

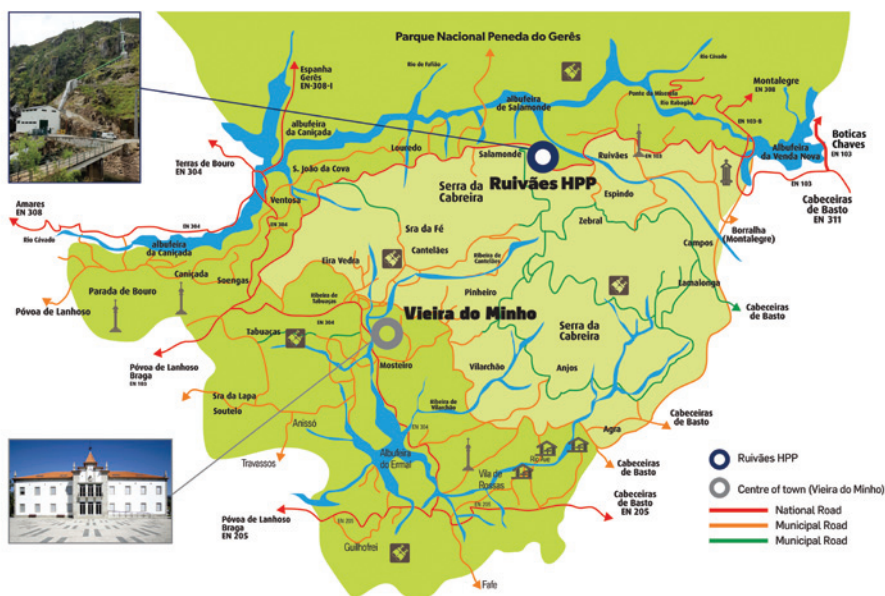


# RUIVÃES HYDROPOWER SCHEME

**Saltadouro River, Chedos and  
Rebordondo Streams**

Municipality of Vieira do Minho

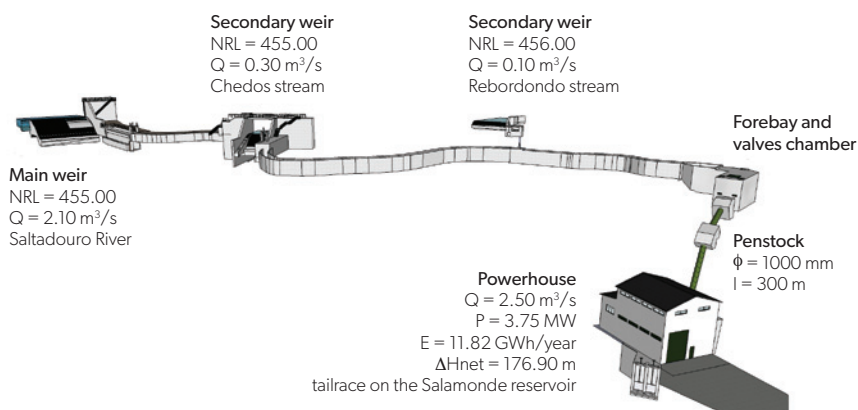




The **Ruivães hydropower plant (HPP)** is located at the final reaches of the Saltadouro River and of two of its small tributaries, the Chedos and the Rebordondo streams, in the Ruivães and Campos parish, Vieira do Minho municipality, district of Braga. The Saltadouro River is a left-bank tributary of the Cávado River, converging with it at the Salamonde reservoir.

The construction of the hydropower plant was launched in August 2015 and its commercial operation started in December 2016.

The Ruivães HPP is a run-of-river scheme, with a small storage capacity (or pondage) in the hydraulic conveyance for concentration of inflows below the minimum compatible with the turbine operation. The hydraulic conveyance develops between the elevations 455.00 and 272.80, corresponding to, respectively, the normal retention level (NRL) in the reservoir created by the weir on the Saltadouro River, and the axis of the turbine's injectors.



General layout of the Ruivães HPP.

The hydropower plant was designed for a maximum discharge of 2.50 m³/s and a maximum gross head of 179.70 m, downstream of the water level in the forebay, to which corresponds the installed capacity of 3.75 MW. The mean annual energy production of 11.8 GWh is fed into the national electricity grid at the Vila Nova-Salamonde electrical line, through a 15-kV interconnection line with a length of 600 m.

The scheme comprehends three small weirs, of which the main is located



Salamonde reservoir and line interconnecting the hydropower plant to the national electricity grid.



ed on the Saltadouro River, and the secondary ones on the Chedos and the Rebordondo streams. The design of the three weirs is identical, being based on overtoppable-gravity profiles provided with Creager-type spillways with crests designed for the 100-year peak flood discharges in the corresponding watersheds. The water intakes, also with similar general designs, are located at specific, slightly lowered areas of the crests of the spillways. They are non-controllable, Tyrolean-type water intakes, provided with trash-racks with bars spaced 5 cm apart and a 20%-slope towards downstream to attain self-cleaning capabilities.



Weir on the Saltadouro River.



The **weir on the Saltadouro River** has a maximum height of 9.50 m, defined as the distance between the top of the lateral abutments, at the elevation 460.40, and the lowest point of the general foundation, at the elevation 450.90. The length of around 18 m between the two lateral abutments of the weir is essentially occupied by a wildlife passage (1.00 m), for the Pyrenean desman, the crest of the spillway (9.75 m) and the water intake (6.45 m plus three small pillars with a total length of 0.80 m).

The spillway crest was set at the elevation 455.40 given the 100-year peak flood discharge of 320 m<sup>3</sup>/s. For this discharge, the maximum elevation of the water at the reservoir is 459.90 (maximum flood level, MFL), which assures the 0.50-m clearance relative to the elevation of the top of the lateral abutments. The water intake is adjacent to the left abutment of the weir, where the spillway crest was lowered to the elevation 455.00 (normal retention level, NRL). The intake is equipped with three trash-racks, each with a net area of 2.15 x 1.99 m<sup>2</sup>. When the water in the reservoir is at the elevation 455.34 (i.e., 0.34 m above the NRL), the diverted flow is 2.10 m<sup>3</sup>/s, that is, the design discharge of the hydraulic conveyance up to the weir on the Chedos stream. The remaining length of the spillway crest, at elevation 455.40, will only be overtopped in the wettest periods, for river flows higher than the design discharge.

Close to the right abutment of the spillway, a wildlife passage was built for the Pyrenean desman (*Galemys pyrenaicus*), a semi-aquatic mammal occurring in the upper reaches of the rivers located in the Country's northern regions. This passage mainly consists of a series of 0.20-m uneven trenches, only 0.09 m deep, built on a canal 1.00 m wide and sloping 1V:3H longitudinally, designed for the discharge of 0.8 l/s.

The weir is provided with a bottom discharge, consisting of a square-section gallery, with an area of 1.20 x 1.20 m<sup>2</sup>, closable upstream by means of a sluice gate operated from a platform built at the same elevation as that of the top of the lateral abutments. Close to this bottom discharge is the ecological discharge main circuit, consisting of a horizontal non-closable pipe Ø<sub>ext</sub> 170 (with axis at elevation 453.61), provided with one metal trash-rack and designed to assure good environmental conditions in the downstream reach of the river. For the reservoir at the NRL, the released discharge is 65.5 l/s, which taking into account the discharge through the Pyrenean-desman passage makes up the total ecological discharge of 66.3 l/s.

At the initial reach of the hydraulic conveyance, downstream of the weir on the Saltadouro River, a lateral spillway, with crest at elevation 453.85 and 20 m long, is designed to return to the river the discharges diverted in excess, under flood situations.



Weir on the Chedos stream. On the left side, upstream view, on the right side, the two lateral spillways and the end part of the Pyrenean-desman ramp.

The **secondary weir on the Chedos stream** and the canal-crossing over the stream constitute a single structure. In fact, when crossing the stream, the canal reach developing from the main weir has its bottom almost at the elevation of the river bed, being involved by the weir. The foundation of the weir is at the elevation 451.00. The distance between the abutments of the weir is 7.50 m, of which 2.15 m are occupied by the water intake, 1.00 m by the Pyrenean-desman passage, 4.05 m by the spillway itself and 0.30 m by a small pillar adjacent to the left abutment. At the abutments vertical walls were built with tops at the elevation 459.70, connected by an overhead, metal pedestrian bridge, with low chord at the elevation 459.30, enabling the access to the hydraulic conveyance that develops downstream, along the Saltadouro River's left bank.

The crest of the spillway was set at the elevation 455.25, from which results the MFL of 458.30, for the 100-year peak flood discharge of  $75 \text{ m}^3/\text{s}$ . It is thus assured the 1.00-m clearance relative to the low chord of the pedestrian bridge.

Near the left abutment of the weir, the crest of the spillway was lowered to the elevation 455.00 (NRL), for installation of the water intake. For the design head of 0.19 m above the NRL, the discharge is  $0.30 \text{ m}^3/\text{s}$ . The water intake is protected by a trash-rack with  $2.15 \times 1.12 \text{ m}^2$ .

At the right abutment of the weir, the wildlife ramp, the bottom discharge and the main ecological discharge were installed. The bottom discharge consists of a square-section gallery, with an area of  $0.80 \times 0.80 \text{ m}^2$ , closable by means of a sluice gate operated from the crest of the weir. Near this discharge is the ecological discharge main circuit, consisting of a non-closable pipe  $\varnothing_{\text{ext}} 63$  (with axis at elevation 454.50), provided at the entrance with a metal trash-rack. The discharge thus assured for the reservoir at the NRL is 9.4 l/s. This discharge plus the one of 1.0 l/s from the Pyrenean-desman passage make up the total ecological discharge of 10.4 l/s. The design of the Pyrenean-desman ramp is similar to the one installed in the main weir on the Saltadouro River.

Between the weir and the downstream canal, there are two lateral spillways, both with crests at elevation 453.78 and with lengths of 1.70 and 2.30 m, designed to deliver to the Chedos stream the discharges diverted in excess under flood conditions. A sluice gate is installed between the two spillways, to isolate the canal.

The **weir on the Rebordondo stream** has a design similar to the ones of the other two weirs, but on a smaller scale. Its crest has a length of 9.50 m, of which 7.10 m are occupied by the spillway itself (with crest at elevation 456.15), 2.15 m by the water intake and 0.25 m by a small pillar near the only abutment of the weir, located at the left bank. The positioning of the crest of the spillway led to the MFL of 457.20 for the 100-year peak flood discharge of  $32 \text{ m}^3/\text{s}$  (top of the abutment at the elevation 457.70 and clearance of 0.50 m).



Weir on the Rebordondo stream. Water intake on the left, bridge-canal on the right.

At the water intake the crest of the spillway was lowered to the elevation 456.00 (NRL). The intake is protected by a trash-rack with  $0.82 \times 2.15 \text{ m}^2$ . For the design head of 0.09 m above the NRL, the diverted discharge is  $0.10 \text{ m}^3/\text{s}$ , being conveyed to the canal through a stainless-steel pressure pipe  $\varnothing_{\text{ext}} 223$ , nearly 14 m long.

The ecological discharge circuit, consisting of a non-closable pipe  $\varnothing_{\text{ext}} 63$  (with axis at elevation 455.70), protected by a metal trash-rack at its entrance, is embedded in the body of the weir. It assures a discharge of  $3.3 \text{ l/s}$ , for reservoir at NRL. Next to the weir is the lateral spillway, with crest at elevation 454.70 and 2 m long.

The **free-surface diversion canal** has a total length of 1075 m, a slab slope of nearly 0.1%, rectangular cross-section and lateral walls with horizontal top edge at the elevation 454.30. Under these conditions the depth of the canal increases from upstream to downstream, from 1.69 m, at the outlet of the lateral spillway downstream of the weir on the Saltadouro River, to 2.89 m, at the forebay entrance. From downstream of the weir on the Chedos stream the canal develops alongside a platform for vehicles.



Diversion canal.

The canal was designed taking into consideration: the design discharge and its increase towards downstream; the need to assure the storage volume of around  $2600 \text{ m}^3$  required for the operation of the power plant under pondage conditions, i.e., for diverted discharges smaller than the minimum compatible with the turbine operation; the positioning of the free surface along it, during floods and power-plant stops, so as to ensure hydraulic heads over the lateral spillways compatible with the return to the water-courses of the discharges diverted in excess; and, most importantly, its non-overflowing during the unsteady regimes occurring after emergency stops, namely when combined with the 100-year floods.

The canal comprises three different reaches: an initial covered one, located between the weir on the Saltadouro River and the weir on the Chedos stream, 88 m long (including the Chedos stream passage) and 1.5 m wide, designed for the  $2.10 \text{ m}^3/\text{s}$  discharge; an in-between reach, developing downstream until the point it receives the discharge diverted at the weir on the Rebordondo stream, 587 m long and 1.65 m wide (including a 33-m long bridge-canal), designed for the  $2.40 \text{ m}^3/\text{s}$  discharge; and a terminal reach, up to the forebay, 400 m long and 1.70 m wide, designed for the maximum discharge allowed by the turbine of  $2.50 \text{ m}^3/\text{s}$ . The canal is provided with three rescue ramps.



Bridge-canal, downstream lateral spillway and adjacent platform for vehicles.



In order to control the propagation of the unsteady regimes after sudden stops, two spillways were built at the same lateral wall of the canal, immediately upstream and downstream of the bridge-canal, each 5 m long, crest at elevation 453.78 and discharging to the Rebordondo stream.

The **forebay**, with a horizontal area of 110 m<sup>2</sup> and a maximum depth of 5.45 m, assures the transition between the free-surface flow along the canal and the pressurized flow in the penstock. Its water intake is provided with a trash-rack, with an area of 4.50 x 3.25 m<sup>2</sup>, including the respective cleaning mechanism. Inside the forebay there is a butterfly valve Ø 1000, for isolation and safety of the penstock, equipped with an automatic closing device in case of overspeed occurrences. The forebay is further equipped with a water-level control system for data transmission to the controller (PLC) installed in the powerhouse, which regulates the automatic opening of the turbine's injectors and consequently enables the unmanned operation of the power plant.

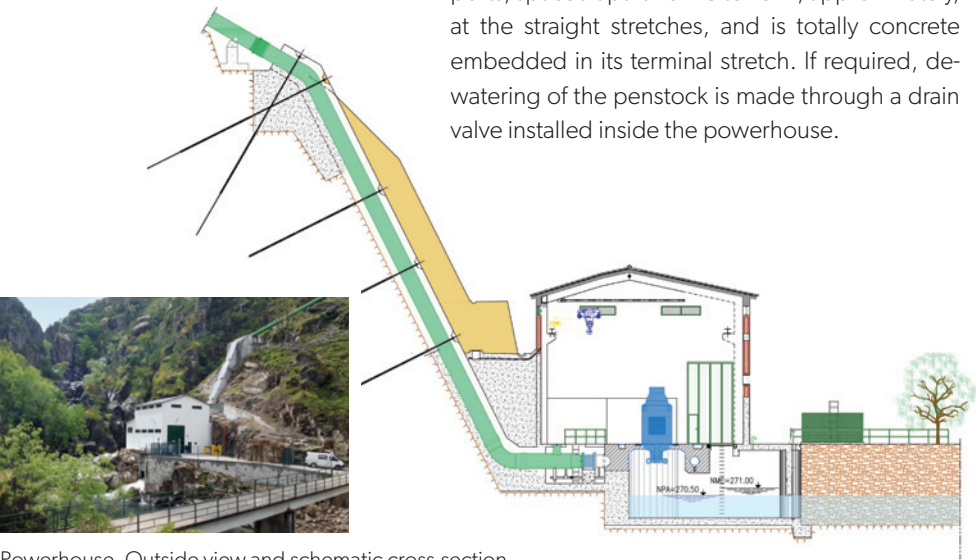
The design of the forebay took into consideration the unsteady regimes, the need of preventing air entrance into the penstock, and the operation of the power plant under pondage conditions. For discharges between the maximum 2.50 m<sup>3</sup>/s allowed by the turbine and the minimum 0.50 m<sup>3</sup>/s compatible with its operation, the water level at the forebay is kept constant at the elevation 452.50. For lower discharges, the minimum level inside the forebay can decrease to the elevation 451.77. From this to the elevation 453.55 the power plant operates under pondage conditions.



View of the initial stretch of the penstock over the Salamonde reservoir.

The **penstock** consists of a spiral-welded steel piping Ø<sub>int</sub> 1000 installed between the elevations 449.50, immediately downstream of the butterfly valve at the forebay, and 272.80 upstream of the turbine isolation valve, at the entrance of the powerhouse (length of around 300 m). The penstock is supported by eight anchor blocks, at the bends, and 24 saddle supports, spaced apart from 8 to 10 m, approximately, at the straight stretches, and is totally concrete embedded in its terminal stretch.

If required, de-watering of the penstock is made through a drain valve installed inside the powerhouse.



Powerhouse. Outside view and schematic cross-section.



Power plant. Aerial view over the terminal reach of the canal, the forebay, the penstock and the powerhouse.

The hydraulic circuit ends at the **powerhouse**, located on the Saltadouro River’s left bank, near its confluence with the Salomonde reservoir. The powerhouse building, with a horizontal area of  $16.00 \times 11.40 \text{ m}^2$ , consists of three floors, at the elevations 271.30, 273.93 and 277.05. The entrance to the building is made at the middle-floor level, where the turbine-generator unit, the electric boards and the control panels are installed. The medium-voltage switchgears are installed in a separate compartment located on the same floor. From this floor it is possible to access the drainage gallery (tailrace), located at the elevation 269.00, through a drainage pit provided with a seal cap. The sanitary facilities and an office occupy a small area at the upper-floor level of the building. The penstock entrance, including a manhole, the drainage circuit and the turbine protection valve are all installed on the floor at the elevation 271.30.

The turbine-generator unit consists of a vertical-shaft, 6-jet Pelton turbine, designed for a maximum discharge of  $2.50 \text{ m}^3/\text{s}$ , a nominal head of 176.90 m, and an installed capacity limited to 3.75 MW. The turbine discharges to a section of the Saltadouro River already under the influence of the reservoir of the Salomonde dam, located on the Cávado River. The main 6.6/15-kV transformer, for a voltage of 4200 kVA, is installed in an outdoor fenced yard near the building. The powerhouse is also equipped with an overhead-travelling crane for heavy-equipment handling.



Turbine’s runner and injectors; generator.



Waterfalls at the confluence of the Saltadouro River with the Salomonde reservoir.

The Ruivães hydropower plant was designed and built as to ensure a good cultural, environmental and landscaping integration in the surrounding area, marked by: the medieval bridge on the Saltadouro River, located upstream of the main weir; the Ruivães roman road, where the bridge is inserted; the local agro-forestry use; and the waterfalls that portray the final reach of the Saltadouro River.

It should also be emphasized: the preservation of the roman road; the necessity to ensure that the rise of the water level caused by the main weir will not interfere with the medieval bridge; the construction of two wildlife ramps for passage of the Pyrenean desman; the obligation to ensure the ecological discharges; and the implementation of several environmental and landscaping integration procedures, including planting riparian trees and hydroseeding the excavation slopes.

The hydropower plant must go through environmental monitoring in order to assess the quality of the aquatic ecosystems in the affected areas over time. A first ecological monitoring was carried out during the construction of the power plant.



Pyrenean desman.

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TECNICAL DATA

Hydrological characteristics	Saltadouro River	Chedos Stream	Rebordondo Stream
Main watershed	Cávado River		
Watershed area	32.9 km <sup>2</sup>	4.7 km <sup>2</sup>	1.5 km <sup>2</sup>
Non-diverted mean annual flow	44.48 hm <sup>3</sup>	8.01 hm <sup>3</sup>	2.28 hm <sup>3</sup>
100-year design discharge (weir section)	320 m <sup>3</sup> /s	75 m <sup>3</sup> /s	32 m <sup>3</sup> /s

Hydraulic circuit	Saltadouro River	Chedos Stream	Rebordondo Stream
Weir	gravity profile and Creager-type spillway		
Normal retention level (NRL)	455.00	455.00	456.00
Height of the spillway relative to the elevation of the general foundation	4.50 m	4.25 m	1.75 m
Water intake	Tyrolean type		
Maximum design discharge	2.10 m <sup>3</sup> /s	0.30 m <sup>3</sup> /s	0.10 m <sup>3</sup> /s
Rectangular cross-section canal – average height and bottom width / length	1.65 x 2.29 m <sup>2</sup> / 1075 m		
Forebay – turbine regulation level / trash-rack dimensions	452.50 / 4.50 x 3.25 m <sup>2</sup>		
Penstock – diameter / length	1000 mm / 300 m		

Powerhouse	
Operation	Run-of-river under pondage; automatic; unmanned
Turbine – type / capacity	Vertical-shaft, 6-jet Pelton turbine / 3900 kW
Generator – type / voltage	Synchronous / 4200 kVA
Elevation at the axis of the turbine’s injectors	272.80
Maximum gross head relative to the NRL / to the regulation level in the forebay	182.20 / 179.70
Allowed power at the turbine’s shaft	3750 kW
Mean annual energy production	11.82 GWh

Connection to the electricity grid	
Main transformer 6.6 kV/15 kV	4200 kVA
Interconnection line 15 kV	0.6 km
Supply voltage	15 kV

General Coordination: HIDROERG – Projectos Energéticos, Lda.

Design: CENOR – Projectos de Engenharia, Lda.

Civil Works: Domingos da Silva Teixeira, S.A. (DST)

Hydromechanical, electromechanical and electrical equipment:

Empreiteiro geral: EFACEC – Engenharia e Sistemas, S.A. / Fornecedores: RAINPOWER, WEG

Connection to the Electricity Grid: Electro-Minho, Lda.

Supervision of the Contracts: PENGEST – Planeamento, Engenharia e Gestão, Lda.