INITIATIVES POUR L'AVENIR DES GRANDS FLEUVES
INITIATIVES FOR THE FUTURE OF GREAT RIVERS

Synoptic sheets

Rivers of the world

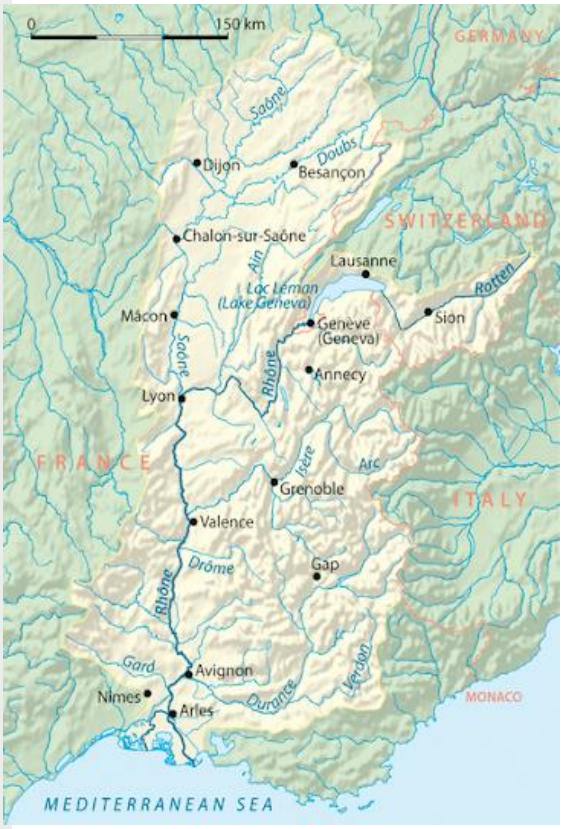
The Swiss Rhone

Initiatives
pour l'Avenir des
Grands Fleuves

The Swiss Rhone

Although the sources of both rivers lie in the massif of Saint-Gothard, the Rhone differs from the Rhine due to its impetuosity. From the glacier located near the Furka to the delta of the Camargue, its course is marked by irregularities: from elbows to rocky gorges, flood plains to steep slopes. To prevent its floods and tame its course, human beings have always attempted to subdue it, though without complete success. Aware of the danger it represents, the Swiss have for long tried to keep it at arm's length.

New challenges have arisen with climate change: the risks of rain and floods are increasing, the glacier may disappear and the ecosystems around it are weakened. Relations with the river are evolving to maintain the services it renders, reconcile human beings and water, and find the economic, environmental, urban and societal conditions of an alliance capable of succeeding in the future.



The origins

The source of the Rhone - *Rotten* in German – lies in the glacier of the same name, on the Furka mountain in the Saint-Gothard massif at the eastern end of Valais, at an altitude of 2,300 m. This massif is also the source of the Rhine, another large river of Western Europe.

The Rhone then crosses the canton of Valais for a distance of 164 km, before flowing into Lake Geneva, the largest lake in Western Europe. On exiting Lake Geneva, the Rhone flows for another 25 km in Switzerland before crossing the border and entering France, where its ends its course in the Camargue delta and flows into the Mediterranean.

The Valais has a sunny climate and is the driest region of Switzerland, resulting from the configuration of the relief of the local terrain. Thus the Rhone plays a fundamental role in this part of Switzerland, as almost all the towns of the canton (Brig, Visp, Sion, Martigny) lie on its banks.

Technical sheet

Length: 812 km including 290 km in Switzerland

Watershed: 97,800 km² (including 7,800 km² in Switzerland)

Hydrological regime: 1/Upstream of Lake Geneva, a *glacial-nival regime* characterised by low water in winter and high discharges when the ice of the glaciers melts in spring and summer. 2/ Downstream, a glacial-nival regime with a maximum discharge between in July, caused by melting ice and snow.

Average discharge: 182 m^3/s at the entrance to Lake Geneva and 251 m^3/s at its outlet. The Arve, a tributary of the Rhone, has a discharge of 80 m^3/s.

Average rainfall: 1538 mm/year (upstream of Lake Geneva)

Swiss cantons crossed: Geneva, Vaud, Valais

Main tributaries in Switzerland (length > 100 km, catchment area > 1000 $km^{2)}$: Vispa, Grande Eau, the Veveyse, the Venoge, Versoix, the Arve, the Allondon

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The Swiss Rhone

Developing the river, From the Middle-Ages to today

History of a ravaging river

At the beginning of the Middle Ages, the Swiss Rhone was slow and less dangerous than towards the end of the Little Ice Age, in meanders and with no main channel. These arms flowed between tree-covered dunes, meadows and fields. **The natural landscape was then quite different of the one we know today, with great biological diversity**. A peasant population settled in the plain, tending cattle, collecting wood and straw, and living off an agropastoral economy. To protect themselves from the potential angry outbursts of the Rhone, the inhabitants built dikes by heaping gravel and stones, intertwined branches and barriers.

At the end of the Middle-Ages, a cold period called the **Little Ice Age** *(from 1350 to 1860)* occurred in the Northern hemisphere, marked by heavy rainfall and the considerable expansion of glaciers. That of the Rhone reached a length of 10 km in 1850. **The Rhone became increasingly dangerous and unstable.** The rivers and torrents transported sediments into the bed, which made it rise. This led to often devastating floods, especially since the Rhone often formed a municipal boundary. During a flood, a terrain cultivated by the inhabitants of a municipality could become inaccessible and then be taken over by another municipality, generating numerous conflicts. Floods could also damage and destroy entire harvests.

The population sought means to tame the river. The flood of 1545 led the Cantonal Assembly to consider adaptive measures to protect the pastures and the main road located downstream of La Morges, a Swiss river in the canton of Valais. **In the middle of the 16th century, the population began to implement its knowledge of river dynamics and the knowhow it had learned**. However, the human and financial resources proved insufficient to carry out major works to build flood protection dikes.

The "corrections" of the Rhone

The flood of October 2000 at Saillon, in the canton of Valais. Source: Wikiwand. Correction of the Rhone upstream of Lake Geneva.

The economy of Valais continues to suffer from the overflows of the Rhone: traffic is interrupted, goods transport is heavily affected and travel becomes difficult. **Two events during the 19th century sealed the fate of the river.** In 1815, the canton of Valais joined the Swiss Confederation which wanted to open out to Italy. In 1860, the flooding of the Rhone triggered federal support motivated by the strategic importance of a good connection to Italy (by road, and later, from 1905, by train (Simplon tunnel).

Several development projects were undertaken on the Rhone. The first two phases of "correction" works were aimed at preventing floods, progressively breaking the links between the river, the population and the natural environment. **It was not until the 2000s that the paradigm changed from "living next to" the river to "living with" it.** The 3rd correction project, which began in 2009 and is still in progress, plans for the global and integrated management of the Rhone, that is to say flood protection, the restoration of natural habitats and the reappropriation of the river by the surrounding population.

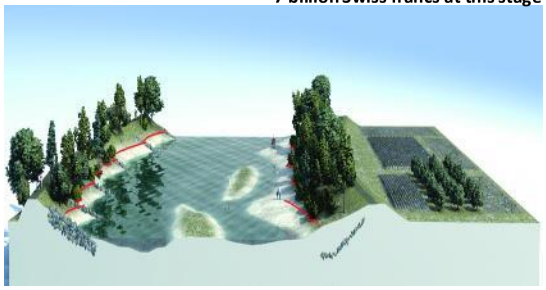
The projects to correct the Rhone

3rd CORRECTION PROJECT: DEEPENING AND WIDENING

Since 2009

- Global project from the source to Lake Geneva: 160 km of river to be developed.
- Strengthen fragile, unstable and poor quality dikes.
- Lower the riverbed and widen it depending on the sections and safety needs - nearly 800 additional hectares planned to carry out the project.
- Recreate a link between the population and river by developing spaces for leisure and relaxation.

7 billion Swiss francs at this stage

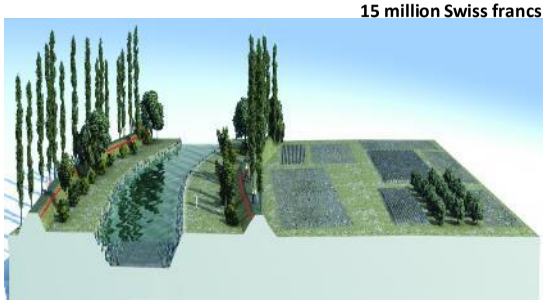


2nd CORRECTION PROJECT: RAISING THE DIKES

1934 - 1961

- Keep the dikes of the first correction, raise and strengthen them.
- Narrow the river bed by linking the heads of groynes and sections of riprap to increase bedload velocity.
- Develop the exploitation of gravel quarries along the river to reduce deposits of materials and avoid raising of the bed.
- A river landscape that remains natural but with the development of industrial and residential areas.

15 million Swiss francs



1st CORRECTION PROJECT: DAMMING

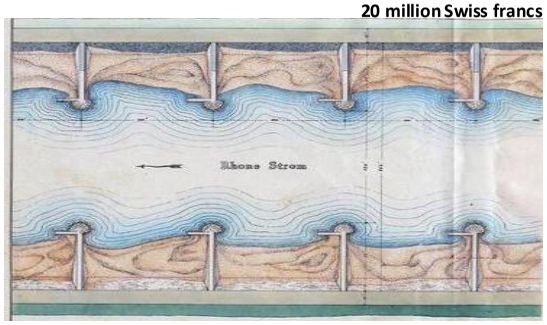
1863 - 1894

- Build two parallel dikes of rockfill and earth to form a new bed, secure the roads and land on the plain.
- Dry the marshes and clear large areas to make arable land available to the population: development of intensive agriculture.

The consequences were:

- × The formation of marshes during floods due to the lack of properly constructed mouths between the tributaries and the newly dammed Rhone
- × The absence and lack of drainage increased flood risks.
- × Rise in the surface of irrigated land

20 million Swiss francs



The Swiss Rhone

Harnessing the power of the river

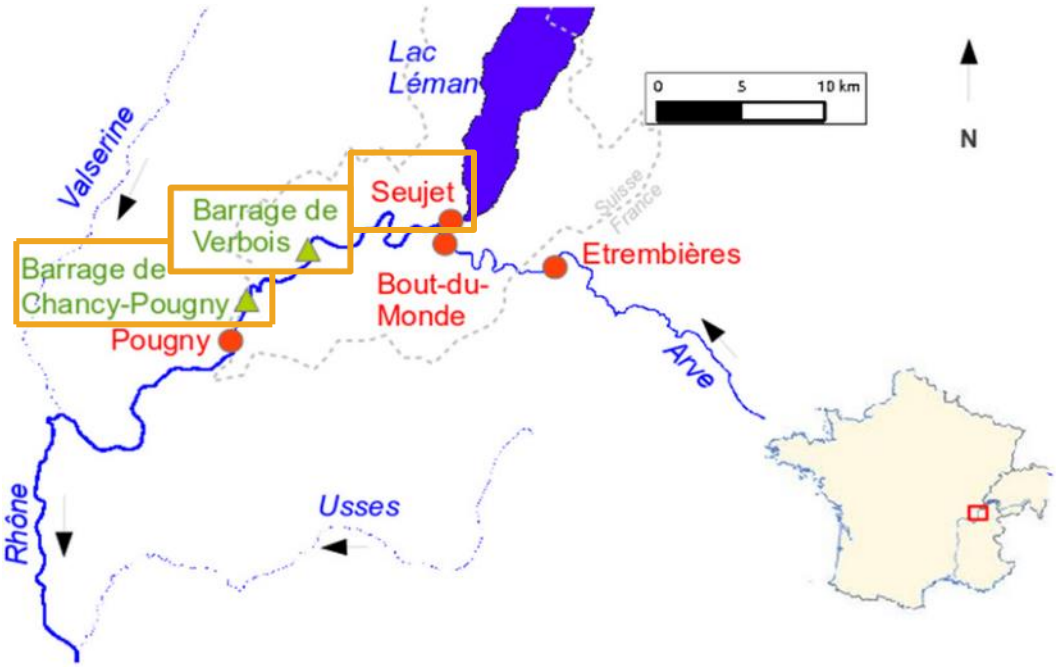
As early as the Middle-Ages, human beings have wanted to harness the river's hydraulic force and water mills multiplied in the canton of Geneva in the 15th century. In the middle of the 19th century (1841-1843), Jean-Marie Cordier, a French engineer, invented a new machine that was installed in the bed of the Rhone. **The mechanical force of the water used up to then to drive pumps and mills was also used to produce electricity using a generator.** Switzerland, with its many mountains and rivers was at the vanguard of the development of hydraulic installations.
Hydroelectricity dams were built in the cantons of Valais – which had the most propitious terrain – and Geneva.

The Federal Council's current strategy determines strong development of hydropower as one of its priority directions, with a goal of attaining an average yearly production of 38.600 GWh by 2050. Currently, the canton of Valais is the highest contributor in hydroelectric production of the Confederation, with 30% of the swiss production.

In the canton of Geneva:
In 1882, Theodore Turrettini built the plant of Coulouvrenière in Geneva, composed of 18 turbines driving two hydraulic pumps. It was the first plant to use pressurised water to supply a huge network of industrial sites and the most powerful run-of the-river development in Europe at the end of the 19th century. **Hydroelectricity in Geneva began at the Pont de la Machine in 1887.**

Demand for electricity rose after the Second World War. **The Services Industriels de Genève (SIG)**, originally a private electricity and gas company when founded in 1896, became an independent entity under public law in 1973.

SIG operates 3 hydropower plants in the canton of Geneva covering 25% of the city's consumption.



Source: Launay, M., Le Coz, J., Diouf, S., Camenen, B., Thollet, F., & Coquery, M. (2019). Re-evaluation of average inflows of suspended materials from the Arve to the Rhone. White Coal, (2), 89-100.

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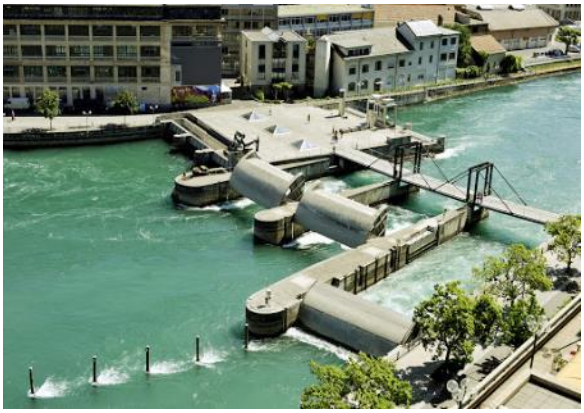
The Swiss Rhone

- **Seujet Dam,** built between 1987 and 1995. It is used to produce electricity, modulate the discharge of the Rhone and regulate the level of Lake Geneva. **Its annual production is low at 25 GWh**, i.e. 1% of the consumption of the inhabitants of Geneva.



- **The works on Verbois dam** began in 1938 and ended in 1943. This dam has four gates, one plant with two lateral dikes and four Kaplan turbines, giving it a **high energy output despite the variations of discharges throughout the year**. It is a run-of-the-river plant, that's to say with a reservoir with a small volume of water. However, thanks to the modulation of the discharge of the Rhone at Seujet dam, the site of Verbois can produce more electricity during periods of high demand. **Annual production is 466 GWh,** representing 15% of the consumption of the population of Geneva.

- **The French-Swiss dam of Chancy-Pougny** was built between 1921 and 1925. It is operated by the Société des Forces Motrices de Chancy-Pougny (SFMCP) whose shareholders are the SIG and CNR (Compagnie nationale du Rhône). It is also a run-of-the-river dam**. Its annual production is 250 GWh**, i.e. 8.3% of the consumption of the canton's consumption.

In the canton of Valais:

Valais has an annual hydroelectricity output of 10 billion kWh, representing between 25 and 30% of Swiss production. About 95% of this energy is produced by 46 large hydropower plants (more than 10 MW of installed capacity), characterised by high heads and a large storage capacity. The remainder comes from 121 small plants. **5 installations are run-of-the-river plants on the Rhone (Ernen, Mörel, Massaboden, Chippis and Lavey).**

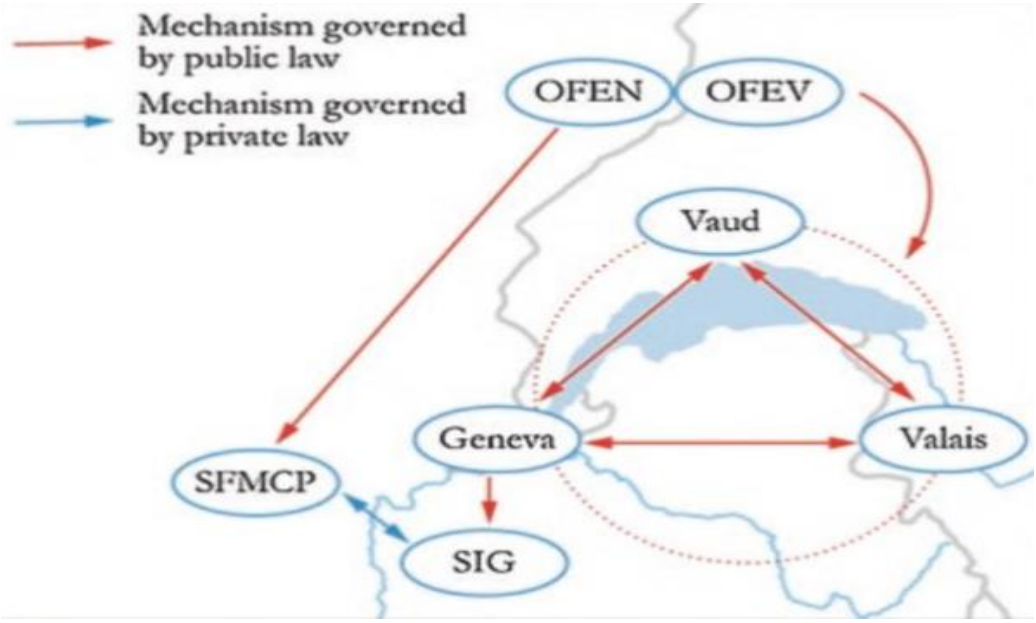
The Swiss Rhone

Governance and international cooperation

Governance

Upstream of Lake Geneva, the Rhone is the property of the Valais and Vaud cantons. Downstream of Lake Geneva, it is the property of the Canton of Geneva and is managed by the Services Industriels de Genève.

The structure of the river's governance in Switzerland is mainly based on legal bodies subject to public law and is characterised by the intervention of a large number of actors.



Source: Bréthaut, C., & Pflieger, G. (2019). Governance of a Transboundary River: The Rhone. Springer.

- **Federal structures**

1. The OFEV (Federal Office of the Environment) is the body responsible for ensuring that the activities linked to operating natural resources (water, air, soil, forests) comply with the sustainable development goals that have been determined relating to preserving biodiversity, conserving the quality of landscapes and carrying out Switzerland's international environmental policy. In addition, the OFEV examines and attributes financial aid in the form of commitment credits to river development projects.

2. OFEN (Federal Energy Office) is a centre reporting to the Federal Department of the Environment, Transport Energy and Communication (DETEC). It deals with all issues relating to energy supplies, and ensuring compliance with safety standards for the production, transport and efficient use of energy.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Office fédéral de l'environnement OFEV

Schweizerische Eidgenossenschaft
Confédération suisse
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Office fédéral de l'énergie OFEN

Initiatives pour l'Avenir des Grands Fleuves

The Swiss Rhone

Governance and international cooperation

Governance

- **Cantonal structures**

The presence of the cantons is strong regarding governance, both in the definition and application of the Inter-cantonal Act relating to the correction and regulation of the waters of Lake Geneva, and in their position as delegators of concession contracts for the management of regulation structures.

1. **The canton of Geneva occupies a key position**. It is situated between, on the on hand, the concerns of the actors located upstream of Geneva (cantons and municipalities bordering Lake Geneva) and, on the other, the actors located downstream. It is the majority shareholder of the founding capital of Services Industriels de Genève (SIG). It represents the authority that determines both the terms of the concession contracts for the dams of Seujet and Verbois and the missions assigned to the SIG.

2. **The canton of Valais lies at the head of the river's watershed. The Environment Service (SEN) of the canton controls the quality of the canton's water**. It works in close collaboration with the Federal Office of the Environment (OFEV) to ensure the drainage of hydroelectric installations and carry out cleaning and flushing operations to reduce their impact on the environment. The Forestry, Waterways and Landscape Service is in charge of natural hazards in the canton. The Service for the protection of the Rhone against flooding manages the 3rd Rhone correction. The Service of Energy and Hydraulic Power must also be mentioned.

3. **The cantons of Vaud, Geneva and Valais collaborate in the framework of the 3rd project to correct the Rhone**: widening and deepening the riverbed and consolidating the dikes to increase the discharge of the Rhone. The General Direction of the Environment ensures that the project conforms to Vaud's policies relating to energy and the climate, environmental protection, the preservation of resources and natural heritage.

- **Industrial actors**

1. The Services Industriels de Genève (SIG): a semi-public company founded as an independent body subject to public law responsible for the operational management of the installations. **SIG produces electricity, distributes heat, gas and water, and manages waste and telecommunications**. Although the company is wholly owned by the public sector - 55% of the shares belong to the State of Geneva, 30% to the City of Geneva and 15% to the municipalities of the canton of Geneva, it nonetheless operates as a traditional industrial entity within a market partially open to competition. SIG **works to achieve the objectives of both the canton of Geneva for a *"society at 2000 W without nuclear energy"* with a 35% reduction of annual energy consumption from now to 2035, and those of the Confederation (Energy Strategy 2050) to ensure that Geneva becomes the most energy efficient region in the world.**

2. The SFMCP (Société des Forces Motrices de Chancy-Pougny) is a joint stock company subject to Swiss law. The hydropower plant of Chancy-Pougny is located on the **hydroelectricity cascade between the installation of the SIG, upstream, and the plants of CNR downstream**.

Governance and international cooperation

International cooperation

1 – Sediment management

The Arve joins the Rhone between the spillway of Seujet and Verbois dam. This torrent is loaded with suspended matter (SM) of which around 500,000 tonnes a year are deposited in the reservoirs of Verbois and Chancy-Pougny. To avoid silting and the dangerous raising of flood water heights liable to threaten the lower-lying districts of Geneva, **sediment removal operations are carried out every 3 or 4 years, starting from Verbois dam, and are assisted by the French operator CNR on its structures on the Upper Rhone.** New management procedures that are better coordinated and more environmentally friendly have been implemented under the name "joint sediment management".

2 – Protecting the waters of Lake Geneva

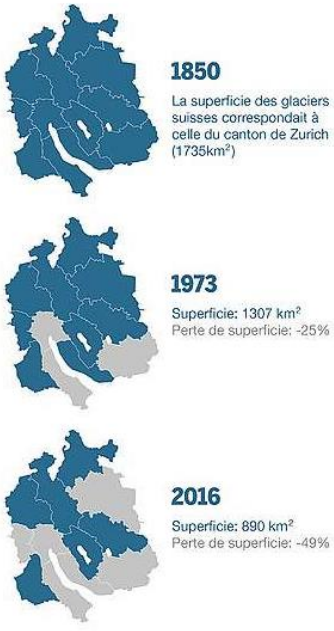
The effects of climate change also require collaboration between France and Switzerland to preserve the lake's waters. **The International Commission for the Protection of the Waters of Lake Geneva (CIPEL)** – founded in 1963 and composed of experts, scientists and elected representatives of the French departments of Ain and Haute-Savoie and the Swiss cantons of Geneva, Vaud and Valais – have implemented an **Action Plan 2011-2020. It sets four strategic directions: the protection of wetlands, preserving the quality of water, the exploitation of the water of Lake Geneva and the combat against climate change** *(cf. Synoptic sheet on Lake Geneva)*.

The Swiss Rhone

The river tomorrow

Vanishing glaciers

Climate forecast models show that climate change will lead to the disappearance of Alpine glaciers by the end of the century. The catalysing factors are: the decrease in summer rainfall, the increase of winter precipitations, the reduction of volumes of snow. The Rhone glacier is currently losing from 5 to 7 meters in thickness every year. In normal climatic conditions, two thirds of its surface is covered by snow at the end of summer. However, this is far from being the case. Despite the use of white anti-reflection covers, the phenomenon of ablation – the disappearance of snow and ice on the surface of the glacier – is accelerating.



The melting of the Rhone glacier will have direct impacts on the discharge of the Rhone. The atmospheric warming of the Alps will modify the rainfall regime, with a reduction from 10 to 40% of summer rains, increase from 10 to 20% of winter rains, and a reduction of the maximum quantity of water due to the early melting of the snow mantle (Gabbi, J., Carenzo, M., Pellicciotti, F., Bauder, A., and Funk, M., 2014). This will **have direct impacts on the discharge of the Rhone,** especially with the aggravation of severe low flow episodes already occurring due to water withdrawals.

Disappearance of Swizz glaciers since 1850.
Source: Greenpeace

Dam lakes and alpine forests will also be affected. The melt water will no longer fill the reservoir lakes as much as it does now, leading to a substantial reduction of hydroelectricity production. As for alpine forests, essential due to their contribution to ensuring the quality of surface water and combating erosion, they will undergo the same effects caused by climate change. Changes in alpine vegetation (reduced summer precipitation), which is becoming sparse, may reduce the protective role of some forests. Surface runoff will be accelerated and the risk of erosion and sediment load in watercourses will increase.

These changes will have other economic impacts. **Winters with less and less snow will lead to the progressive disappearance of ski resorts at medium and low altitudes**. Thus, it will be necessary to reconsider facilities for tourists. Moreover, in the canton of Valais, on the Rhone plain, periods of high heat would make agricultural irrigation difficult or even impossible during certain periods of the year.

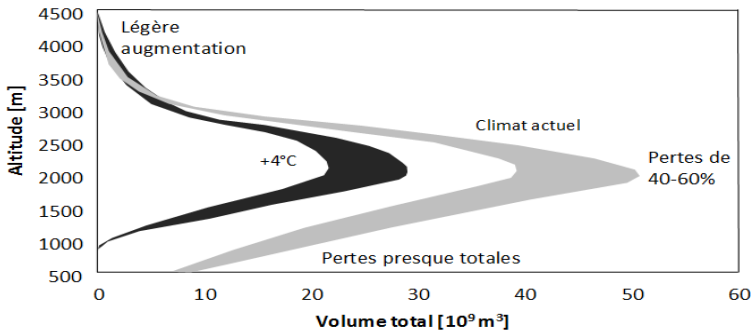
The Swiss Rhone

*The effects of climate change on melting glaciers**

To understand the phenomenon of ablation, it's necessary to understand the crucial role played by snow, an essential element in mountain hydrological systems. The seasonal nature, quantity and duration of the snow mantle have impacts on glaciers and influence peak flows in alpine rivers. The volume of snow is defined by multiplying the thickness of the snow cover and the surface area under it. In winter, the volume of snow is distributed as a function of altitude and the continental character of the climate.

Scenario 1: Normal seasonal temperatures
Below an altitude of 2,000 m, the surface area is large but the quantity and volume of snow are low. Above 2000 m, the surface areas and terrain covered by snow and its volume are small, but the thickness of the snow mantle is considerable.

Scenario 2: Increase in winter temperatures of 4°C
The duration of snow cover will decrease to 100 days between altitudes between 1,500 and 2,000 m, winter rains will no longer be sufficient to offset the effect of higher temperatures on snow cover. Although the changes will be minimal at high altitudes, there will be almost no snow at lower ones.



Distribution as a function of altitude of the seasonal maximum volume of snow in the Swiss Alps for the current climate (grey) and a climate with winters 4°C warmer (black).

The absolute volume of a glacier depends on factors such as altitude, orientation and avalanche contributions. Its mass balance is determined by the volume accumulated in the form of snow (accumulation) and the volume melted (ablation). Climate change modifies the thickness of the snowpack, but also the altitude of the equilibrium line. Alpine glaciers have surface temperatures close to the freezing point. This means that an increase in temperature above 0°C can accelerate the melting of the glaciers. **Climate models indicate that by 2100, 50 to 90% of the Alpine glaciers could disappear.**

*BENISTON Martin, B. (2018, June 27). The impact of climate change on Alpine snow cover and glaciers: consequences for water resources. Available on: https://www.encyclopedie-environnement.org/eau/role-glaciers-debits-fleuves-cas-rhone-alpin/

The Swiss Rhone

The river tomorrow

Protecting the river and its biodiversity

- **The different infrastructures on the Rhone have favoured the development of intensive agriculture, roads, and industrial zones.** However, these often pollutant activities that emit CO_2 have a considerable impact on the river. For example, between 1930 and 1976, at Viège in Haut Valais, the chemical and pharmaceutical company Lonza spilled from 200 to 250 tonnes of mercury into an affluent canal of the Rhone. This chemical element progressively accumulated in the sedimentary layers. As some farmers used these sediments for filling and fertilizing agricultural surfaces, the pollution spread spatially towards the Rhône plain. This diffusion also took place towards Lake Geneva, a significant part of the mercury spilled having been carried by the Rhône to the lake. The cessation of spills by Lonza in 1976 was linked to studies in Lake Geneva.

- **Other substances, such as micropollutants, have been identified in wastewater in Switzerland and France.** They are residues from agricultural, industrial and domestic products, like cosmetics, detergents and drugs. The State of Geneva, the Services industriels de Genève (SIG) and the conurbation of Annemasse have decided to invest €13 million to reduce by 80% the amount of micropollutants in the water treated. The two countries plan to link up two wastewater treatment plants, Ocybèle in France and Villette in Switzerland, where the wastewater will be treated before being discharged into the Arve and then join the Rhone. At the cantonal scale, **the STEP of Aïre operated by SIG will also be used to treat the wastewater of Geneva and thus preserve the quality of the water of the Rhone**.

- **Preserving the fauna and flora.** The construction of dams can lead to disturbing the balance of aquatic species. SIG has therefore decided to equip its dams with **fish passes** allowing thousands of fish to swim upstream easily, and **wooden ramps to help beavers cross the Rhone to reach Lake Geneva.**

Fish pass at Verbois dam.

Wooden ramp for beavers at Seujet dam.

The Swiss Rhone

The river tomorrow

Buddleias, butterfly bushes.

Human and industrial activities have also had an impact on the flora. **Invasive exotic species - neophytes – threaten biodiversity, agricultural activities and human health**. In order to protect alluvial areas, various actors like the cantons, farmers, doctors and the municipalities, work together to prevent these neophytes from invading crops and proliferating. **For example, in the valley of the Allondon in Geneva, Buddleias, also called *butterfly bushes*, are regularly uprooted to allow sites to return to their natural states.** In recent years the valley has become the home of a large number of species including reptiles, butterflies and bats.

The need to strengthen cross-border governance

The Rhone is not immune to cross-border tensions, aggravated by the impacts of climate change. Strong interdependence between France and Switzerland regarding the water of the Rhone should give rise to a legal framework. Failing adapted legal instruments, management is often limited to punctual collaborations to solve specific problems, though without a global vision of the challenges.

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Synopsis sheets

Rivers of the World

The French Rhone

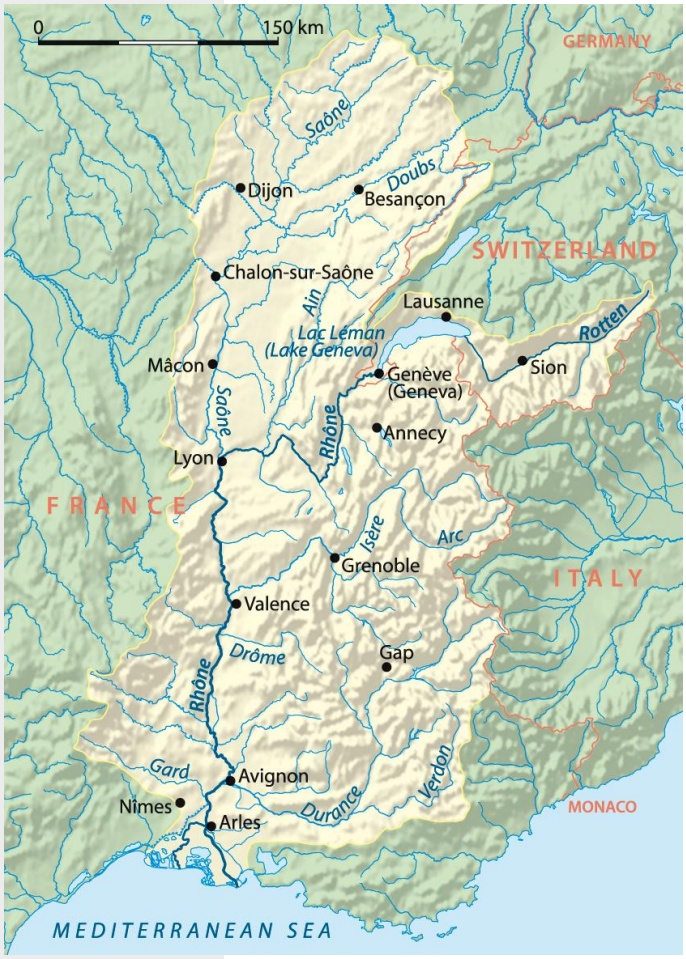
Initiatives pour l'Avenir des Grands Fleuves

The Rhone in France

The source of the Rhone is the Furka glacier located on the Saint-Gothard massif in Switzerland, in the canton of Valais, from where it flows 810 kilometres before reaching the Mediterranean Sea. This length includes the 72 km of Lake Geneva and 522 km in France. It is the most powerful French river with a discharge of 1,800 m³/s at its mouth. Developed from the 19th century onwards, it is a natural and vital corridor for fauna, flora and man.

The current situation presents a large number of challenges for the Rhone: economic, political, environmental and legislative: the deregulation of the European electricity market and the expiry of the structural concession contract, transformations of the European energy mix, water pollution and changes to environmental standards, etc.

Genesis of an economic and societal corridor



The origins

The Rhone springs from the formation of the Rhone Valley, a huge gouge caused by the separation of the Earth's crust about 55 million years ago. After marine, river and lagoon episodes, the Mediterranean Sea retreated 6 million years ago leaving the river to sculpt its bed. This was then followed by a large number of geological and climatic episodes until the final metamorphosis occurred, from the end of the 19th century: climate change – the end of the Little Ice Age - coincided with a change in the socioeconomic context (rural exodus and voluntary reforestation of mountain areas), and technological breakthroughs: henceforth the technological resources needed to control the river with hydraulic structures became available.

Initially intended to protect against flooding following the record floods of 1840 and 1856, the works then focused on making the Rhone navigable.

Starting in 1884, the senior engineers of the Rhone, Messrs Jacquet and Girardon, developed flow control strategies using groynes, dikes, wing dikes, etc. CNR's hydroelectric development schemes were added to these structures, starting in the 1950s.

A new chapter began twenty years ago, with great attention being given to the hydrological functioning of the river and its surrounding habitats that had suffered from the construction of the installations.

Technical sheet

Average outflow	1 700 m3/s
Length (en France)	522 km
Watershed	96,500 km2 with 4 massifs that strongly structure its hydrology: the Vosges, the Jura, the Alps and the Massif Central
Affluents	Ain, Saône (main tributary 480 km long), Isère, Drôme, Ardèche, Durance, Gard

Initiatives pour l'Avenir des Grands Fleuves

The Rhone

Caractéristiques	
Upper Rhone (Lake Geneva - confluence with the Saone)	The Rhone flows for more than 200km crossing the Jura mountains and the foothills of the Alps before reaching the plain of the Ain and then Lyon. There is a succession of narrow gorges (canyons of Bellegarde, Yenne, Creys-Mépieu) and wide flood plains (the marshes of Chautagne and Lavours, the plain of north Isère). The waters of Lake Bourget (France's largest natural lake) flow into the Rhone via the canal of Savières (whose flow reverses when the Rhone is in flood.
Middle Rhone (Lyon-Valence)	Narrow alluvial plain, intense pressure from industry and agriculture. Three natural sites: the natural habitats of the river's oxbows and islets; the nature observation centre of Ile du Beurre, the nature reserve of Ile de la Platière and the meander of Oves.
Lower Rhone (downstream of Montélimar-Delta)	Three specific characteristics: its regime is modified by the flows of tributaries from the Cevennes and the southern Alps; the geomorphology of the alluvial plain and delta of Camargue increase the risk of flooding. The flow of water end sediment influence the stability and equilibrium of marine ecosystems.

Multiple uses

Hydroelectricity production

In France, hydropower is the second largest source of electricity production (12% share of annual production) behind nuclear power and is the leading renewable energy source. The Auvergne-Rhône-Alpes region stands out as the leading French region in terms of installed hydropower capacity and hydroelectric power generation, with 11,608 MW installed, or 45% of French installed capacity and 20,792 GWh produced, or 43% of French production (as of 12/31/2017 - RTE 2018 balance figures).

Most of this production in the Rhone Valley comes from the nineteen run-of-river waterfalls developed by CNR on the river between the Swiss border and the sea (approximately 14,000 GWh produced on average per year, or ¼ of French hydroelectric production). The remainder comes mainly from the Alpine power plants.

The production on the river varies according to the daily and seasonal flows. The energy produced is not very modulable. Only the Génissiat dam (Ain-Savoie) has a storage capacity of 50 million m3 among the CNR facilities. Throughout the hydroelectric chain, part of the flows are stored in the forebays of each power station, making it possible to satisfy peak hourly demand each day.

The importance of the Rhone basin in terms of electricity production is reinforced by the existence of high voltage lines that follow the valley and ensure the interconnection between the various production sites.

Rhone

Multiple uses

Navigation

A major corridor linking Northern Europe to the Mediterranean, **the Saone-Rhone river network** has been a thriving trade route throughout the ages. In Gallo-Roman times, the Rhone, prolonged by the Saone, was one of the busiest rivers in the Roman Empire after the Nile. In the Middle Ages, it transported salt, metals, wood and cereals. In the 19th century, it went through a period of decline due to competition by rail. Although activity on the river continued, it was not until CNR developed its infrastructures and opened it up to wide gauge traffic along more than 300 km, that navigation along the Rhone Valley underwent a new lease of life.

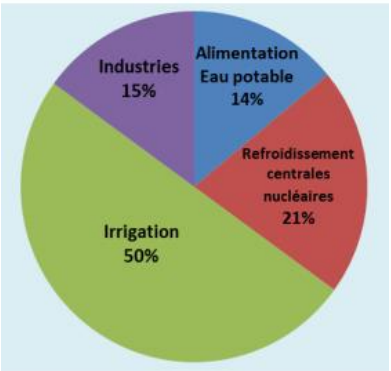
The current multimodal network is composed of 18 industrial and port sites, including the Port of Lyon, and it is connected to the Mediterranean sea thanks to a direct access to the ports of Marseille-Fos and Sète. There are 230 companies that moved along the river, and an average of 6.4 million tons of goods are transported every year. The growth potential is still very important, yet the activity intensity is uneven.

Irrigation

The areas irrigated by the Rhône total 221,000 hectares, of which 120,000 hectares can be irrigated by the CNR thanks to 170 water intakes. The equivalent of 2 billion m3 of water are withdrawn annually for the agricultural irrigation system of the Rhone Valley, for the use of 15,000 farms.
In the Drôme department (1st agricultural department in the region), 80% of the agricultural irrigation volumes come from the Rhone and the Isere.

Productions and exploitation structures are varied, with specific development paces: rice growing demands large quantities of water, around 30,000 to 50 000 m^3/ha depending on the type of soils, but it is in decline. The surface areas cultivated in Comtat and the lower plain of the Rhone are shrinking due to the expansion of urban and industrial areas. Lastly, the progression of drop-by-drop techniques reduces water consumption by fragile crops (orchards and vegetables). These different factors could lead to a decrease in consumption. On the contrary, large surface areas dedicated to arboriculture are being transformed into plots for rapeseed/maize type crop rotation, following Italian and Spanish competition, and due to the aid provided by the CAP. The subsequent increase in water consumption could be accentuated as the biofuels sector develops.

Agriculture in the Rhone Valley is facing multiple challenges, including strong variations in prices, increasing regulations in favour of the environment, food safety and products quality, adaptation to climate change, exploding urbanisation… New models need to be found to ensure a better water management.



The Rhone

Multiple uses

Withdrawals of water for energy production and industrial activities

On the **scale of the watershed of the Rhone**, most of the withdrawals are made from the tributaries and surface water. Irrigation and hydroelectricity production are the uses that require the most withdrawals.

The withdrawals **from the Rhone Valley and its alluvial groundwater** make up 22% of the net withdrawals on the scale of the entire basin. The major share of withdrawals are taken from the lower Rhone and are used mainly for agricultural purposes, especially rice-growing in the Rhone delta.

Annual withdrawals linked to energy production amount to about 12,800 million m^3. The river water is used as a cold source for cooling the coal-fired power plant of Aramon and the nuclear power plants of Bugey, Saint-Alban, Cruas and Tricastin. The energy produced annually by this sector amounts to 90,000 GWh.

The chemical and petrochemical sector also makes significant withdrawals (30% of total industrial withdrawals), as do materials processing activities (cement, paper, waste, etc.).

Tourism and leisure

The Rhone attracts a large number of activities along the Valley, with the redevelopment of its banks, the development of tourism, and the restoration of navigability to the Upper Rhone. Growing numbers of canoeists, swimmers, jousters and pleasure boaters demonstrate renewed interest from the public in these activities. The most visited sites include the Miribel-Jonage Park and the leisure centres of Roches-de-Condrieu, Épervière at Valence and Barthelasse at Avignon.

The ViaRhôna is a biking track linking the Leman lake to the Mediterranean sea along the river. It represents a great development potential for the regions' touristy activities.

There is also an increase of tourism on the river itself: a boom in the river cruisers caused the number of passengers to rise from 12 500 in 1998 to 198 444 in 2018.

The Rhone

Governance and international cooperation

1/ Management of the French Rhone

Ownership: Water "*belongs to the common heritage of the nation*" (the Environment Code). The bed of the Rhone and its banks belong to the Public Fluvial Property of the State.

Management

In France, for the most part, the State entrusted its public fluvial property to Voies Navigables de France (VNF) on 20 August 1991. However, regarding the Rhone, VNF's competences are subordinated by the missions also entrusted by the State to Electricité de France (EDF), and above all CNR.

Each part of the river is managed by one specific actor. Here are these actors, starting from the upstream part of the Rhone, where it crosses the french border:

- From the Swiss border to downstream of the restitution of the Sault-Brenaz diversion: CNR under its overall concession.
- From downstream of the restitution of the Sault-Brenaz diversion to the confluence with the Ain: VNF
- From the confluence with the Ain to the confluence between the Jonage Canal and the Miribel Canal: EDF under the Cusset concession (term set at 31 December 2041), and to date VNF for the Miribel Canal
- From the crossing of Lyon to the confluence between the Rhône and the Saône: CNR for the Rhône bed, VNF for the banks.
- From the confluence of the Rhône and the Saône to the diffluence of the Petit Rhône and the Grand Rhône at Arles/Fourques: CNR under its global concession.
- For the Grand Rhône between Arles and Port-Saint-Louis du Rhône: CNR does not have any hydroelectric development there, and its management in this sector is limited to the operation, maintenance and possible improvement of the waterway, including the Barcarin lock.
- For the Petit Rhône between Fourques and the sea: VNF (if the extension of the concession granted to CNR is extended, this section will be managed by CNR)

These actors are in charge of the unique public river domain. In the "natural" and non built sectors, dikes that belong to local communities are not considered part of the domain, and they are managed by mixed unions or by union associations.

Governance

The governance structure of the French Rhone is very different than the one of is Swiss part, as it depends mainly on the coordination between private or semi-private actors. Contractual measures and the actors' slight auto-organisation for the management and share of water make the situation highly complex. Numerous agreements were made between the two main actors who have an industrial use of the Rhone: CNR (hydroelectricity production) and EDF (nuclear plants cooling).

Public actors are part of the actors' configuration, but they do not directly interfere in the operational management of the river.

The Rhone

Governance and international cooperation

1/ Management on the French Rhone

Legal system

The SDAGE

The Schéma Directeur d'Aménagement et de Gestion des Eaux (Organisation and Management of Waters Leading Plan) is a planning document that allows a consistency between the various uses of the Rhone in the Rhone-Mediterranean river basin. The SDAGE gives the lead on the fundamental orientations allowing a balanced management of the water resource and the necessary dispositions to get to it. It is produced by the Basin Committee and approved by the basin coordinating prefect.

The Basin Committee

The Basin Committee is a place for debate and for defining the main parts of the water management and the preservation of water environments policy in the basin, with the respect of the national policy plan. The Committee is a real "water parliament" and it gathers representatives of the State, of local elected members and of private users.

The Rhone Plan

Given the particularly high stakes associated with the river, the Prime Minister entrusted the basin coordinator with the elaboration, in partnership with the local authorities, of a Rhone plan conceived as a global project for sustainable development, a plan that was approved by the Inter-ministerial Committee for Regional Development in March 2006. The major floods that occurred in 2002 and 2003 catalyzed the will of the actors in this territory to build a global management project in order to go further than the previous specific action programs (ecological restoration, dike reinforcement...): if the definition of a flood prevention strategy was the initial objective, the extension to other themes was quickly justified. A second Rhone Plan was concluded for the period 2015-2020.

The Rhone plan has a triple ambition:
- to reconcile flood prevention and development pressures in flood-prone areas ;
- to respect and improve the living environment of the inhabitants;
- to ensure the long-term economic development of this strategic territory.

It is organized around six thematic sections: heritage and culture; flood risk prevention; water quality, resources and biodiversity; energy; river transport and tourism.

The Rhone

Governance and international cooperation

Actors

CNR: CNR is the Rhone operator, in charge of the management of 19 hydroelectricity production constructions, of the guarantee of good navigation conditions on the river and of the supply of water for agricultural uses (irrigation). CNR is the first french producer of 100% renewable energy (water, wind and sunlight); it is an incorporated company with a non-profit legal status, meaning that the revenues made from hydroelectricity production must be used for the two other missions, and the capital is distributed between public and private shareholders.

The concession comes with a bill of specifications and a leading plan. By signing these two documents, CNR commits itself to operate constructions and actions on the river. The current leading plan goes from 2003 to 2023. It contains actions directly linked to CNR's main responsibilities but also guidelines about the environment protection. In 2004 CNR created **General Interest Missions** which are programs made for and in cooperation with local territories. These actions can be in favour of economic and touristic development around the river; maintenance of fish continuity and rehabilitation of the Old Rhône; electric mobility; services to river users...

Key-number: In 15 years, 431 M € invested in general interest missions:
- 1st and 2nd GIM plans (2004-2008/2009-2013): 286 M €
- 3rd GIM plan (2014-2018): 145 M €
Ongoing: 4th GIM plan (2019-2023): 115 M €

Key dates
May 27th 1921: Rhone construction law
1933: Creation of CNR
1934: CNR is granted the exclusive concession of the Rhone for the next 90 years
1935: beginning of the construction of the port of Lyon called Edouard Herriot
1937: Beginning of the construction of Genissiat, first hydroelectric plant (Ain department)
1946: Nationalisation of electricity (creation of EDF)
1948-2000: Creation of a convention between CNR and EDF: EDF operates the plants, sells the production and keeps the revenues, while CNR builds all the Rhone works (19 plants from 1948 to 1986) and is paid for its missions thanks to a negotiated contract with EDF.
2000: liberalisation of the electricity market
2001: CNR changes status and is an independent electricity producer again
2003: Modifications of the stockholding system: a decree gives CNR a new status, and Electrolabel, a subsidiary of the Suez group, becomes a stockholder
2003: Creation of CN'Air, a subsidiary dedicated to wind power and photovoltaic development
2004: Start of the General Interest Missions
Since 2004: CNR diversified into wind and solar power and worked to develop new renewable energies (hydrogen, marine currents) and electric mobility, while offering its knowhow in managing intermittent energies and engineering services to third parties. It has fulfilled 3 plans of the Missions in the General Interest and launched a fourth in 2019.

The Rhone

Governance and international cooperation

Other actors on the Rhône

VNF: Voies Navigables de France (VNF) is a public administration in charge of the management of the majority of the navigable routes in France; its administrative supervision is done by the State through the General Board of infrastructures, transportation and sea water of the Ministry in charge of ecological transition, sustainable development and energy.

EDF manages nuclear plants located on the sides of the Rhône. EDF needs a continuous supply of 130m^3/s in order to be able to cool down the temperature in the Bugey plant. For that matter EDF can use the waters of Arve for which it has a consecutive priority (granted by the State) of its uses for nuclear production and navigation.

The Basin coordinating Prefect: The Rhone-Mediterranean basin coordinating Prefect is the prefect of the Rhone-Alpes region, where the rhone-Mediterranean Basin Committee is located.

The DREAL: The authority in charge of CNR's surveillance through the concession contract

ZABR: The ZABR gathers 21 research institutions which study the interactions between the river environment of the Rhone and the societies that develop on its basin through a multidisciplinary approach. It is a support for research programs that work on bringing elements that will help public decision regarding a sustainable management of waterways and their watersheds.

BRL: The National Planning Company of the Bas-Rhone and Languedoc Regions (NPCBRLR, turned into BRL in 1993) was created by an order in 1955. Its mission is to ensure the irrigation of the Oriental Languedoc and to diversify productions that are generally excessively specialized in viticulture.

The Rhone

Governance and international cooperation

2/ International cooperation

1 – The management of water quality: the CIPEL

The surveillance of the lake Geneva waters quality is done by the CIPEL. Created in 1962 by a convention between France and Switzerland, the International Commission for the Protection of the Geneva Waters (CIPEL) insures the surveillance of the lake's water quality of the one of its upstream basin. With the results obtained, the CIPEL makes recommendations every year in order to encourage the French and Swiss governments to take measures against the potential sources of pollution in the lake.

2 – Water volumes management

The Inter-canton Act
The regulation of lake Geneva is the sole responsibility of the Valais, Vaud and Geneva cantons thanks to an inter-canton Act (signed in 1884 and renewed in 1984). Its purpose is to guarantee the populations and the infrastructures safety. For historical reasons , French public and regional entities were not (and are still not) included in this regulation system.

The Emosson's international convention
The Inter-canton Act has an exemption called the Emosson's international convention (August 23rd 1963). It states that the water flow coming from the French watershed of Arve that was redirected during the Swiss construction of Emosson towards lake Geneva must be given back to France by a volume of 87 million m^3 .

The "Emosson waters" that are available for France are stored in the Leman lake; they are supplied by the Seujet in order to allow navigation, and more importantly to allow the cooling of the nuclear plants temperatures during very low water level periods.

In concrete terms, the lake's water level regulation is managed in Geneva thanks to the Seujet dam. This dam is under the responsibility of the SIG.

3 – The sediment management

The Arve meets the Rhone between the spillway of the Seujet and the Verbois dam. This torrent is concentrated with suspended matters (SM) that get stuck in the Verbois and Chancy-Pougny's installations, up to about 500 000 tons a year. To avoid this siltation phenomenon and a dangerous increase of the water level in the Verbois installation that could threaten some areas of Geneva, sediments evacuation operations take place every 3 or 4 years. They used to be called "hunts", but a more eco-friendly and better coordinated management was created and named "mixed sedimentary management".

4 – The Chancy-Pougny dam management

The Chancy-Pougny installation was first conceded in 1915. As it is a franco-swiss dam, the concession is attributed to both countries. The operator is called The Chancy-Pougny Motive Power Company (CPMPC Inc.)

Rhone

Structures

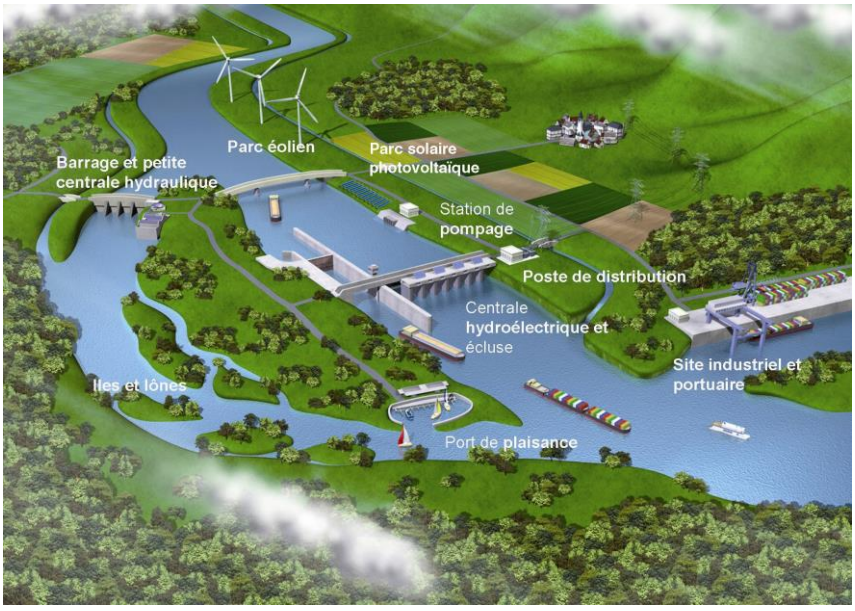
Hydroelectric production

CNR has built and operates 19 dams on the Rhône River and 49 hydroelectric power plants. With 57 wind farms and 46 photovoltaic plants throughout France, CNR will have nearly 4,000 MW of installed capacity by 2021.

Built on the Rhône between 1938 and 1986, CNR's hydroelectric plants are all remotely controlled from the Intermittent Generation Optimization and Control Center in Lyon.

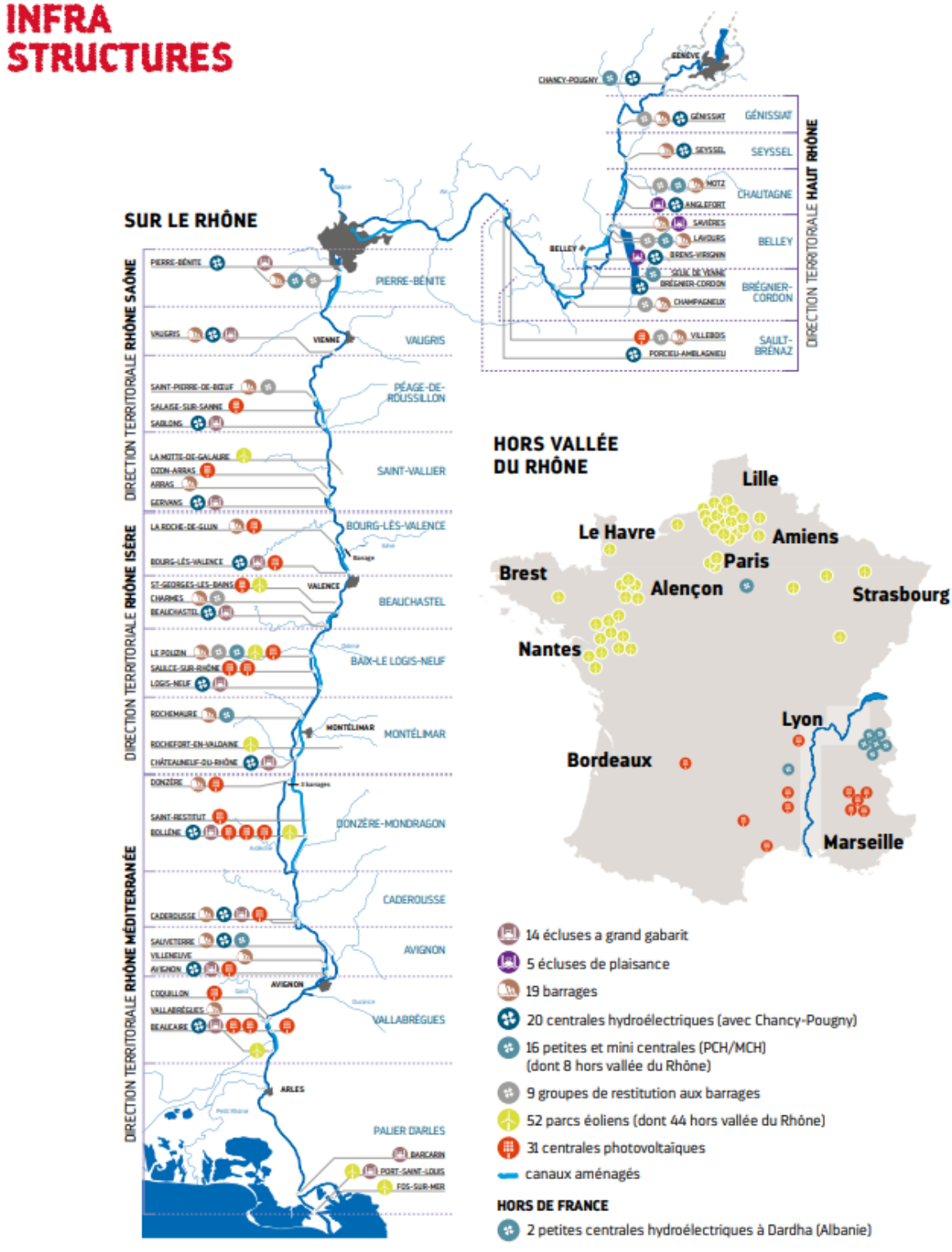
The two other major hydroelectric power plants on the Rhône River are the Cusset plant (EDF) and the Franco-Swiss Chancy-Pougny plant (SFMCP).

General scheme of the Rhone's development by CNR



The Rhone

CNR's works (Annual report 2019)



The Rhone

CNR's works

Navigation

Locks

CNR manages:
- 14 large locks
- 5 pleasure locks

Industrial installations and ports

CNR manages 18 multimodal platforms, including the port of Lyon:

- 184 ha on the left bank, south of the Lyon agglomeration, where the Saone and Rhone rivers meet. It gathers 70 industrials.
- The port of Lyon is a multimodal platform connected to 550 km of large leak. It is equipped to serve by several modes: river and maritime modes, rail, road and pipelines.

Additionally: 8 activity sites.

In 2020, 3.7 million tons of goods were transported on the Rhone as well as 65.516 containers.

Rhone

Envisaging tomorrow's river

The river is characterised by diverse hydrographic conditions, a wide range of uses and the fact that it crosses a border, which involves coordination mechanisms and mediation between two different regulatory frameworks. This complexity has now been increased by the new challenges confronting the river.

The impact of climate change in the Rhone basin

According to river forecasting models, climate change will have impacts on discharges, temperatures and on the severity of extreme events (low water and heavy floods).

The RMC Water Agency estimates that an increase of 30% in withdrawals from the Rhone by 2060, combined with an equivalent fall in the Rhone's discharge linked to climate change, will exceed the capacity of the river.

Is the structure of the Rhone's governance robust enough to resist a change in the river's hydrographic regimes?

How will the configuration of actors and the different agreements evolve if the discharges of the Rhone are affected by recurrent extreme situations (from the standpoint of floods and periods of low water)?

Evolution of the hydrological regime

In winter, the snow will remain only at higher mountain altitudes; falls in volumes and more premature thaws will lead to more irregular flows in Alpine rivers. Increased evaporation rates throughout the year will reduce annual discharges and result in low summer flows in many rivers, inevitably causing conflicts between water users. However, how floods will evolve is less clear.

Result: a change in the relations of each economic actor with the river, especially during the low flows of the Rhone.

The delta

The Rhone delta is one of the most fragile French coastal areas with respect to climatic hazards.

Building dikes on the river does not allow the deltaic plain to defend itself against the rising sea level. The reduction of sediment deposits and consolidation of the mouth reduce the supply of sand to replenish the beaches. The unequal though fast retreat of the coastline is due to the exhaustion of sand supplies and increasingly aggressive sea dynamics.

Water pollution

The River Rhone is exposed to micro-pollutants due to the characteristics of the territory it crosses: industrial activities, large towns and cities, intensive agriculture and very busy highways close by, etc.

Different substances have been identified in the river, especially downstream of Lyon. Thanks to the Rhone's capacity to dilute them, the contamination is mostly found in the sediments and very little in the water. However, their effects on organisms have been observed.

Actions have been carried out to reduce discharges of micro-pollutants, with operations such as SPIRAL-Eau in the city of Lyon. Nonetheless, this task requires active engagement.

The Rhone

Envisaging tomorrow's river

Reinforcing the governance system at the basin scale

Cross border governance

The Rhone is by no means unaffected by cross border tensions, aggravated by climate change about which most of the actors ignored the impacts.

Creating a common vision of the Rhone's management

A common vision of the river started to emerge as early as the 1960s among specialists on fluvial topics, with initiatives that brought together experts from different disciplines (the natural sciences and the social and human sciences, etc.) to deal with the challenges of the Rhone. The *Zone Atelier Bassin* of the Rhone (ZABR) still drives this interdisciplinary approach. The notion of "hydrosystem"*, a term now employed all over the world, first came into use for the Rhone.

* A system composed of interconnected water and wetlands in a specific geographic sector, notably a watershed.

Increasing river transport

The landlocked nature of the Saone-Rhone basin to the north of Lyon for wide gauge boats, impedes the flexible management of hulls (the place where the goods carried by boats are stored). The adaptation of equipment to changes in traffic is difficult and requires costly transfers from boats. Certain port infrastructures and naval repair sites are saturated. Landlocked to the north, the traffic on the navigable waterway of the Rhone Valley is oriented southwards to the ports of Marseille-Fos and Sète. It suffers from the lack of competitiveness of Marseille-Fos in comparison to Genoa and Barcelona.

With the Rhone Plan, the actors involved have launched projects to overcome these handicaps.

The choice of energy policies

Energy transition

From a policy above all focused on nuclear and fossil fuels, European governments are tending to take the path of supporting the development of renewable energy sources, especially hydroelectricity. Consequently, the policies adopted by the Rhone's management are being reshaped by the presence of the hydroelectric sector and stronger environmental policies with, among other, the influence of European regulations. The management of the Rhone will be influenced by changes in energy policies and by the place of hydroelectricity in the energy mix at European scale, and by fluctuations of electricity prices.