



HYDROELECTRIC DEVELOPMENTS

HYDROELECTRIC DEVELOPMENT OF THE RABAÇAL RIVER NEARBY BOUÇOAIS-SONIM

PORTUGAL

HYDROELECTRIC DEVELOPMENT OF THE RABAÇAL RIVER NEARBY THE REBORDELO VILLAGE

Client: ENGIL – Sociedade de Construção Civil, S.A.

Final Design and Technical Assistance:

2003 / 05

Hydraulic Circuit

- The hydraulic circuit is installed between the reservoir and the power station, has a length of some 1700 m excavated in the granite formation of the right bank of the river. The excavation diameter is of 4,20 m, being concrete lined in the sections whose conditions so require, a thickness of 0,30 m, defining a hydraulic with an internal diameter of 3,60 m.

Fish facilities

- Fish lift following a fish ladder with successive basins designed for 0,450 m³/s.

Access roads

- Access road to the dam (linking to the NR 103) with some 2650 m.
- Access road to the power plant (linking to the NR 103) with 650 m.
- Re-establishment of the CM 511 between Vale do Arneiro and S. Jomil over a length of 360 m.

DESCRIÇÃO

The Rabaçal Hydro Power Project is located nearby the Rebordelo village, in the Rabaçal river, a sub-affluent of the international Douro river.

The project purpose is the electric power generation, within the legislation in force applicable to independent organisations, i.e., the installed capacity shall be up to 10 MW.

The project site is extremely hilly, with steep slopes cut in the granite formations and with a very steep river (average slope of 1%), creating good conditions for the project construction.

It involves the following structures:

Dam

- | | |
|-----------------------|---------------------------------------|
| – Type: | Concrete arch-gravity dam |
| – Height: | 35 m |
| – Crest length: | 127 m |
| – Dam volume: | 21,4 x 10 ³ m ³ |
| – Reservoir capacity: | 3,13 x 10 ⁶ m ³ |
| – Maximum flood flow: | 1480 m ³ /s |
| – Spillway: | overflow, without gates |

Power Station

The power station is located on the right bank of the Rabaçal river, about 1,7 km downstream the dam, taking advantage of the difference in height of about 20 m between the two sites, and has the following characteristics:

- | | |
|-----------------------------|------------------------|
| – Installed capacity: | 8 750 kW |
| – Head: | 42,5 m |
| – Nominal flow: | 24,4 m ³ /s |
| – Number of units: | 1, Kaplan turbines |
| – Design flow: | 24,4 m ³ /s |
| – Annual energy generation: | 24 GWh/year |





HYDRAULIC DEVELOPMENTS

Dams

ODELOUCA II DAM

PORTUGAL

ODELOUCA HYDRAULIC DEVELOPMENT. ODELOUCA II DAM AND ODELOUCA-FUNCHO HYDRAULIC CIRCUIT

Client: Instituto da Água
(INAG)

Design:
1999/01

**Technical Assistance to the
Owner:**
2001/04 (Tunnel)

2002/03 (Dam) (works
interrupted)



Structure for flow regulation at
the Funcho side

The first studies of the Odelouca dam were concluded in 1977. During 1995 and 1996 the design review was completed with the corresponding environmental impact studies. Owing to environmental constraints, the Owner moved the dam site to the Odelouca valley, upstream the confluence with the Monchique stream, in the district of Faro, Algarve region. It was then necessary to undertake a new dam design called Odelouca II.

The project has the essential purpose of public water supply to the municipalities of Vila do Bispo, Lagos, Portimão, Lagoa, Silves, Albufeira and West Loulé.

Dam:

- Type: Zoned earthfill dam with clayey core
- Height: 76 m
- Crest Length: 415 m
- Volume of Dam: $2\,020 \times 10^3 \text{ m}^3$
- Reservoir capacity: $157 \times 10^6 \text{ m}^3$
- Maximum flood flow: $1\,513 \text{ m}^3/\text{s}$ ($t = 1000$ years)
- Spillway: $2\,205 \text{ m}^3/\text{s}$ – channel with frontal weir controlled by three gates
- Bottom outlet: gallery ($\varnothing 2,0$ m) installed in the provisional diversion tunnel
- Provisional diversion: in tunnel, 435 m long, set up on right bank
- Access roads: 3,3 km long, with current engineering works to cross streams

ODELOUCA-FUNCHO HYDRAULIC CIRCUIT (TUNNEL)

- Length: 8 150 m
- Diameter : 2 130 m
- Volume of concrete : $16\,300 \text{ m}^3$
- Design flood in tunnel: $9 \text{ m}^3/\text{s}$





**ABRILONGO DAM
INTEGRATED IN THE
XÉVORA
HYDROAGRICULTURAL
PROJECT**

Client:

IEADR - Instituto de Estruturas
Agrárias e de Desenvolvimento
Rural
(Ministry of Agriculture)

**Final Design, Tender
Documents and Procurement
Processes:**
1992/93

**Technical Assistance to
Supervision:**
1998/2000

Investment Cost:
12.500.000,00 Euro

The Abrilongo dam is part of the Portugal/Spain Xévora irrigation project and envisages the irrigation of 5 000 ha in Portugal and 6 500 ha in Spain.

MAIN CHARACTERISTICS

- Location: Campo Maior, Portalegre
- Type: Earthfill dam
- Height: 30 m
- Crest length: 1 063 m
- Volume of dam: $500 \times 10^3 \text{ m}^3$
- Gross capacity of reservoir: $18,9 \times 10^6 \text{ m}^3$
- Maximum flood flow: $610 \text{ m}^3/\text{s}$ (T = 1000 years)
- Spillway: $420 \text{ m}^3/\text{s}$
- Bottom outlet: $5 \text{ m}^3/\text{s}$ - conduit \varnothing 800 mm



**KOUDIAT-ACERDOUNE DAM**

Client:
Agence Nationale des Barrages
(ANB)

Tender Design:
1989/93

Investment Cost:
50.000.000,00 Euro

DESCRIPTION:

The Koudiat-Acerdoune rockfill dam with clay core is located at about 60 km east Algiers in the Isser Oued. Its purpose is the water supply and irrigation.

MAIN CHARACTERISTICS:

- Type: ER
- Height: 111 m
- Crest Length: 385 m
- Volume of Dam: 4 820 x 103 m³
- Reservoir Capacity: 640 x 106 m³
- Maximum Flood Flow: 8 600 m³/s
- Spillway: 7 340 m³ - labyrinth weir
- Bottom Outlet: 180 m³/s - culvert



**STUDIES OF THE KERRADA DAM****CLIENT:**

Agence Nationale des Barrages
(ANB)

**Preliminary Study
Final Design, Tender
Documents and Procurement
Processes:**
1998/2000

Financing:

International Bank for
Reconstruction and
Development (IBRD)

Investment Cost:

17.800.000,00 Euro

DESCRIPTION

The studies of the Kerrada dam followed those of the Sidi Hadjel dam, since these concluded that the Sidi Hadjel dam would flood 12,5 km² of very rich agricultural soils and due to environmental impacts. The Kerrada dam is located on the right bank of the oued Cheliff, on the oued Kerrada, in Hadjadj, Wilaya of Mostaganem.

MAIN CHARACTERISTICS

- Type: Earthfill
- Height: 112 m
- Crest Length: 1 325 m
- Storage Capacity: 195 hm³
- Volume of dam: 11 800 x 10³ m³
- Bottom outlet: 35 m³/s

The studies included:

- Hydrological study of the Kerrada reservoir and catchment area;
- Geological and Geotechnical studies;
- Definition of the geological survey and geotechnical tests;
- Hydrological studies of the new dam site;
- Definition of alternative solutions in function of the survey results;
- Selection of a final solution and preparation of the detailed design and tender documents of the Kerrada dam and water transfer from the Cheliff intake.



HYDRAULIC DEVELOPMENTS

Dams

KEDDARA DAM

ALGERIA

KEDDARA DAM

Client:

Agence Nationale des Barrages
(ANB)

Final Design:

1980 / 1982

Technical Assistance:

1982 / 1986

Investment Cost:

60.000.000,00 Euro

The Keddara dam is located near Algiers on the Boudouaou river. Its purpose is the water supply.

MAIN CHARACTERISTICS:

TYPE:	ER
HEIGHT:	108 m
CREST LENGTH:	486 m
VOLUME OF DAM:	4 400 x 10 ⁶ m ³
RESERVOIR CAPACITY:	146 x 10 ⁶ m ³
MAXIMUM FLOOD FLOW:	735 m ³ /s
SPILLWAY:	280 m ³ /s - canal
BOTTOM OUTLET:	60 m ³ /s - tunnel

It is a limestone rockfill dam 106 m high, with a clay central core protected by thick and suitably graded filter layers.

The foundation watertightness is granted by a deep grout curtain and a consolidation grouting treatment under the core. In order to make easier the deep treatment of the foundation and its drainage, a gallery following the dam axis was built.

An efficient connection between the core and the curtain is assured by the consolidation treatment





REHABILITATION OF THE JABURU I DAM

Client:

Secretaria dos Recursos
Hídricos do Estado do Ceará

**Final Design, Tender
Documents and Procurement
Processes:**
1998/2000

**Supervision and Monitoring
of Construction Works:**
2002/...

Financing:
World Bank

Investment Cost:
9.000.000,00 Euro

HYDRAULIC DEVELOPMENTS

Dams

JABURU I DAM

BRAZIL

DESCRIPTION:

The Jaburu I dam, built between 1981 and 1983, is located at the Ibiapaba mountain range, Tianguá municipality, northeast to the State of Ceará, near the border with the State of Piauí.

The main objective of this dam is public water supply and irrigation.

Within the scope of this project inspection visits to the dam and several basic studies were carried out, these including hydrological studies, topographical surveys and a mechanical investigation campaign, which comprised as well the installation of hydraulic piezometers at the dam's embankment and foundation. These studies were the basis of the reconnaissance and diagnosis of the main problems and deteriorations of the work and of the further analysis and detailing of the envisaged rehabilitation solutions.

MAIN CHARACTERISTICS

- Type: Zoned earthfill
- Height: 47 m
- Crest length: 770 m
- Reservoir capacity: 210 hm³
- Maximum flood flow: 1 224 m³/s (T = 1000 years)
- Spillway: formed of a channel 450 m long, a 29 m wide "low-ogee" control weir and channel ranging from 5 to 10 m wide. Q (T = 1000 years) = 158 m³/s.
- Water intake: steel pipe under the dam's embankment, with downstream control.



**IRAI DAM****Client:**

SANEPAR, Companhia de
Saneamento do Paraná

**Tender Design/Final Design,
Tender Documents and
Procurement Processes:**
1996

**Technical Assistance, Works
Supervision and
Management:**
1996/99

**Behaviour and Safety
Analysis:**
1999/02

Financing:
International Bank for
Reconstruction and
Development (IBRD)

Investment Cost:
10.350.000,00 Euro

DESCRIPTION:

Located in the Curitiba Region, the Iraí dam envisages the reinforcement of the water supply to the Curitiba metropolitan area and the downstream flood control.

MAIN CHARACTERISTICS

- Type: TE
- Height: 19 m
- Crest length: 1 220 m
- Volume of Dam: $786 \times 10^3 \text{ m}^3$
- Reservoir capacity: $58 \times 10^6 \text{ m}^3$
- Maximum flood flow: $1\,005 \text{ m}^3$
- Spillway: $80 \text{ m}^3/\text{s}$, shaft with non-controlled weir
- Bottom outlet: $16,2 \text{ m}^3/\text{s}$, gallery



**HARREZZA DAM****Client:**

DGIH – Direction Générale des
Infrastructures Hydrauliques
(Ministère de l'Hydraulique)

Final Design:

1979/82

**Technical Assistance to
Construction Works:**

1983/88

Investment Cost:

44.900.000,00

The Harrezza dam is located nearby the El Khemis Wilaya on the Harrezza river. Its purpose is irrigation.

MAIN CHARACTERISTICS:

- Type: TE
- Purpose: Irrigation
- Height: 41 m
- Crest Length: 1 787 m
- Volume of Dam: $3\,900 \times 10^3 \text{ m}^3$
- Reservoir Capacity: $70 \times 10^6 \text{ m}^3$
- Maximum Flood Flow: $800 \text{ m}^3/\text{s}$
- Spillway: $350 \text{ m}^3/\text{s}$ – canal
- Bottom Outlet: $50 \text{ m}^3/\text{s}$ – tunnel





GOVE HYDROELECTRIC DEVELOPMENT

ANGOLA

**GOVE HYDROELECTRIC DEVELOPMENT.
Gove Dam Rehabilitation and Construction of Hydropower Plant and respective Substation**

Client: GABHIC - Gabinete para Administração da Bacia Hidrográfica do Rio Cunene

**Detailed Design and Tender Documents:
2002/05**

Studies executed in concertium with the local consulting engineers Progest

Hydropower Station and substation.

Its purpose is to generate electrical power to supply, in the short term, the town of Huambo. It has an installed capacity of 60 MW and generates in average some 150 GWh/year. The substations will be located nearby the power plant occupying an area of 10.000 m².

The GOVE dam is located in the Province of Huambo, some 120 km South of the town of Huambo. It has been constructed with the main purpose of flood control of the Cunene river flows and was completed in 1975. The dam has been subject to sabotage actions (in 1986 and 1990) that endangered its exploitation.

In the former design a hydroelectric power station has been planned to be incorporated in the dam. Thus, this station is now part of the works to be executed

The consortium COBA/PROGEST was in charge of the detailed design and tender documents for the dam rehabilitation as well as the associated infrastructures and the design of the new hydro power plant.

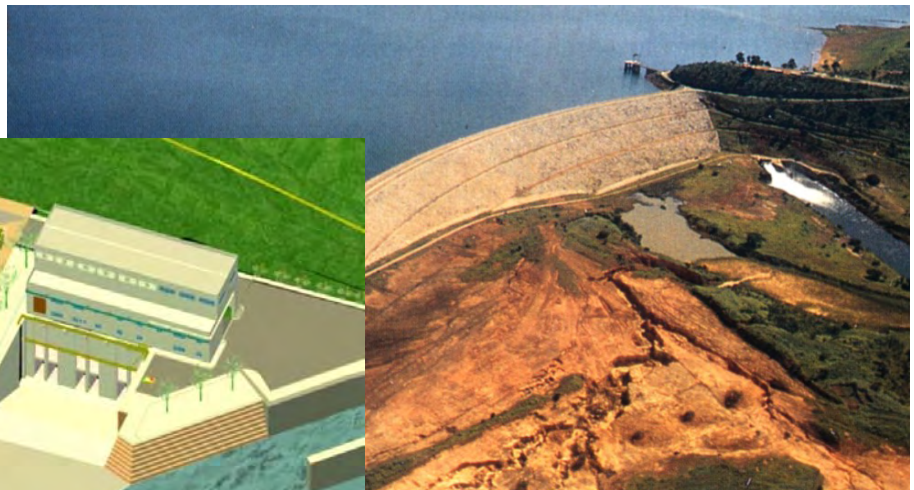
Dam:

The Gove dam site covers a basin area of 4 667 km² and the reservoir, with the NWL at (1590,00), has a storage capacity of 2547 x 10⁶ m³.

The Gove dam has a homogeneous embankment cross-section and a rockfill toe. The maximum height above the foundation is 58 m and the crest length is 1 112 m. The dam volume is 4 x 10⁶ m³.

Given the sabotage damages, the dam and existing infrastructures were object of rehabilitation studies that comprised:

- Rehabilitation of the dam nearby the left abutment;
- foundation treatment for reinforcement of the cut-off structure;
- treatment of longitudinal and drainage galleries to minimise the seepage and to improve the consistency of the interface fills of the gallery;
- protection of downstream rockfill face to prevent the serious evolution of erosion and the migration of fill fines;
- dam external drainage;
- drainage pumping system and drainage at the toe of dam;
- dam heightening in 1 m;
- dam monitoring plan;
- remedial actions in the water intake and in the bottom outlet;
- repair and strengthening of the initial protection of the outlet channel affected by erosion;
- Repair and improvement of lighting and electrical power supply to several dam infrastructures;
- control and prevention of the serious evolution of gullying;
- improvement of the dam left abutment ring road and the Operators building area;
- rehabilitation and improvement of lodging-house and operators building area;
- rehabilitation of the airfield pavement ant upgrade the movement area according to the ICAO' standards applicable to an Airfield code 2C.



**FUNCHO DAM INTEGRATED
IN THE ODELOUCA-FUNCHO
HYDRAULIC DEVELOPMENT****Cliente:**

Instituto da Água (INAG),
(Ministry of Environment and Water
Resources)

General Layout:

1972

Design:

1983

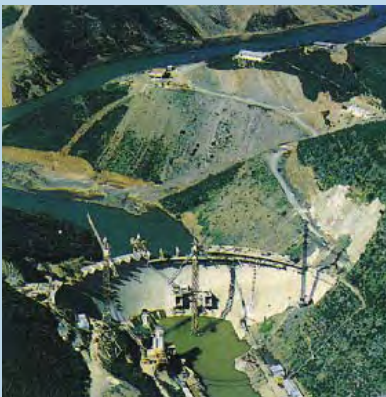
**Final Design and Technical
Assistance:**

1987/93

Purposes: The Funcho dam aims at the flows regulation of the Arade stream for irrigation and water supply to the "Barlavento Algarvio" (Western region of Algarve)

MAIN CHARACTERISTICS

LOCATION:	Arade River, Silves, Algarve
TYPE:	VA
HEIGHT:	49 m
CREST LENGTH:	210 m
VOLUME OF DAM:	$44 \times 10^3 \text{ m}^3$
RESERVOIR CAPACITY:	$43 \times 10^6 \text{ m}^3$
MAXIMUM FLOOD FLOW:	$800 \text{ m}^3/\text{s}$
SPILLWAY:	$75 \text{ m}^3/\text{s}$ - overflow with gates
BOTTOM OUTLET:	$2 \times 162 \text{ m}^3/\text{s}$ - 2 orifices



Downstream Aerial View



Upstream View



HYDROELECTRIC DEVELOPMENTS

HYDROELECTRIC DEVELOPMENT OF THE RABAÇAL RIVER NEARBY BOUÇOAIS AND SONIM

PORTUGAL

HYDROELECTRIC DEVELOPMENT OF THE RABAÇAL RIVER NEARBY THE BOUÇOAIS AND SONIM VILLAGES

Client: ENGIL – Sociedade de Construção Civil, S.A.

Final Design and Technical Assistance:
2003 / 05

Hydraulic Circuit

- The hydraulic circuit is installed between the reservoir and the power station, being formed of a tunnel with some 1350 m excavated in the granite formation of the right bank of the river and of a penstock with a length of 65 m. The tunnel excavation diameter is 4,20 m, being concrete lined in the sections whose conditions so require, a thickness of 0,30 m, defining a hydraulic with an internal diameter of 3,60 m.

Fish facilities

- Fish lift following a fish ladder of successive basins designed for 0,450 m³/s.

Access roads

- Access road to the dam (linking to the NR 103) and to the powerhouse with a length of some 2650 m.

DESCRIÇÃO

The Rabaçal hydro-electric development, tributary of the Tua river (tributary of the international Douro river), is located near the Bouçoais and Sonim villages.

The project purpose is the electric power generation, within the legislation in force applicable to independent generating companies, i.e., the installed capacity shall be up to 10 MW.

The site relief is very hilly, with steep slopes cut in the granite formations and with a very steep river (average slope of 1%), creating good conditions for the project construction.

It involves the following structures:

Dam

– Type:	Concrete, gravity
– Height:	43 m
– Crest length:	87 m
– Dam volume:	19,5 x 10 ³ m ³
– Reservoir capacity:	1,4 x 10 ⁶ m ³
– Maximum flood flow:	1500 m ³ /s
– Spillway:	overflow, without gates

Power Station

The power station is located on the right bank of the Rabaçal river, about 1,3 km downstream the dam, taking advantage of the difference in height of about 28 m between the two sites, and has the following characteristics:

– Installed capacity:	10 000 kW
– Head:	53 m
– Nominal flow:	22 m ³ /s
– Number of units:	2, Francis turbines
– Design flow:	22 m ³ /s
– Annual energy generation:	30 GWh/year





**STUDIES OF THE
ARACOIABA DAM**

CLIENT:

Secretaria dos Recursos
Hídricos do Estado do Ceará

**Final Design, Tender
Documents and Procurement
Processes:
1997/98**

**Technical Assistance and
Monitoring and Supervision
of the Construction Works:
2000/03**

**Investment Cost:
10.500.000,00 Euro**

DESCRIPTION:

- Type: Earthfill
- Purpose: Water Supply
- Height: 35 m
- Crest length: 1 750 m
- Volume of dam: $1\,330 \times 10^3 \text{ m}^3$
- Reservoir capacity: $170 \times 10^6 \text{ m}^3$
- Maximum flood flow: $1\,270 \text{ m}^3$
- Spillway: unlined canal





**ALQUEVA MULTIPURPOSE DEVELOPMENT.
ÁLAMOS DAMS, WATER CONVEYANCE AND LINKING CANAL BETWEEN THE RESERVOIRS**

Client:
EDIA - Empresa de Desenvolvimento e Infra-estruturas do Alqueva

Comparative Study of Alternatives:
1997

Final Design:
1999/01

Technical Assistance:
2004/06

Investment Cost:
17.850.000,00 Euro

HYDRAULIC DEVELOPMENTS

Dams

ÁLAMOS I, II AND III

PORTUGAL

The Álamos Dams are comprised in the Alqueva - Loureiro inter-basin linking within the water diversion project from the Alqueva reservoir, this linking being formed by the following components: Alqueva – Álamos Pumping System; Álamos Dams; Álamos – Loureiro Canal.

The studies of the Álamos Dams include: Water conveyance canal to the Álamos III reservoir, starting at the penstock's end (about 1 000 m long); Álamos I, Álamos II and Álamos III Dams; Interconnection canal between the Álamos III Dam reservoir and the reservoir formed by the Álamos I and Álamos II Dams (about 700 m long).

ÁLAMOS I DAM

- Type: TE
- Height: 35 m
- Crest length: 234 m
- Volume of dam: $321 \times 10^3 \text{ m}^3$
- Reservoir capacity: $5,8 \times 10^6 \text{ m}^3$
- Bottom outlet: concrete gallery, 2 m \varnothing and 180 m long

ÁLAMOS II DAM

- Type: TE
- Height: 37 m
- Crest length: 289 m
- Volume of dam: $505 \times 10^3 \text{ m}^3$
- Reservoir capacity: $5,8 \times 10^6 \text{ m}^3$

ÁLAMOS III DAM

- Type: TE
- Height: 33 m
- Crest length: 316 m
- Volume of dam: $398 \times 10^3 \text{ m}^3$
- Reservoir capacity: $5,8 \times 10^6 \text{ m}^3$
- Bottom outlet: concrete gallery, 2m \varnothing and 180m long.





AL IZDIHAR DAM

Client:

ANB – Agence Nationale des Barrages

Technical Assistance And Complementary Studies:
1985/89

Investment Cost:
24.700.000,00 Euro

MAIN CHARACTERISTICS:

- Type:: TE
- Objective: Water supply and Irrigation
- Height: 71 m
- Crest Length: 665 m
- Volume of Dam: $4\,125 \times 10^3 \text{ m}^3$
- Reservoir Capacity: $110 \times 10^6 \text{ m}^3$
- Maximum Flood Flow: $4\,465 \text{ m}^3/\text{s}$
- Spillway: $3\,000 \text{ m}^3/\text{s}$ –canal
- Bottom Outlet: $115 \text{ m}^3/\text{s}$ - tunnel





**COVA DA BEIRA
HYDRAULIC DEVELOPMENT.
SABUGAL DAM, SABUGAL-
MEIMOA WATER WAY AND
SABUGAL POWER STATION**

**CLIENT: INAG (Instituto da
Água) and IHERA (Instituto
de Hidráulica, Engenharia
Rural e Ambiente) for the
construction phase**

Feasibility Study/Design:
1972/74

**Design Review, Tender
Documents and Procurement
Processes:**
1993/94

**Technical Assistance to
Supervision**

Dam:
1997/2000

Waterway:
1999/underway

HYDRAULIC UNDERTAKINGS

Dams

SABUGAL DAM AND SABUGAL-MEIMOA WATERWAY

PORTUGAL

DESCRIPTION:

COBA has been committed the studies associated with the Sabugal development including the Preliminary Design, the Design and Revision of the Design. These studies have started early the 70's and, in 1993, the "Instituto da Água" of the Ministry of Environment and Water Resources opened a call for tenders to update the Design and Contract Documents of the dam and of the Sabugal-Meimoa waterway with a view to commencing the construction works. These were completed in 1994 and the dam construction started in 1997 with the Technical Assistance of COBA. The Sabugal-Meimoa waterway construction started in 1999 with the Technical Assistance of COBA.

The project, that envisages the water supply, the irrigation and the power generation, includes the **Sabugal dam** and respective hydraulic and safety structures (intake tower, bottom outlet, water intake and spillway) and the **Sabugal-Meimoa waterway** (intake tower, diversion tunnel, surge chamber, penstock) and **power plant**.

DAM

- Type: Earthfill Dam
- Height: 58,5 m
- Crest Length: 1 005 m
- Volume Content of Dam: 1 900 x 10³ m³
- Reservoir Capacity: 110,4 x 10⁶ m³
- Maximum Flood Flow: 569 m³/s (T = 1000 years)
- Spillway: 182 m³/s – canal
- Bottom Outlet: 28.3 m³/s - pipeline Ø 1500

SABUGAL-MEIMOA WATERWAY

- Tunnel Length: 4 150 m
- Design Flow: 5,07 m³/s
- Penstock: metallic 600 m long and Ø from 1550 mm to 700 mm

POWER PLANT

- Gross Head: 211 m
- Installed Capacity: 9,5 MW
- Yearly Energy Generation: 33 Gwh

