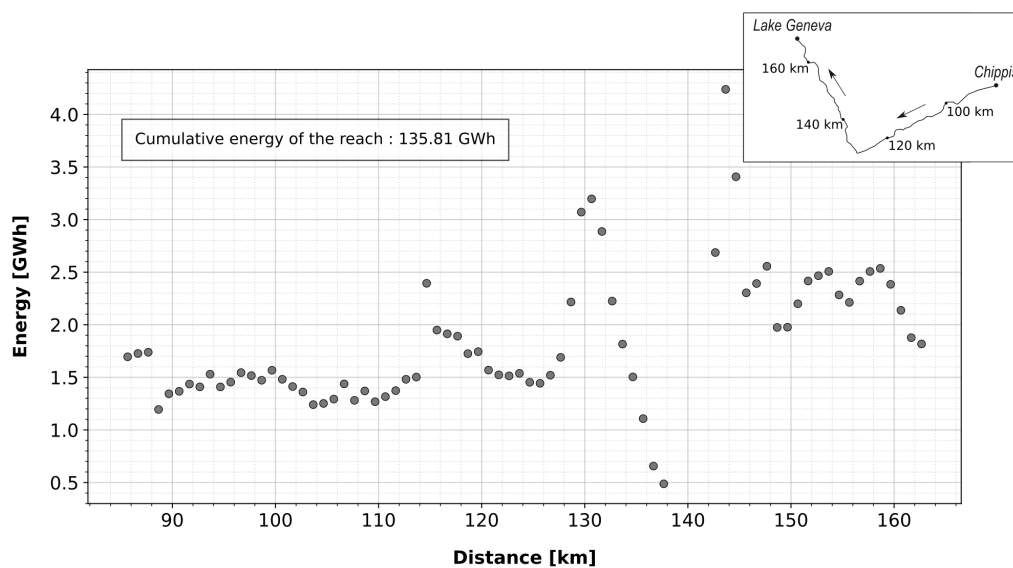


Figure 33. Resulting integrated yearly theoretical hydrokinetic energy along the longitudinal profile of the Chippis–Porte du Scex stretch of the Rhône River.

3.1.5 Resulting estimated hydrokinetic energy of artificial channels

Among the four main run-of-river hydropower plants installed along the Rhône River in the Canton of Valais, the Chippis–Rhône and Lavey hydropower plants have been selected to estimate the hydrokinetic potential of their main headrace and tailrace channels, respectively. The Ernen–Mörel run-of-river hydropower complex also presents a free-surface headrace channel several kilometres long, with the particularity of being underground over almost its entire length, making it hardly suitable for the installation of any hydrokinetic energy conversion device for maintenance and safety reasons. The Gletsch–Oberwald hydropower plant presents only a short tailrace channel and is characterised by a high head and a relatively small discharge, making it unsuitable for hydrokinetic energy recovery.

3.1.5.1 Headrace channel of the Chippis–Rhône hydropower plant

The summary of the main characteristics, the resulting estimated theoretical hydrokinetic potential, as well as the main discharge, discharge velocity, water depth, and power statistical variations of the headrace channel of the Chippis–Rhône hydropower plant is provided in **Appendix C**. This artificial channel, with a length of 2.15 km and an average

bottom slope of 0.4‰, presents, as illustrated in **Figure 34** and **Figure 35**, a regular trapezoidal cross-section along the considered stretch between the Susten dam, located on the Rhône River, and the remaining downstream underground section. Considering the previously established criterion of a minimum spacing greater than 20 times the bottom width (more than 92 m in this case) between two consecutive production cross-sections, a total of 21 sections has been retained.

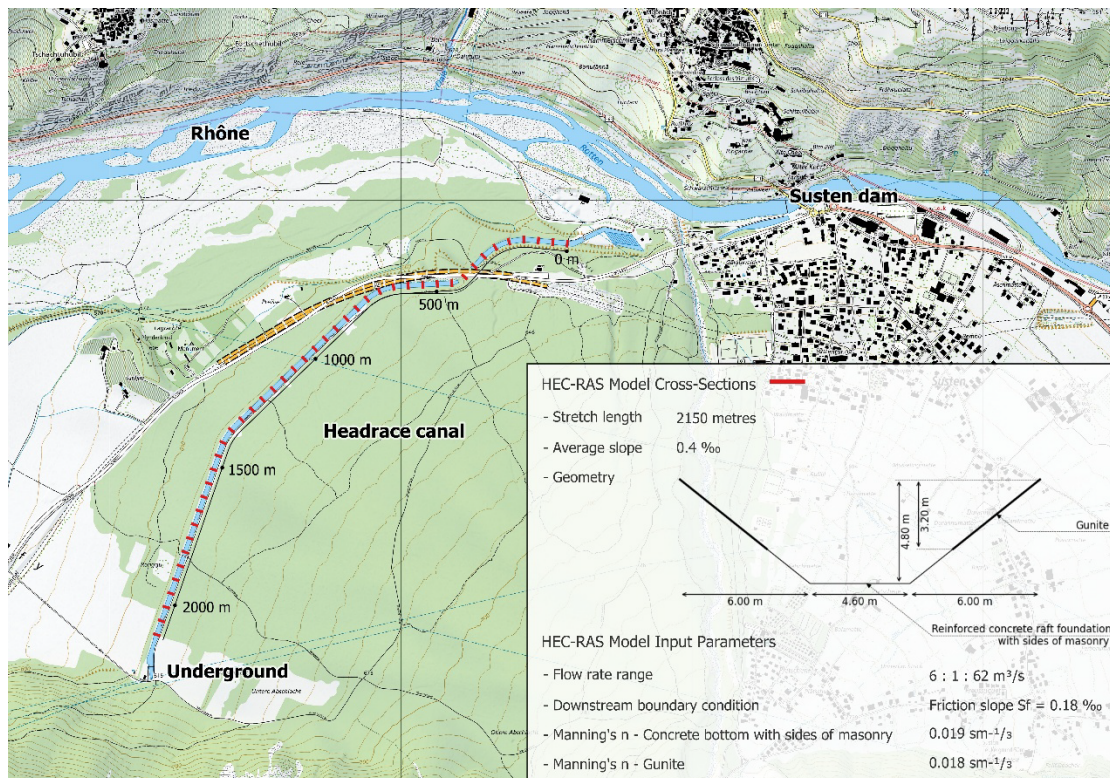


Figure 34. Location and cross-sectional geometry of the Chippis-Rhône hydropower plant artificial headrace channel, together with the main HEC-RAS simulation conditions.

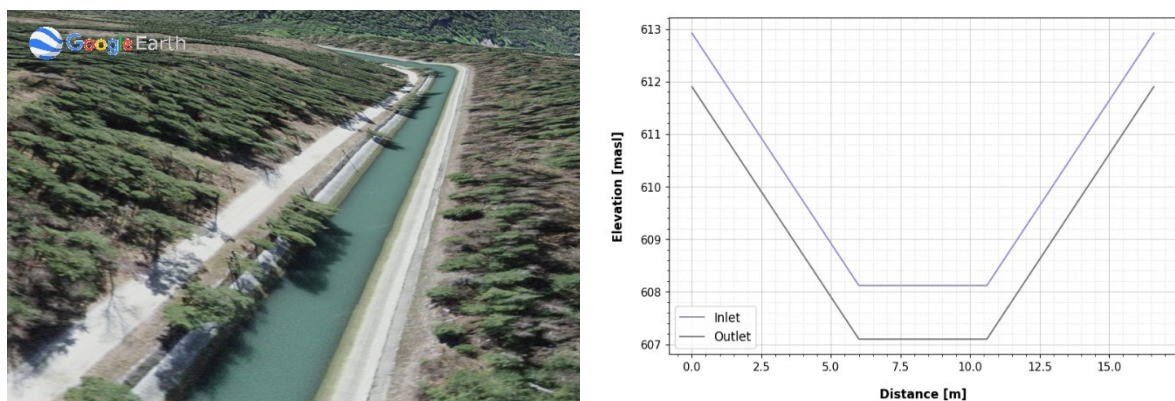


Figure 35. Synthetic aerial view and cross-sectional geometry of the inlet and outlet sections of the considered Chippis-Rhône headrace channel stretch.

The yearly daily discharge distribution, obtained from data collected between 2013 and 2023, is provided in **Figure 36**. Over this period, a global minimum discharge of 4.53 m³/s, a maximum discharge of 62 m³/s, an average discharge of 35.9 m³/s, and a median discharge of 29.61 m³/s are obtained.

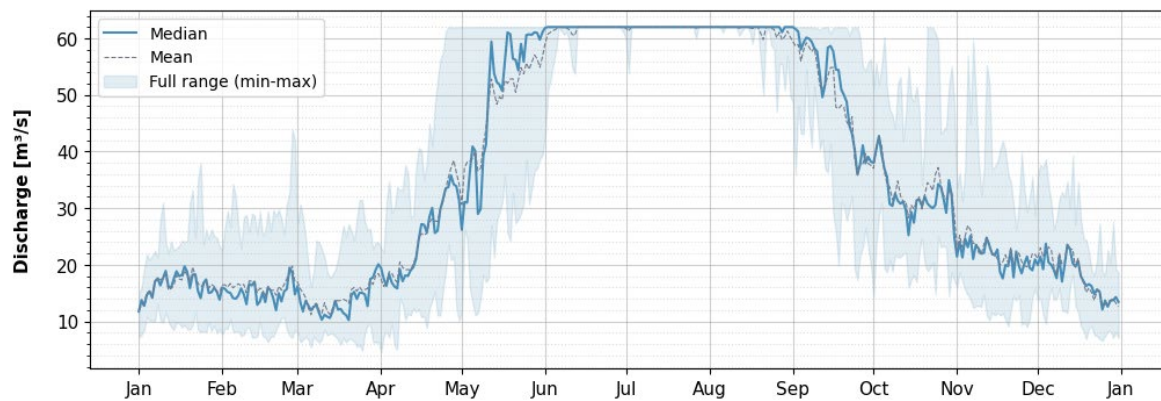


Figure 36. Yearly daily discharge distribution of the Chippis-Rhône hydropower plant artificial headrace channel obtained from data collected between 2013 and 2023.

In the absence of statistical water depth data, the flow in the channel has been modelled using a HEC-RAS simulation to complete the dataset required for the hydrokinetic potential estimation. The main specifications of the simulation setup are also provided in [Figure 34](#). The simulations have been performed for discharge values at intervals of 1 m³/s between 6 m³/s and 62 m³/s, the latter representing the maximum discharge capacity of the channel infrastructure. The validation of the simulation input and output values is presented in the left plot of [Figure 37](#), which shows a good agreement between the simulated water depth along the channel and the values estimated from the channel design for the maximum discharge and an outlet friction slope of 0.18‰. The influence of the outlet friction slope on the resulting flow velocity along the channel may be observed in the right plot of the same figure, with a significant difference of around 20% between the two tested values. The second simulated outlet friction slope value of 0.4‰ corresponds to the average channel bed slope presented previously.

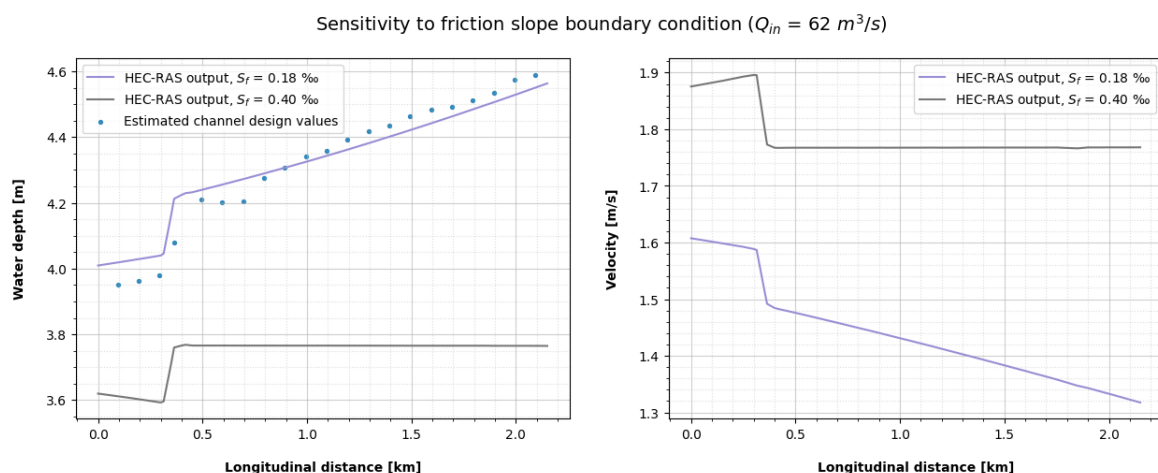


Figure 37. Resulting water depth and discharge velocity along the channel for the two output friction slope values considered in the flow simulation of the Chippis-Rhône headrace channel stretch.

The resulting median values and interquartile ranges of the discharge velocity and water depth along the channel are reported in [Figure 38](#). The large variation observed at km 0.3, also visible in the plots of the previous figure, is induced by a significant local bottom slope, which changes from 0.4‰ to 3.4‰. Apart from this local variation, the median flow

velocity decreases from 1.4 m/s to 1.1 m/s between the inlet and outlet sections of the considered stretch, whilst the median water depth varies between 2.7 m and 3.2 m.

The exceedance probability curve of the median daily discharge is provided in **Figure 39**. The mean of the median daily discharge values is 35.9 m³/s, corresponding to an exceedance probability of 42%, whereas the median of the entire daily discharge profile is 29.61 m³/s.

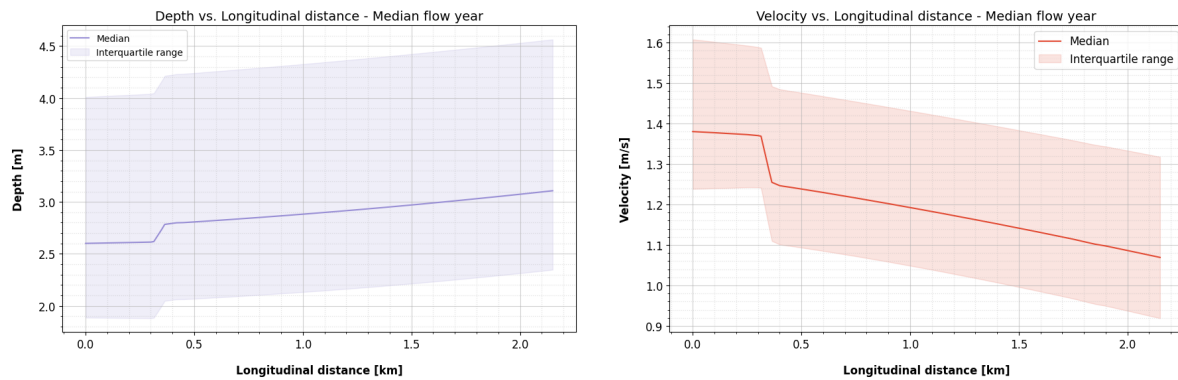


Figure 38. Resulting simulated median and interquartile water depth and discharge velocity along the Chippis-Rhône headrace channel stretch.

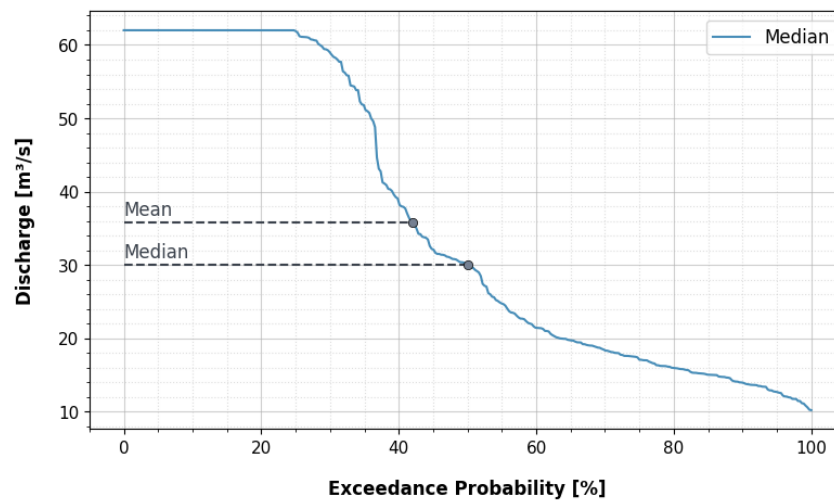


Figure 39. Exceedance probability of the median daily discharge for the Chippis-Rhône headrace channel, obtained from data collected between 2013 and 2023.

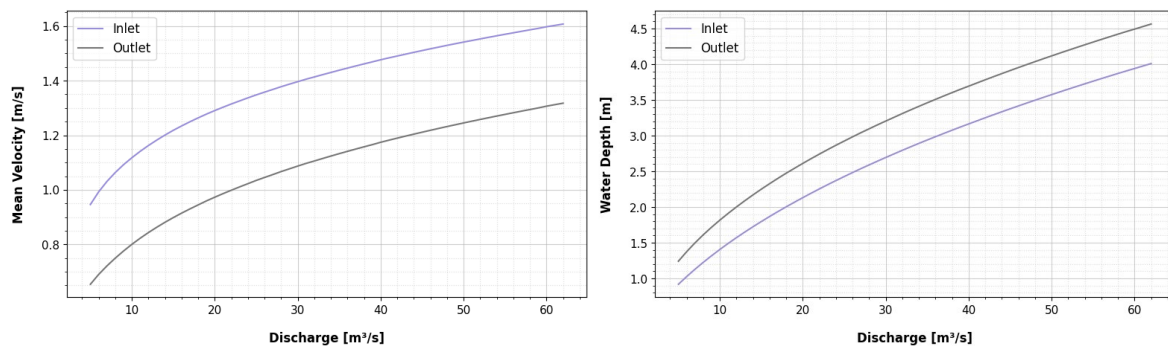


Figure 40. Discharge velocity and water depth versus discharge obtained from HEC-RAS simulations for the inlet and outlet sections of the considered Chippis-Rhône headrace channel stretch.

Figure 40 presents the variations in discharge velocity and water depth with discharge obtained from HEC-RAS simulations for the inlet and outlet sections of the considered Chippis-Rhône headrace channel stretch. The obtained relationships show similar trends, with higher flow velocity values at the inlet than at the outlet section and, conversely, greater water depths at the outlet than at the inlet.

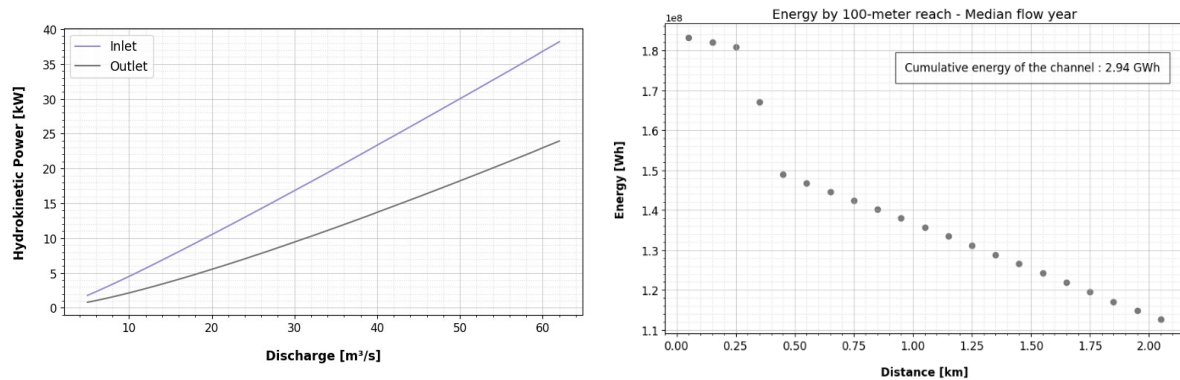


Figure 41. Resulting theoretical hydrokinetic power as a function of discharge (left) and integrated theoretical median hydrokinetic potential energy for the 21 considered cross-sections of the Chippis-Rhône headrace channel stretch (right).

Table 4. Resulting estimated theoretical hydrokinetic potential of the considered Chippis-Rhône headrace channel stretch.

	Inlet	Outlet	Total
Median power	20.91 kW	12.85 kW	-
Integrated median energy	183 MWh/year	113 MWh/year	2.94 GWh/year

The resulting variation of the theoretical hydrokinetic power as a function of discharge at the inlet and outlet sections of the channel is shown in the left plot of **Figure 41**, with generally higher values at the inlet than at the outlet section, in accordance with the previously presented discharge velocity values. The right plot shows the integrated theoretical median hydrokinetic potential energy obtained for the 21 considered cross-sections of the Chippis-Rhône headrace channel stretch, highlighting a higher potential in the upstream part of the channel that decreases continuously towards the outlet section. As summarized in **Table 4**, the resulting total integrated theoretical hydrokinetic energy potential of this artificial channel is 2.94 GWh per year, with 183 MWh/year and 113 MWh/year at the inlet and at the outlet sections respectively. Finally, the corresponding theoretical median hydrokinetic power, obtained by dividing the annual energy by the number of hours in a year, is 20.91 kW at the inlet section and 12.85 kW at the outlet section.

3.1.5.2 Tailrace channel of the Lavey hydropower plant

As for the Chippis-Rhône case, the summary of the main characteristics, the resulting estimated theoretical hydrokinetic potential, as well as the main discharge, discharge speed, water depth, and power statistical variations of the tailrace channel of the Lavey

hydropower plant is provided in [Appendix D](#). This artificial channel, built in the 1950s, has a length of around 600 m and an average bottom slope of 0.25‰. It returns to the natural course of the Rhône River the discharge released by the three Kaplan turbines of the Lavey hydropower plant (see [Figure 42](#) and Hasmatuchi et al. [16]). As shown on the left-hand side of [Figure 44](#), the artificial channel has a regular trapezoidal cross-section with a bottom width of 18 m along the considered 500 m stretch. As particular features, the channel presents a pronounced narrowing at the outlet of the hydropower plant, a region that lies outside the stretch considered in this study, and a bridge located approximately in the middle of the considered reach, supported by two rectangular piers founded on the channel bed. Considering again the criterion of a minimum spacing greater than 20 times the bottom width between two consecutive production cross-sections, only two sections have been retained for this case.



Figure 42. Geographic location and photograph of the Lavey hydropower plant tailrace channel considered for the hydrokinetic potential evaluation.

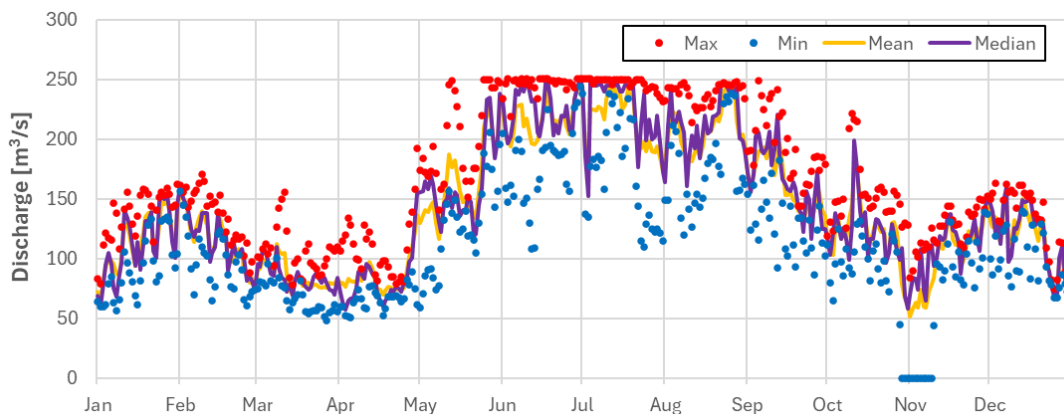


Figure 43. Yearly daily discharge distribution of the Lavey hydropower plant tailrace channel obtained from data collected between 2010 and 2012.

The yearly daily discharge distribution, obtained from data collected between 2010 and 2012, is provided in [Figure 43](#). Over this period, a global minimum discharge of 0 m³/s (corresponding to periods when the hydropower plant was under important maintenance, generally during the winter season), a maximum discharge of 250.5 m³/s, an average discharge of 142.15 m³/s, and a median discharge of 133.3 m³/s are obtained. The exceedance probability curve of the median daily discharge is presented on the right-hand side of [Figure 44](#). The mean of the median daily discharge values and the median

of the entirely daily discharge record are very similar, indicating that the discharge distribution is only weakly skewed.

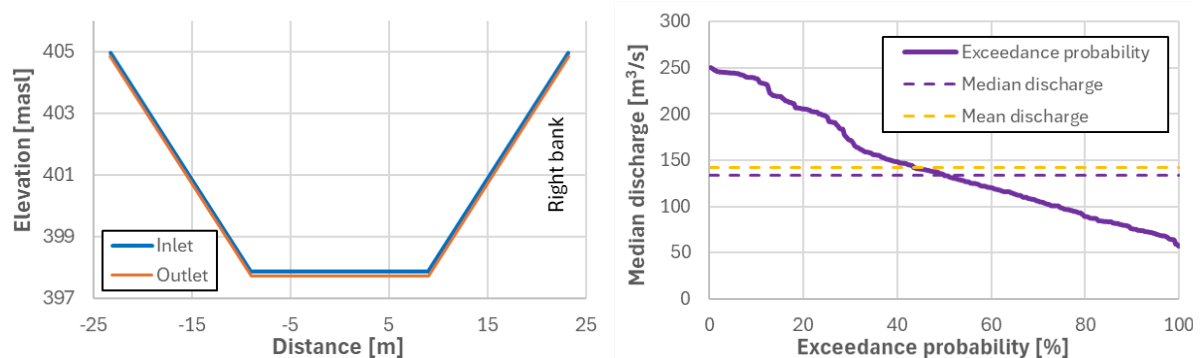


Figure 44. Cross-sectional geometry of the inlet and outlet sections (left) and exceedance probability of the median daily discharge (right) of the Lavey tailrace channel.

The relationships between discharge velocity, water depth, and discharge (shown in **Figure 45**) are obtained from three years of average daily discharge and water depth measurements at two locations corresponding to the inlet and outlet sections of the channel (see Hasmatuchi et al. [15]). The trends at the inlet and outlet sections of the considered channel stretch are similar, with higher water depth values at the inlet than at the outlet section and, conversely, higher flow velocity values at the outlet than at the inlet. The maximum flow velocity is 1.56 m/s at the considered inlet section and 1.79 m/s at the outlet section. The water depth, influenced by the channel geometry at the downstream junction with the Rhône River, varies approximately between 4.0 m and 5.0 m at the outlet section and between 5.0 m and 5.5 m at the inlet section.

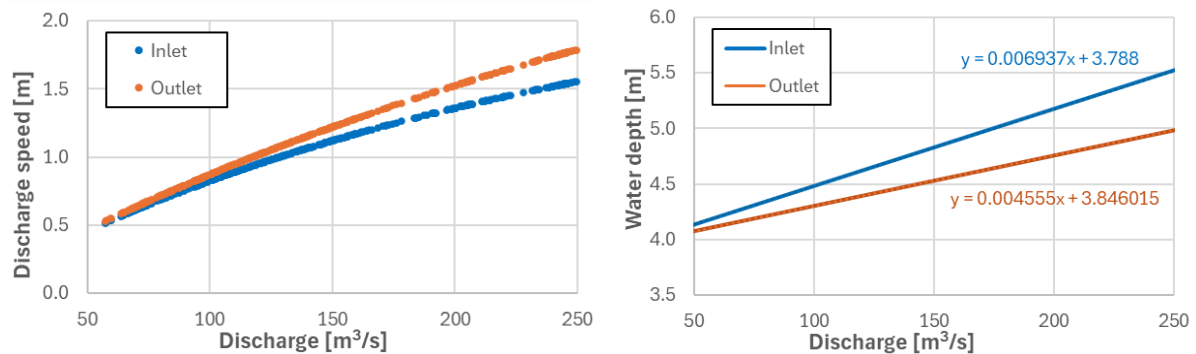


Figure 45. Discharge velocity (left) and water depth (right) variation with the discharge for the inlet and outlet sections of the considered Lavey tailrace channel stretch.

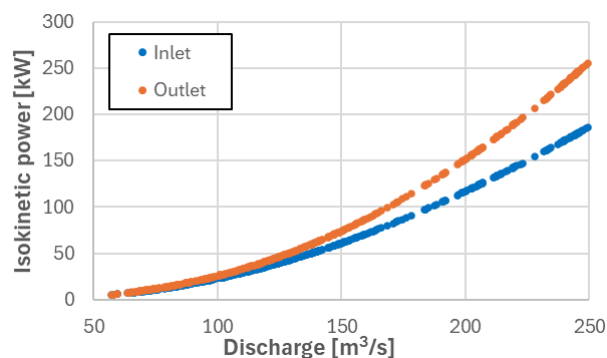


Figure 46. Resulting theoretical hydrokinetic power as a function of discharge for the inlet and outlet sections of the considered Lavey tailrace channel stretch.

Table 5. Resulting estimated theoretical hydrokinetic potential of the considered Lavey tailrace channel stretch.

	Inlet	Outlet	Total
Median power	66.76 kW	85.31 kW	-
Integrated median energy	585 MWh/year	747 MWh/year	1.332 GWh/year

The resulting variation of the theoretical hydrokinetic power as a function of discharge at the inlet and outlet sections of the channel is shown in **Figure 46**, with higher values at the outlet than at the inlet section. As indicated in **Table 5**, the resulting total integrated theoretical hydrokinetic energy potential of the Lavey tailrace channel is 1.33 GWh per year, with 585 MWh/year and 747 MWh/year at the inlet and outlet sections, respectively. The corresponding theoretical median hydrokinetic power, obtained by dividing the annual energy by the number of hours in a year, is 66.76 kW at the inlet section and 85.31 kW at the outlet section.

3.2 Hydrokinetic potential of the Canton of Geneva

3.2.1 Global hydrographic maps

The main rivers and creek were previously introduced in [Figure 3](#) and it could be shown that the Canton of Geneva has two main rivers: the Rhône River and the Arve River. Regarding the Rhône River, its elevation profile in the Canton of Geneva is shown in [Figure 47](#). The river has three hydropower plants and approximately 8 natural tributaries. Except for the Arve River, the discharge contributions from the natural tributaries are negligible compared with the discharges of the Rhône and the Arve Rivers.

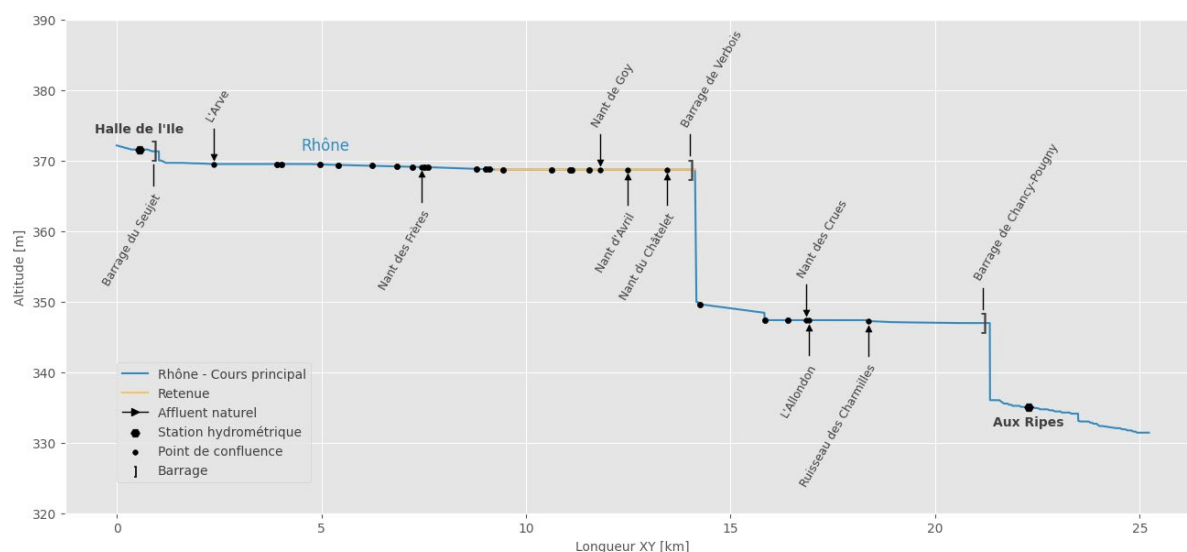


Figure 47. Elevation profile of the Rhône River along its path with its main tributaries on the territory of the Canton of Geneva (see [Appendix B](#)).

3.2.2 Numerical model calibration and validation

The HEC-RAS model was set up following the procedure described in Section 2.4. The quantitative overview is given in [Table 6](#), totalling 218 bathymetries shown in [Figure 50](#). To illustrate the shape of the Arve and Rhône Rivers, examples of bathymetry are given in [Figure 48](#). As it can be seen, the riverbed width is close to the one observed in the Canton of Valais.

Table 6. Description of the HEC-RAS model developed for the Canton of Geneva.

Rhône River: Number of bathymetries	200
Rhône River: Mean distance between bathymetries	120 m
Arve River: Number of bathymetries	18
Arve River: Mean distance between bathymetries	500 m
Outlet friction loss	2.00 ‰

To finalise the HEC-RAS model, the Manning coefficients need to be calibrated to fit the computed discharge with the measured ones. The selected hydrological gauging stations are “Aux Ripes” located near the end of the Rhône path in the Canton of Geneva, see [Figure 48](#), and “Bout du Monde” for the Arve River, see [Figure 49](#).

For the “Bout du Monde” hydrological gauging station, it could be seen that the calibrated Manning coefficient values are quite different from the ones obtained for the calibration performed on the Rhône River. One explanation can be that the number of bathymetries is too coarse, especially for this part of the Arve River that is meandering. In addition, the software HEC-RAS doesn’t consider meanders. Therefore, these reasons can induce less reliable results and explain this difference of values.

To assess the “Bout du Monde” Manning coefficients, simulated data obtained from the Canton of Geneva were used. These data are simulated data to evaluate the water height for several discharge conditions. Using them, Manning coefficients are computed and shown in **Figure 49** by red points. Their values are closer to what was observed on the Rhône River. Therefore, the calibrated curve was shifted to fit the red points and the resulting curved name “shifted calibrated curve” was used to estimate the rating curves.

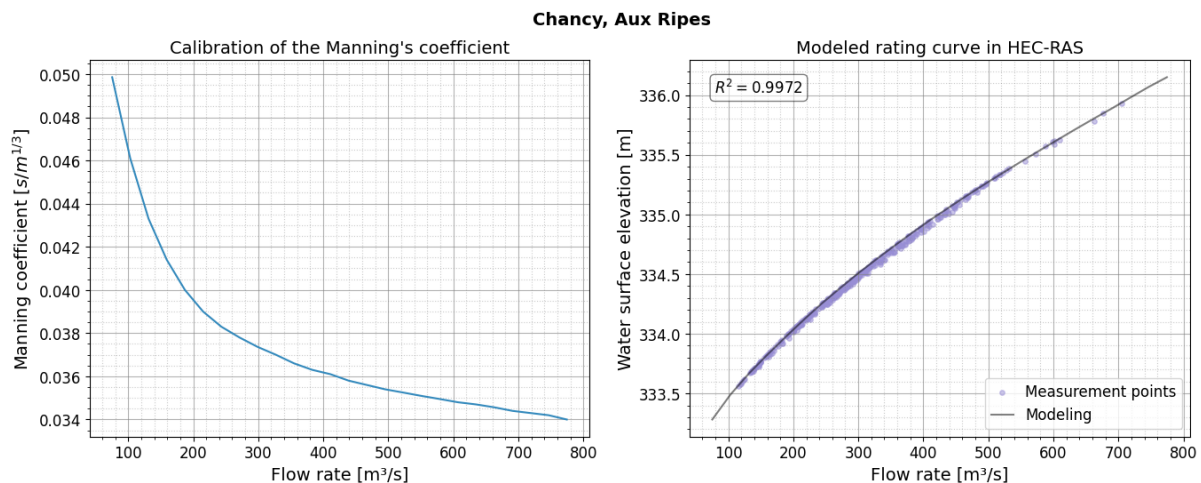


Figure 48. Calibration of the Manning coefficient for the Geneva HEC-RAS model using the hydrological gauging measurements at the station “Aux Ripes”.

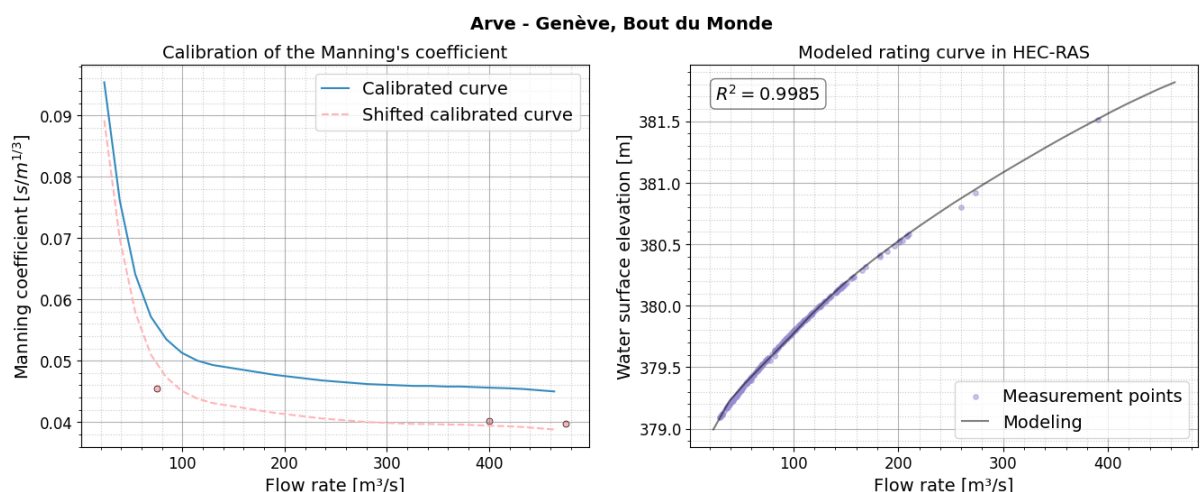


Figure 49. Calibration of the Manning coefficient for the Geneva HEC-RAS model using the hydrological gauging measurements at the station “Bout du Monde”

Knowing the expected discharge throughout the year, different scenarios are computed using the model to create the rating curves database which provides the relationship

between cross-section average velocity and water height with regards to the discharge, and this for each bathymetry location, see **Figure 50**.

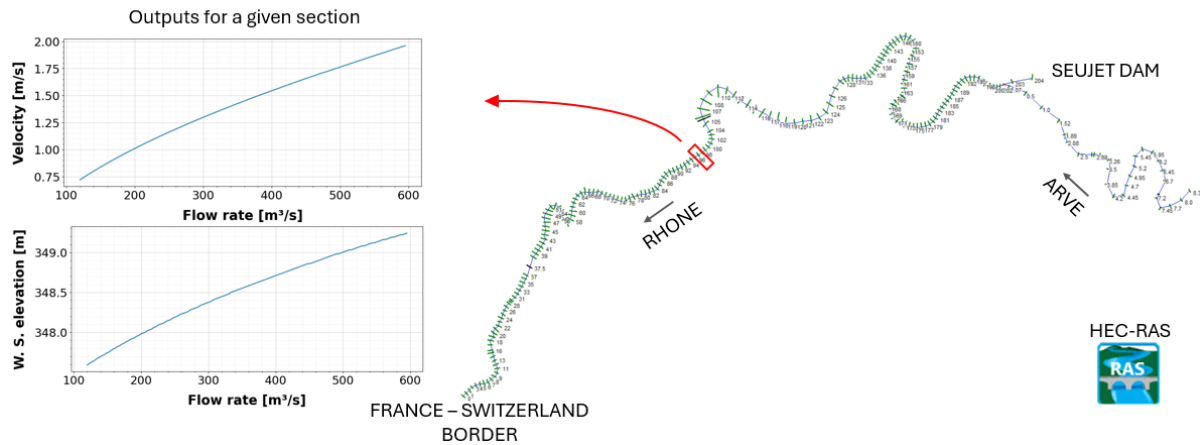


Figure 50. HEC-RAS model for Geneva case study. Each green line with its identification number represents a cross-section bathymetry of the Rhône River or Arve River. The graphs show, for a given cross-section, the relationship between velocity and flowrate, and between water surface elevation and flowrate.

3.2.3 Estimation of the yearly discharge distribution

The locations of the hydrological gauging stations in the Canton of Geneva are shown in **Figure 3**. Summing up the daily discharge of the Rhône just downstream Geneva Lake with the daily discharge of the Arve River allows to compare with the daily discharge measured near the end of the Rhône River path in the Canton of Geneva. The resulting discharge comparison during the year of 2025 confirms that the discharges from the natural tributaries can be neglected, see **Figure 51**. This can also be confirmed by looking at the Allondon tributary which represent the biggest catchment basin flowing into the Rhône between the two hydrological gauging stations. This catchment basin is approximately 146 km². Over the period 1986-2025, the mean annual discharge is 3.2 m³/s whereas for the Rhône at “Aux Ripes” station the mean annual discharge is 338 m³/s. There is a difference of 2 orders of magnitude between the two discharges. Also, the comparison with a monthly granularity shows that the maximum monthly discharge for the Allondon was 4.9 m³/s in January, whereas the minimum monthly discharge for the Rhône River was 259 m³/s in October. In the worst scenario, the contribution from the Allondon can reach 2% of the Rhône River.

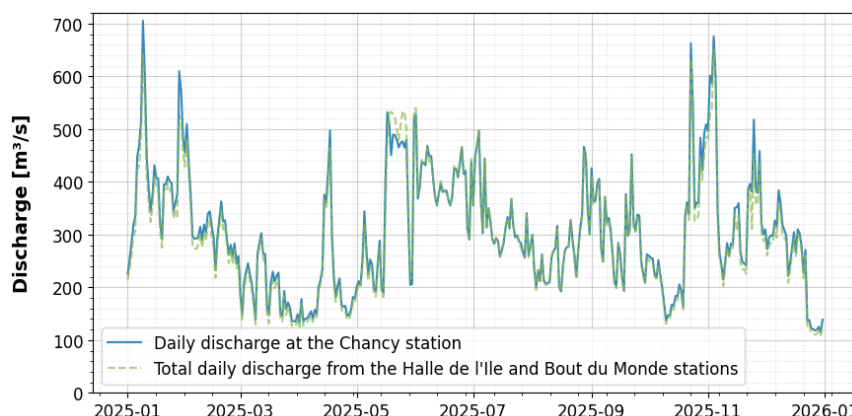


Figure 51. Comparison of the upstream discharges during the year 2025 with the downstream daily discharges.

Using the data from 2014 to 2025, the expected daily discharge during the year is given in **Figure 52** for the Rhône River at the station “Aux Ripes”. In average, the daily discharge is of 300 m³/s in winter and increases to approximately 460 m³/s in summer. The lowest monthly mean is about 65 m³/s whereas the maximum is about 1000 m³/s. The median curve is used in the following to compute the velocity and water height profiles.

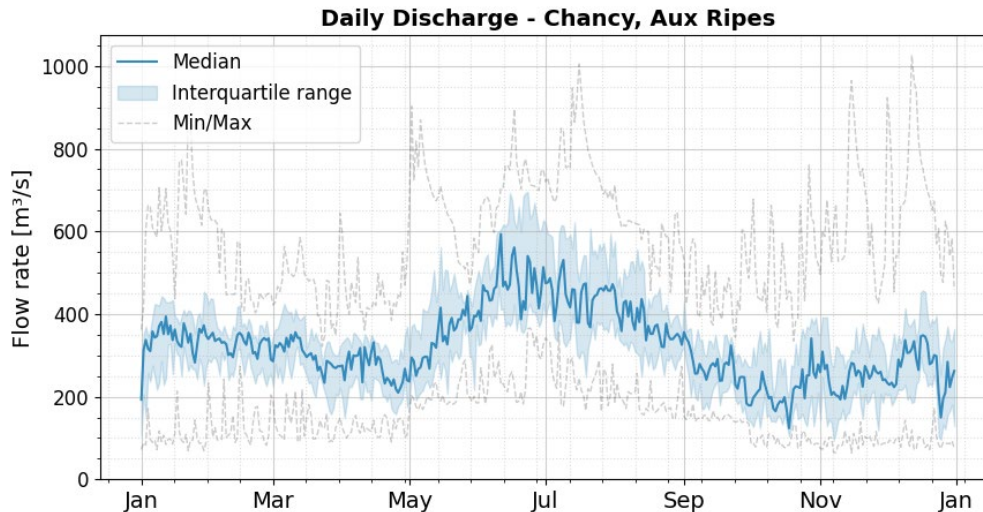


Figure 52. Yearly daily discharge distribution at the hydrological gauging station “Aux Ripes”.

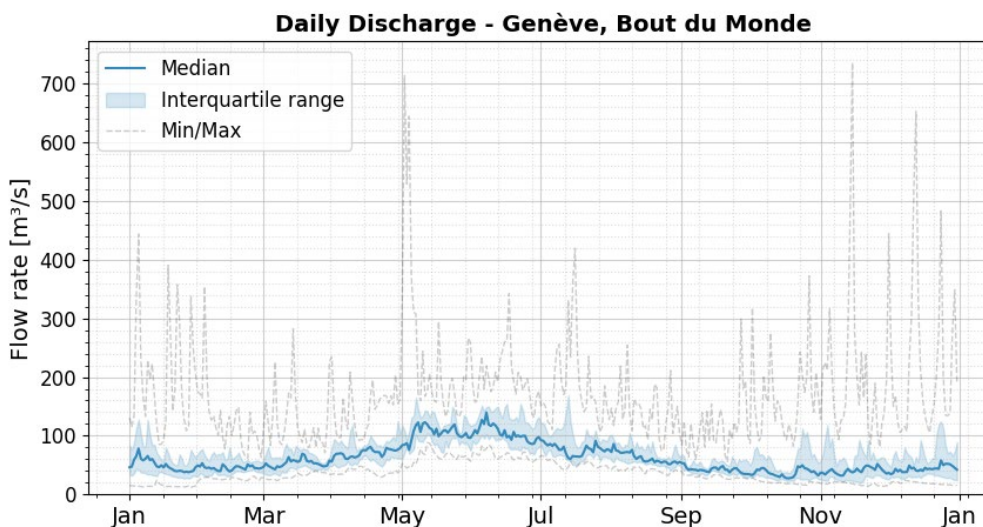


Figure 53. Yearly daily discharge distribution at the hydrological gauging station “Bout du Monde”.

3.2.4 Resulting estimated hydrokinetic energy of natural rivers

Using the rating curves database with the typical discharge distribution along the Rhône River path, the evolutions of the cross-section average velocity as well as the water depth are shown in **Figure 54** and **Figure 55**, respectively. Each graph provides several information. First, the thick line represents the quantity (velocity or water height) when the median of the typical year-long profile is used, see **Figure 52**. Then, using the interquartile range of the daily discharge provides the interquartile range of the two quantities, shown by a shaded area. Finally, using the minimum and the maximum of the daily discharge provides the expected minimum and maximum of the two quantities represented by dot-lines.

Along the path, two significant changes at approximately 13 km and 21 km can be seen. These changes are due to the presence of the Verbois and Chancy-Pougny dams. As expected, the presence of a dam induces a gradually decrease of the velocity with an increase of the water height. Therefore, upstream the dams, the velocity is in average lower than 1 m/s. The last stretch of the Rhône shows velocities around 1.7 m/s.

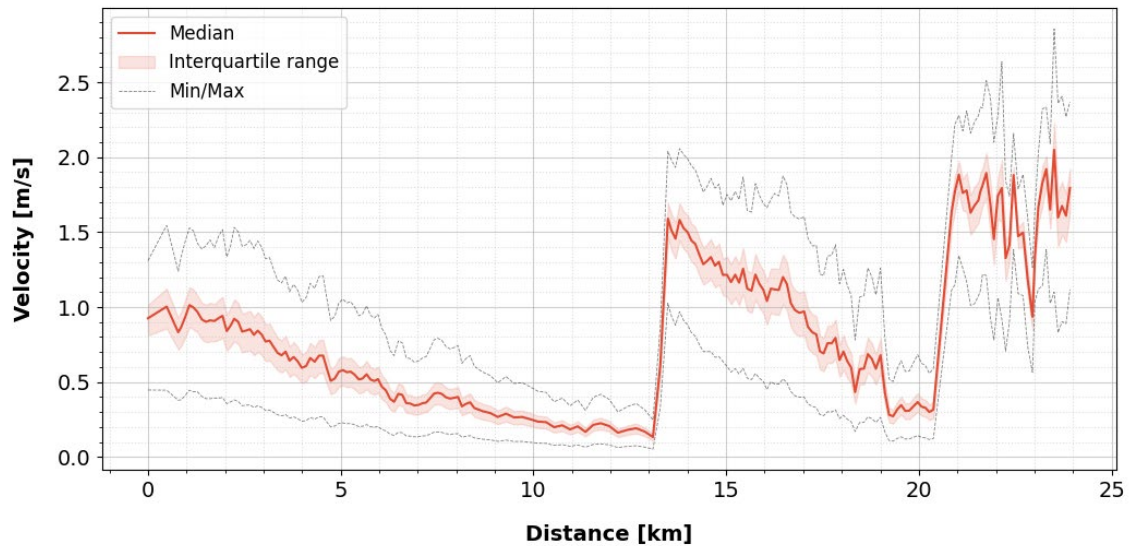


Figure 54. Statistical evolution along the Rhône River path in the Canton of Geneva of the cross-section average velocity. The 0 km distance corresponds to the location of the Seujet dam. The 24 km distance corresponds to the location with the French border. At approximately 13 km is located the Verbois dam and at 21 km the Chancy-Pougny dam.

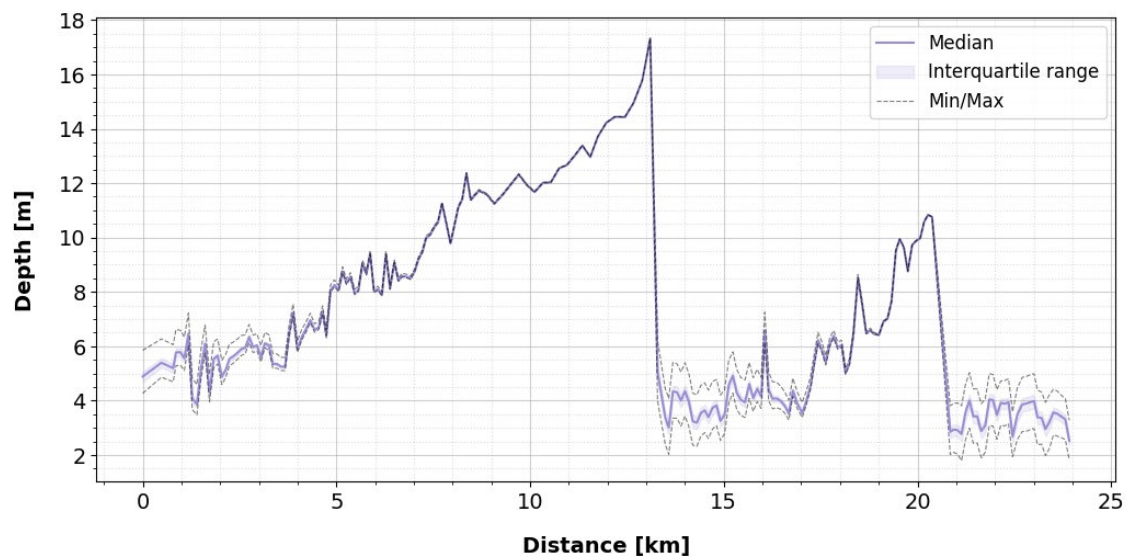


Figure 55. Statistical evolution along the Rhône River path in the Canton of Geneva of the water depth. The 0 km distance corresponds to the location of the Seujet dam. The 24 km distance corresponds to the location with the French border. At approximately 13 km is located the Verbois dam and at 21 km the Chancy-Pougny dam.

Overall, only the downstream reach of the Rhône River of the Canton of Geneva (from approximately 21 km) exhibits a significant hydrokinetic potential. Indeed, the cross-section average velocity is around 1.7 m/s with a water depth of approximately 3.5 m. The computed average cross-section velocity shows strong variation, that results from

the bathymetry, which is shown in **Figure 56**. This is due to two factors: rapid variations in water depth, which can reach up to 10 m, and the presence of a weir located in the area corresponding to the gap in the colour scale.

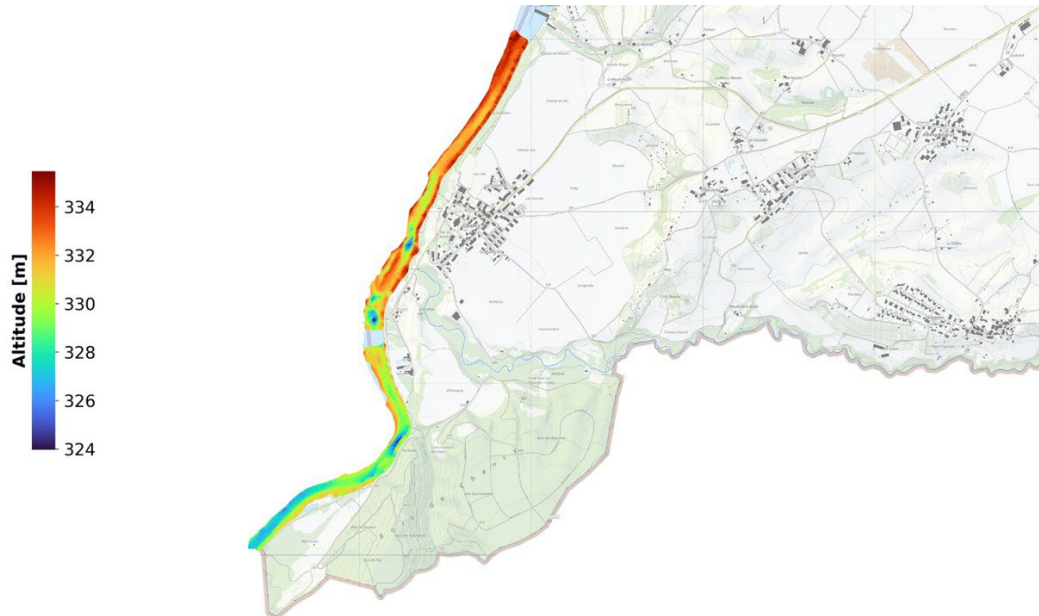


Figure 56. Bathymetry of the Rhône River downstream the Chancy-Pougny hydropower plant.

Finally, following the methodology introduced in Section 2.6.1, the expected annual theoretical potential energy along the path is shown in **Figure 59**. However, the averaged width of the riverbed with its altitude are not available as in the Canton of Valais, see as for example **Figure 25**. Therefore, based on the Valais case study data, an evaluation between the area obtained from HEC-RAS and the area used to compute the energy is shown in **Figure 58**. Therefore, for each bathymetry cross-section, the simplified cross-sectional area was obtained by multiplying the total wetted flow by 0.96. The resulting analysis produced the grey points shown in **Figure 59**, representing the annual theoretical hydrokinetic potential for one-kilometre-long river reaches. To recall, the length is chosen to be 20 times the riverbed width. **Figure 57** illustrates three examples of bathymetry along the Rhone River path in Geneva, showing that the riverbed widths are like the ones observed in the Canton of Valais. Therefore, the reach length is maintained to 1 km.

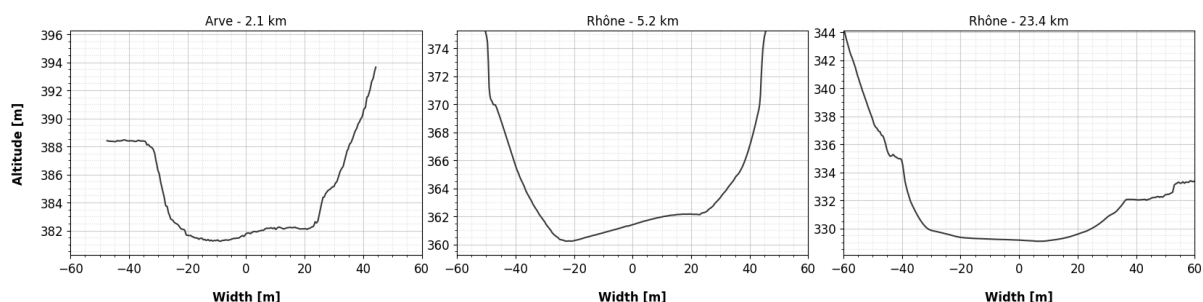


Figure 57. Examples of cross-section bathymetry along the Arve and Rhône Rivers. The distance given in km represents the location of the bathymetry along the longitudinal distance. For the Rhône River the 0 corresponds to the Seujet dam and the Arve River the location of the French border.

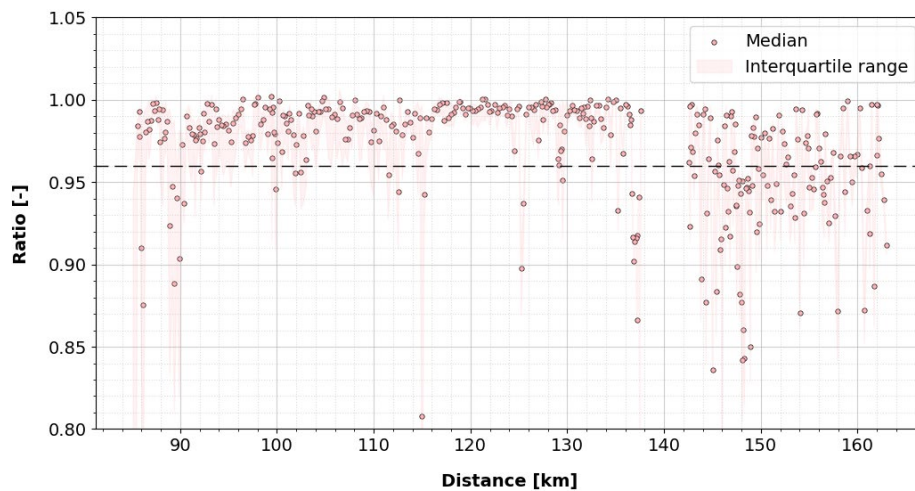


Figure 58. Resulting A^*/A ratio between the considered simplified cross-sectional area and the total wetted flow area for the median discharge along the longitudinal profile of the Chippis-Porte du Scex stretch of the Rhône River in Valais. The average ratio is 0.96.

As previously mentioned, the most favourable reach is located near the downstream end of the Geneva section of the Rhône River with annual theoretical potential energy of approximately 4 GWh per reach and, when summed up, the total potential along the Geneva part of the Rhône reaching approximately 33 GWh.

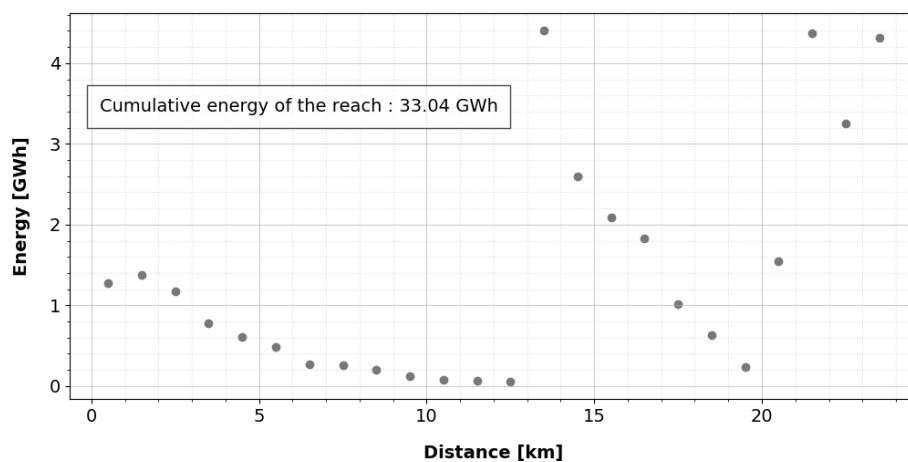


Figure 59. Statistical evolution along the Rhône River path in the Canton of Geneva of the annual theoretical potential energy. The 0 km distance corresponds to the location of the Seujet dam. The 24 km distance corresponds to the location with the French border. At approximately 13 km is located the Verbois dam and at 21 km the Chancy-Pougny dam.

The same methodology was applied to the Arve River. The resulting cross-section velocity and water height along the path are shown in [Figure 60](#) and [Figure 61](#), respectively.

Similarly to the Rhône River, spikes in the velocity profile can be seen and the reason is that the Arve River have several weirs along its path, see [Figure 62](#).

In comparison with the Rhône, the velocity is in average below 1 m/s and the water depth is around 2 m. This result could be expected due to the meanders hinting on a weak river slope.

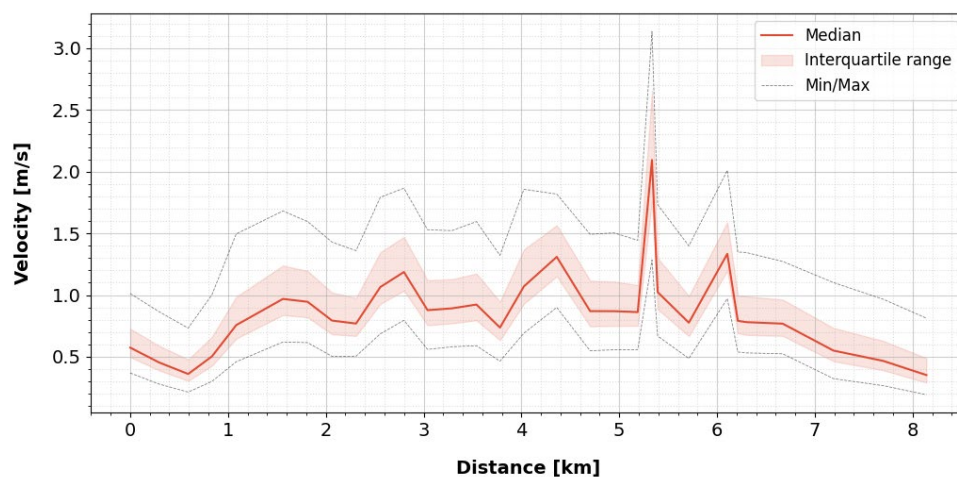


Figure 60. Statistical evolution of the cross-section average velocity along the Arve River path in the Canton of Geneva. The 0 km distance corresponds to the upstream location at the French border. The ~8 km distance corresponds to the location where the Arve River merges into the Rhône River.

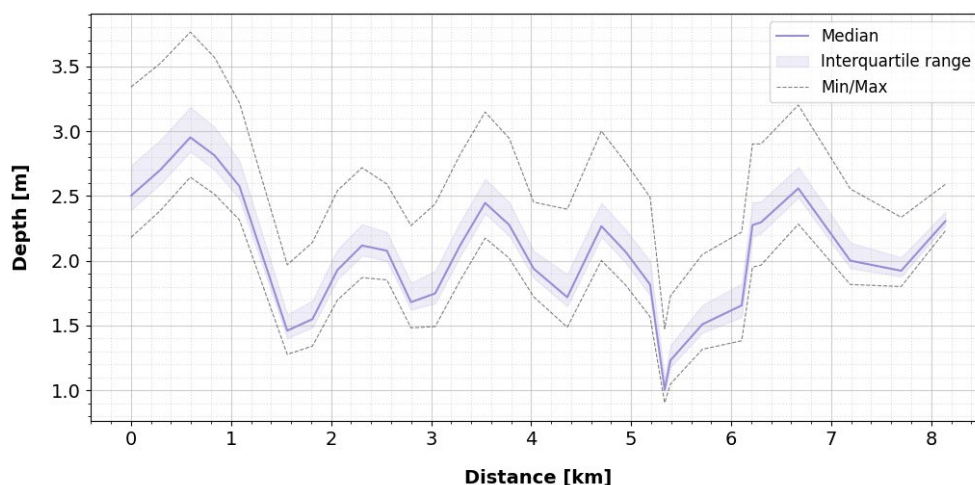


Figure 61. Statistical evolution along the Arve River path in the Canton of Geneva of the water depth. The 0 km distance corresponds to the location at the French border. The ~8 km distance corresponds to the location where the Arve River merges into the Rhône River.



Figure 62. Example of the presence of weirs along the Arve River path.

Finally, the annual theoretical potential energy along the path is shown in **Figure 63**. In average, the potential is around 0.3 GWh per kilometre and the total along the path is 2.47 GWh.

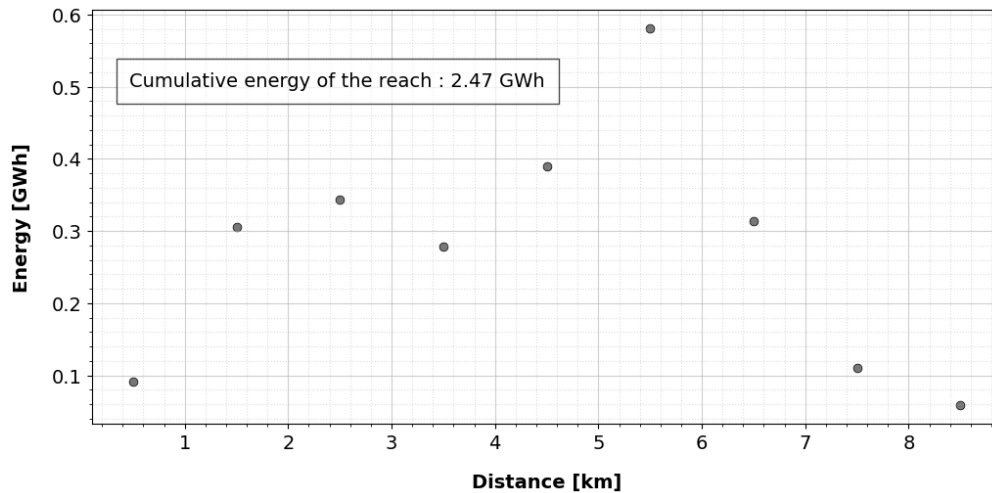


Figure 63. Statistical evolution of the annual theoretical potential energy along the Arve River path in the Canton of Geneva. The 0 km distance corresponds to the upstream location at the French border. The ~8 km distance corresponds to the location where the Arve River merges into the Rhône River.

3.2.5 Resulting estimated hydrokinetic energy of artificial channels

The Rhône River in the Canton of Geneva is equipped with three run-of-river hydropower plants, while the Arve River contains one. Since none of these schemes discharges through an artificial tailrace channel suitable for hydrokinetic energy assessment, no artificial channels were considered in the Geneva case study.

3.3 Atlas rendering

3.3.1 Canton of Valais

The prepared GIS data for the Atlas are presented for the Canton of Valais in **Figure 64**, which shows the computed annual theoretical potential energy along reaches of 1 km long. The energy per reach varies between 0.5 and 4.7 GWh/year with two areas standing out. The first one is after the Rhône elbow near Martigny with a potential energy of 3.1 GWh/year, thanks to a local steeper slope. The second one is after the Lavey hydropower plant with a reach having the maximal annual potential energy. The potential is estimated to be 4.24 GWh/year and the reason is because of a steeper slope. That is why the MBR (Massongex Bex Rhône) project with an installed capacity of 15 MW is currently under development with the objective to generate from 2031, 80 GWh per year [17].

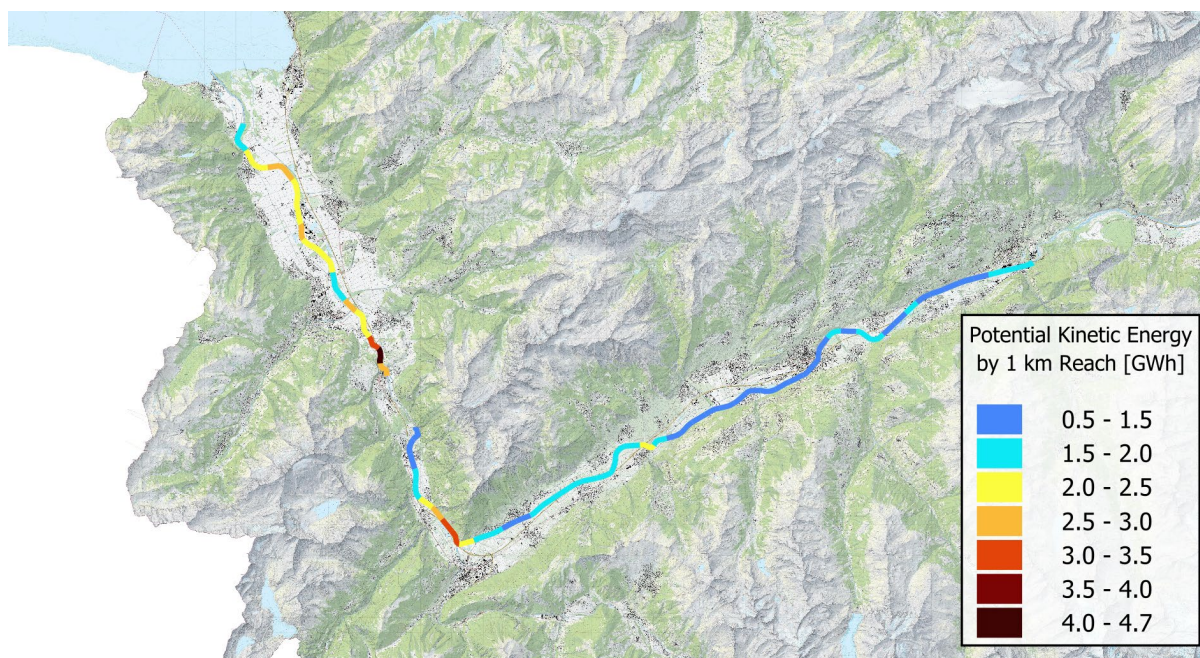


Figure 64. Representation of the prepared GIS data to be included in the Atlas for the Canton of Valais. The colours represent the computed annual theoretical potential energy along the path. For the Rhône River, the reach length is 1 km.

3.3.2 Canton of Geneva

The prepared GIS data for the Atlas are presented for the Canton of Geneva in **Figure 65**, that shows the computed annual theoretical potential energy along reaches of 1 km long. The energy per reach varies between 0.0 GWh/year and 5.0 GWh/year with one area standing out downstream the hydropower plant of Chancy-Pougny, i.e. the last stretch in the Canton of Geneva. Along this path, reaches are between 3.5 GWh and 5 GWh per year. This part has a steeper slope, the presence of a weir ensuring that any project downstream it won't affect the existing hydropower plant. However, there are still ongoing discussion regarding the construction there of a new hydropower plant. A feasibility study was conducted in 2010 and with a maximal electrical power of 25.1 MW the average annual production would be around 140 GWh. The documents are available on the SIG website [18].

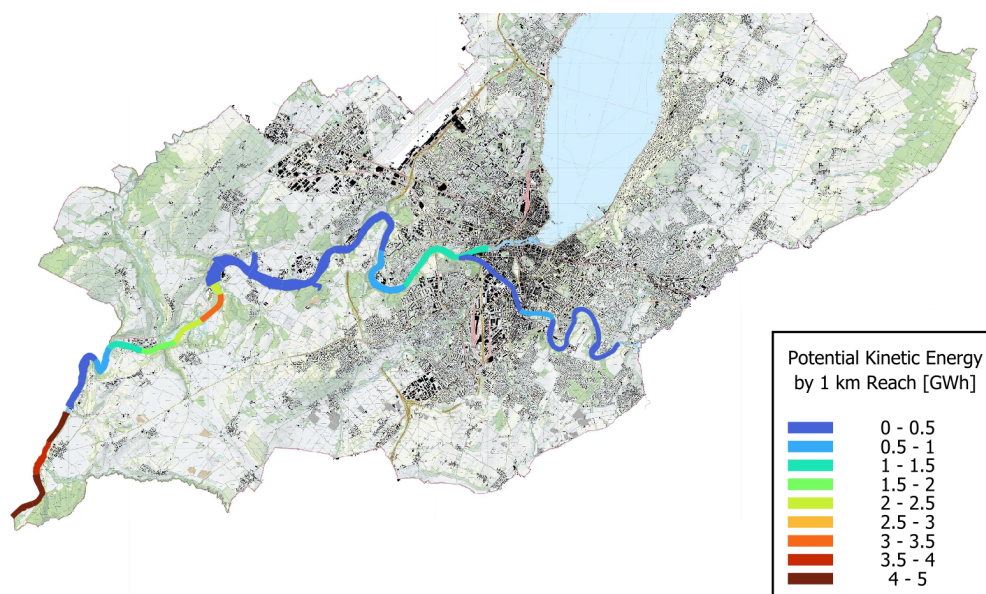


Figure 65. Representation of the prepared GIS data to be included in the Atlas for the Canton of Geneva. The colours represent the computed annual theoretical potential energy along the path.
For the Rhône River, the reach length is 1 km.

3.4 Discussions

The present study showed that the annual theoretical potential energy is in the order of 1-2 GWh per stretch, considered as 1 km long for the Rhône and the Arve Rivers. However, the authors would like to highlight the main sources of uncertainty associated to these estimates.

The study assumes that the available bathymetry data provide an adequate representation of the river geometry. No dedicated field survey was conducted to validate these data or to identify reaches where significant sediment transport may alter the riverbed morphology over time.

The evaluation of the discharge contribution from the natural tributaries is also subject to uncertainty. For ungauged catchments, the methodology relies on numerical simulations of the monthly natural discharge provided for each catchment basin, without explicitly accounting for the effects of dams or other hydraulic infrastructures that modify the natural flow regime. Additional uncertainties arise from the temporal disaggregation of the monthly discharge into daily values and from the manual identification of whether the runoff reaches the main river directly or is diverted through a hydropower scheme. In the latter case, uncertainties are also associated with the determination of the location where the diverted water is returned to the main river. Nevertheless, the presence of hydrometric stations along the main river made it possible to constrain these uncertainties through model calibration and validation, ensuring that the resulting discharge model remains consistent with the observed river flow.

The dam representation implemented in the HEC-RAS supposes a significant change in the riverbed profile approaching the structure, resulting in a velocity reaching 0 m/s at the location of the dam. However, this assumption is not fully representative of run-of-river hydropower plants, where the flow generally maintains a finite velocity as it approaches the intake. Consequently, the computed velocity, water depth, and hydrokinetic energy profiles are affected in the vicinity of these structures.

Another source of uncertainty is the downstream wake recovery distance of hydrokinetic turbines. In the proposed methodology, a longitudinal spacing of 20 turbine diameters between two successive rows of turbines was assumed. The same criteria were used for the theoretical potential and defined the length of a stretch as 20 times the riverbed. However, this criterion assumed that the number of hydrokinetic turbines per section can be maximised. In addition, the nature of the flow was not considered. Indeed, more turbulent the flow is, shorter is the length of the hydrokinetic turbine wake.

The methodology to compute the theoretical potential energy requires to define the area of the section and the velocity. For the cross-sectional area, the riverbed width was adopted for natural rivers, while the channel base width was used for artificial channels. The available data for the Rhône part in Canton of Valais provided this valuable information, i.e. the riverbed width with its altitude with regards to discharges were available. Although these data are of high quality, they remain subject to uncertainty. The velocity is obtained from the discharge and the entire cross-section area. Therefore, the selected velocity followed a conservative approach.

Also, an important uncertainty, are the bathymetries. Indeed, this study provides results based on actual data. If a river has lots of sediment transport, the bathymetry geometry will evolve and thus the results of this study.

4 Conclusions and perspectives

4.1 Conclusions

In the framework of the SHINES project, a study focusing on the available theoretical hydrokinetic energy potential in two Swiss cantons was carried out. These two cantons are the Alpine Canton of Valais and the Canton of Geneva, located in the Swiss Plateau.

These two cantons share the same main river, the Rhône River, which originates at the Rhône Glacier in the Canton of Valais and flows downstream to southern France, where it reaches the Mediterranean Sea in the Camargue delta. In addition to this main river, the Canton of Geneva is crossed by another significant tributary, the Arve River, which originates in France near the Mont Blanc massif. A particular characteristic of the Rhône in the Canton of Valais is its Alpine setting, with numerous existing hydropower plants. Therefore, significant work was carried out to estimate the daily discharge of all natural and artificial tributaries along the course of the main river.

This study shows that the theoretical hydrokinetic energy potential is mainly concentrated in the Rhône River. In addition, two artificial channels associated with run-of-river hydropower plants in the Canton of Valais were identified as having significant hydrokinetic energy potential. These are the headrace channel of the Chippis-Rhône hydropower plant and the tailrace channel of the Lavey hydropower plant.

To summarize, the total annual theoretical hydrokinetic energy potential estimated in this study, at this stage, reaches approximately 200 GWh and is distributed as follows:

- 160 GWh for the Wallis section of the Rhône River.
- 33 GWh for the Geneva section of the Rhône River.
- 3 GWh for the Geneva section of the Arve River.
- 3 GWh for the headrace channel of the Chippis-Rhône hydropower plant.
- 1 GWh for the tailrace channel of the Lavey hydropower plant.

4.2 Perspectives

The accomplished work allowed us to complete a comprehensive database of the main parameters governing the feasibility and potential of hydrokinetic energy recovery for the main rivers (namely the Rhône and the Arve) flowing through the Cantons of Geneva and Valais. Beyond the estimation of the theoretical hydrokinetic energy potential, the next steps will focus on:

- Refinement of the database by adjusting or filtering the limited number of river sections exhibiting unfeasible results in terms of water depth or flow velocity values, mainly generated by the inability of the HEC-RAS model to reproduce complex local three-dimensional flow effects.
- Selection of the most promising locations along the natural rivers in the Cantons of Geneva and Valais as well as the estimation of their theoretical hydrokinetic energy potential.
- Assessment of the techno-economic hydrokinetic energy potential of the selected natural and artificial sites.
- Finalization of the database and development of the online Atlas, including several layers presenting the main hydrokinetic parameters and energy potential indicators.

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Appendix

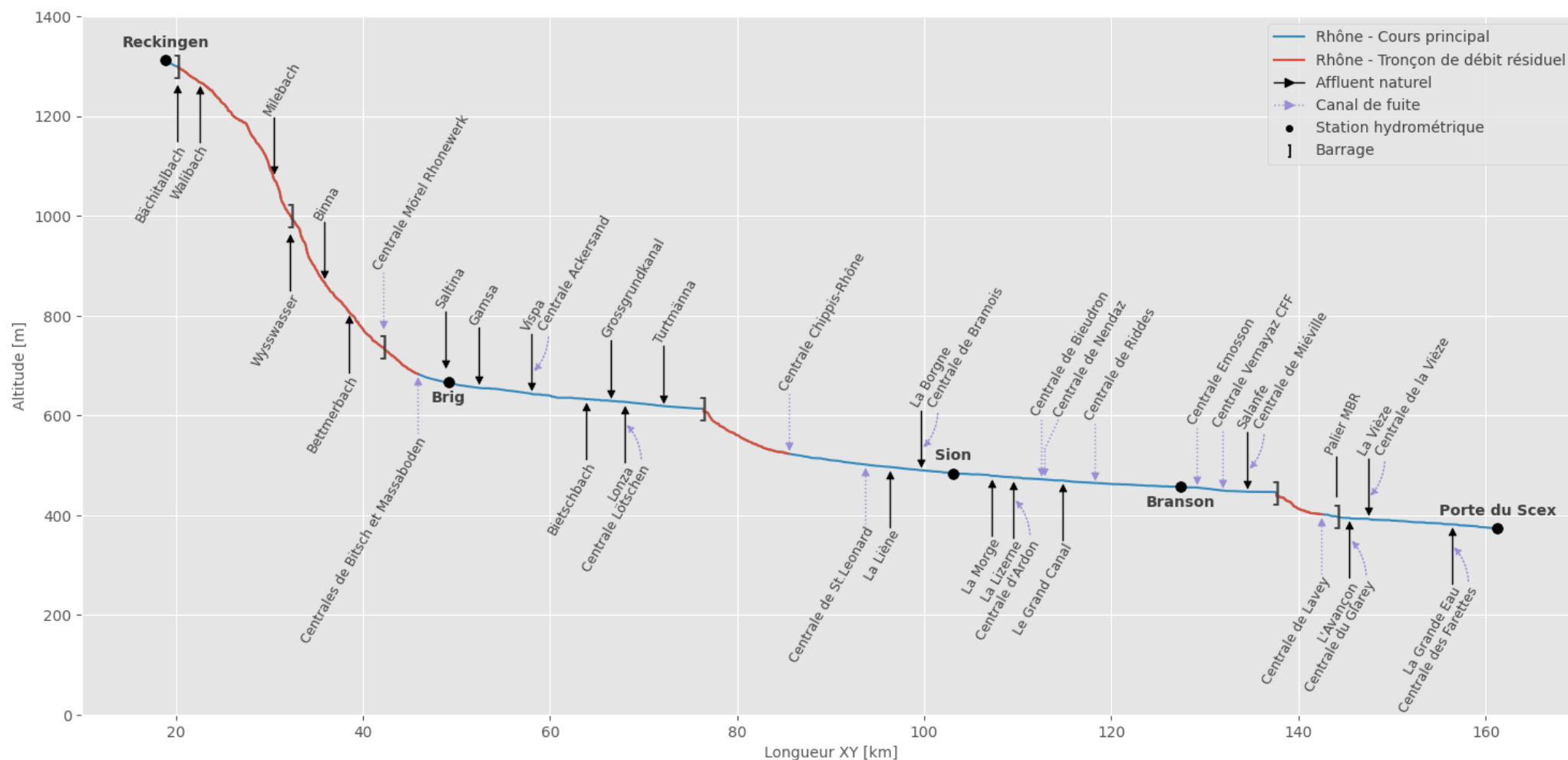
Appendix A. *Schematic hydrographic map of the Canton of Valais.*

Appendix B. *Schematic hydrographic map of the Canton of Geneva.*

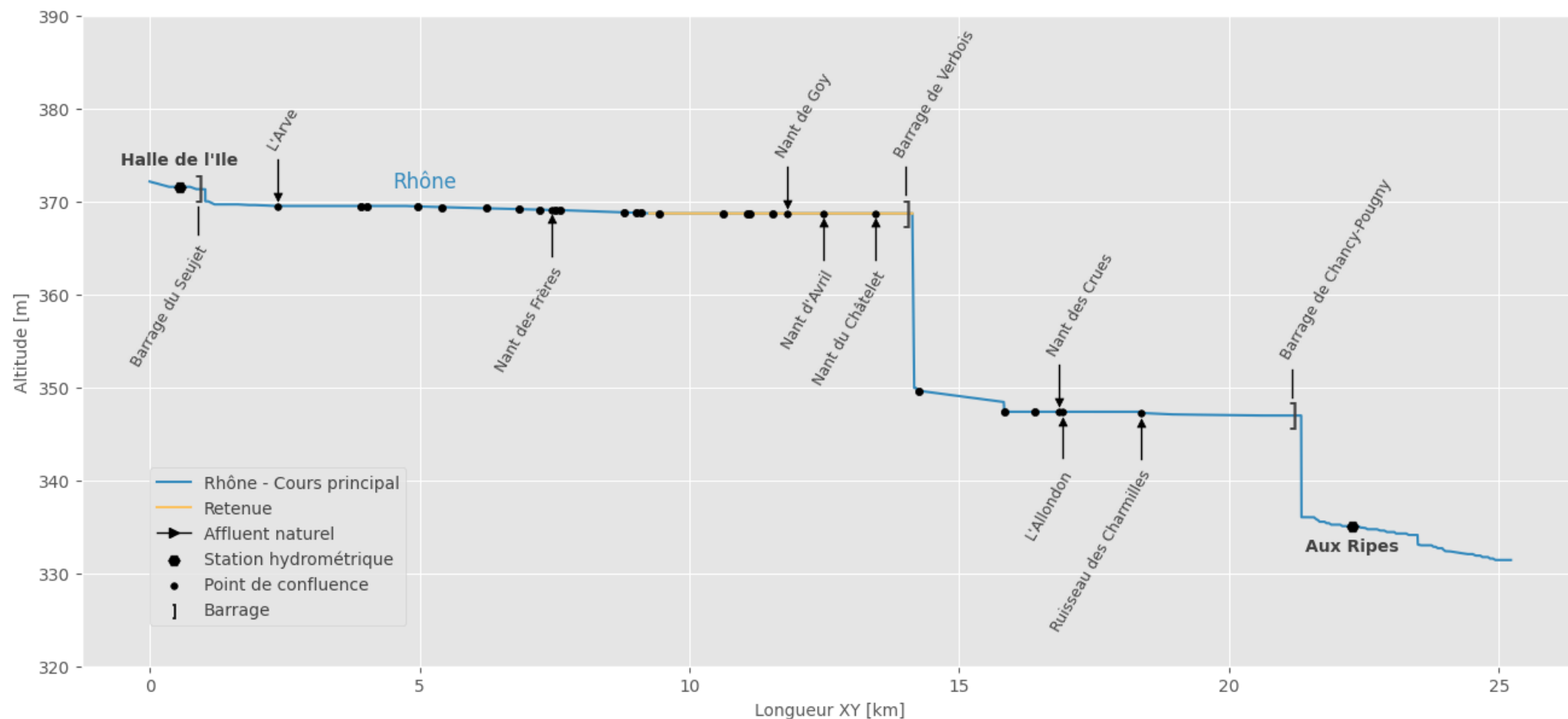
Appendix C. *Hydrokinetic theoretical potential summary of Chippis-Rhône headrace channel.*

Appendix D. *Hydrokinetic theoretical potential summary of Lavey tailrace channel.*

Schematic hydrographic map of the Canton of Valais



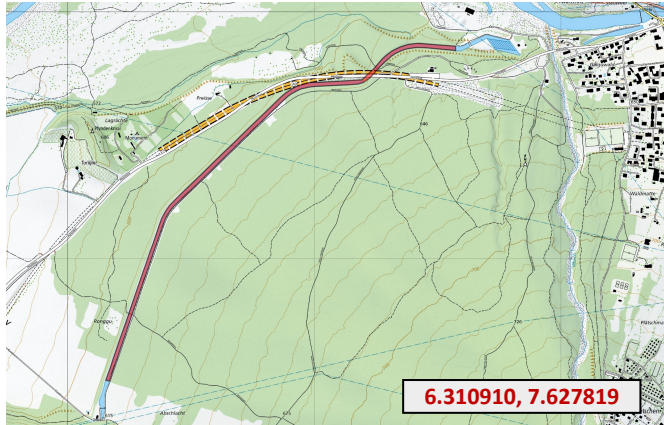
Schematic hydrographic map of the Canton of Geneva



Isokinetic theoretical potential summary – Valais case study

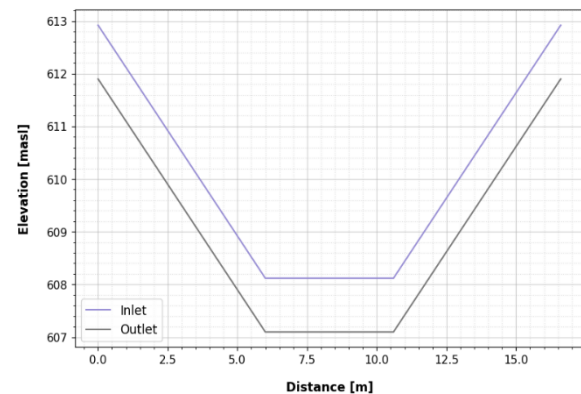
Site: Rhone River – Chippis-Rhone hydropower plant headrace channel

Location:



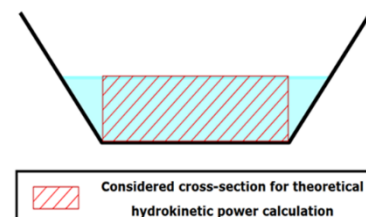
Main characteristics:

	Inlet	Outlet
Max. discharge	62.00 m ³ /s	
Mean discharge	35.90 m ³ /s	
Median discharge	29.61 m ³ /s	
Min. discharge	4.53 m ³ /s	
Max. discharge speed	1.61 m/s	1.32 m/s
Median discharge speed	1.39 m/s	1.08 m/s
Min. discharge speed	0.95 m/s	0.65 m/s
Max. water depth	4.01 m	4.56 m
Median water depth	2.67 m	3.18 m
Min. water depth	0.92 m	1.24 m
Max. wetted area	38.57 m ²	47.06 m ²
Median wetted area	21.25 m ²	27.34 m ²
Min. wetted area	5.28 m ²	7.64 m ²
Section type	Artificial channel	
Total section length	2150 m	
Number of production sections	21	
Mean bottom slope	0.4 ‰	
Manning's coefficient	~ 0.019 sm ^{1/3}	
Statistical data period	Jan 2013 – Dec 2023	

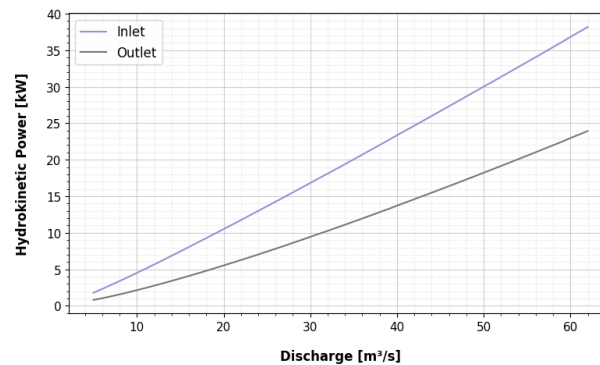
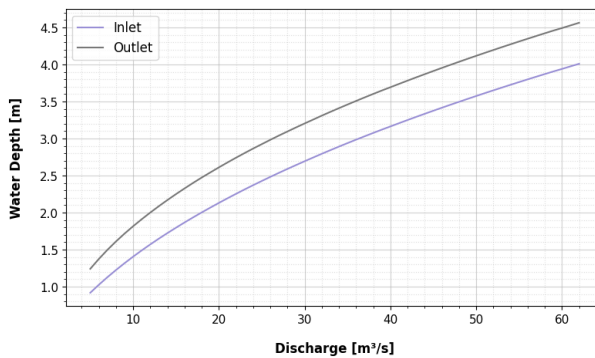
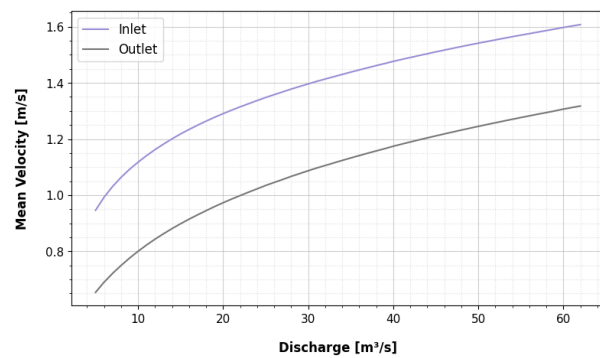
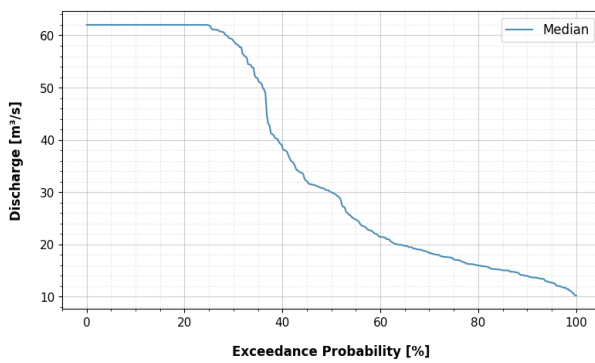
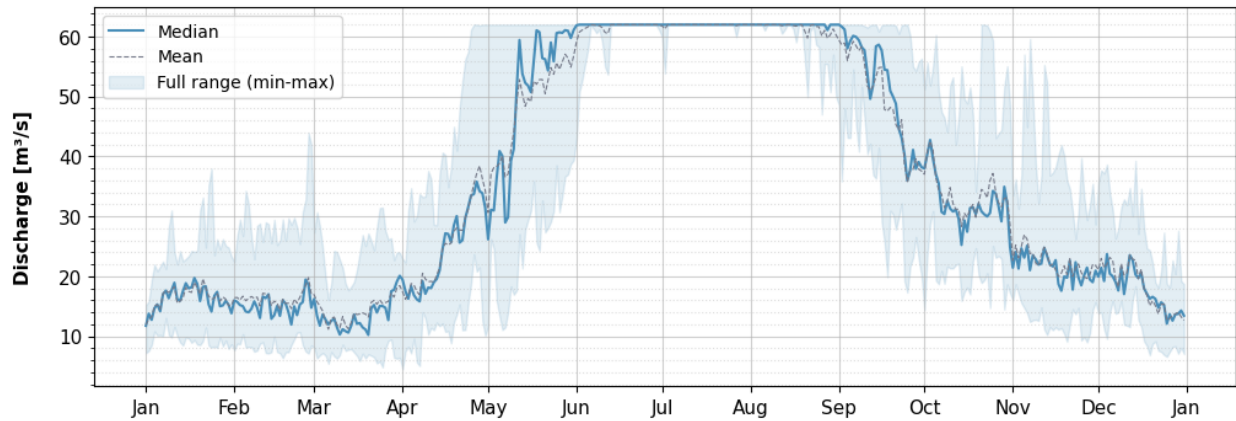


Estimated theoretical isokinetic potential:

	Inlet	Outlet	Total
Median power	20.91 kW	12.85 kW	-
Integrated energy	183 MWh/year	113 MWh/year	2.94 GWh/year



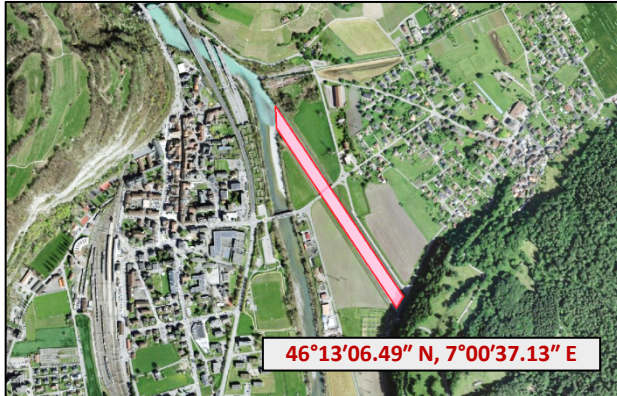
Main statistical variations:



Isokinetic theoretical potential summary – Valais case study

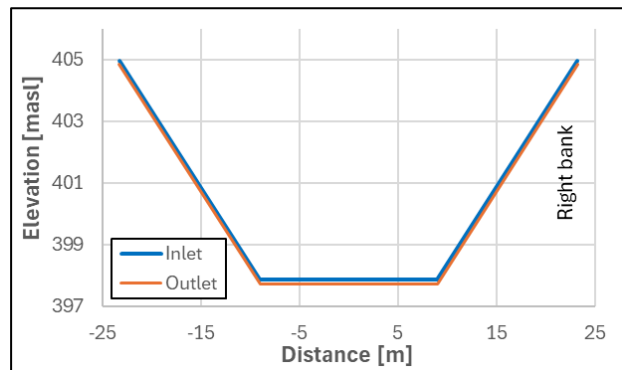
Site: *Tailrace channel of Lavey powerplant*

Location:



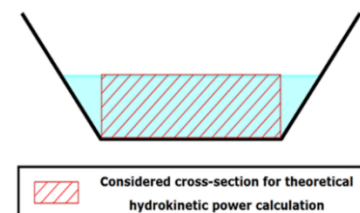
Main characteristics:

	Inlet	Outlet
Max. discharge	250.5 m ³ /s	
Mean discharge	142.15 m ³ /s	
Median discharge	133.3 m ³ /s	
Min. discharge	0 m ³ /s	
Max. discharge speed	1.56 m/s	1.79 m/s
Median discharge speed	1.03 m/s	1.11 m/s
Min. discharge speed	0 m/s	0 m/s
Max. water depth	5.53 m	4.99 m
Median water depth	4.71 m	4.45 m
Min. water depth	3.79 m	3.85 m
Max. wetted area	160.79 m ²	139.72 m ²
Median wetted area	129.44 m ²	119.99 m ²
Min. wetted area	97.00 m ²	98.94 m ²
Section type	Artificial channel	
Section length	500 m	
Number of production sections	2	
Mean bottom slope	0.25 ‰	
Manning's coefficient	0.033	
Statistical data period	Jan. 2010 – Dec. 2012	



Estimated theoretical isokinetic potential:

	Inlet	Outlet	Total
Median power	66.76 kW	85.31 kW	-
Integrated median energy	585 MWh/year	747 MWh/year	1.332 GWh/year



Main statistical variations:

