AIMORÉS HYDROELECTRIC POWERPLANT ON THE DOCE RIVER

This paper was written by Michael Sucharov based on reports and drawings furnished by SPEC. Front Photo and Photo 3 were furnished by CEMIG, Photo 2 and Figure 2 by courtesy of Embrapa Monitoramento por Satélite, the other photos by courtesy of Panoramio (Photo 1 by Elpídio Justino de Andrade, Photo 4, 5, 6 & 7 by Gilberto Rodrigues Filho).

AIMORÉS HYDROELECTRIC POWERPLANT ON THE DOCE RIVER

1. INTRODUCTION

Aimorés or Eliezer Batista Hydroelectric Powerplant has a final installed capacity of 330 MW and is owned by Consórcio Brasileiro de Aimorés - CBA, which belongs to the Vale do Rio Doce Company (CVRD) and CEMIG, the State of Minas Gerais Power Company. It is a low head run of river powerplant similar to the downstream development of Mascarenhas built in the late 60's. It is located on the Doce River in the municipality of Aimorés, by the city of the same name, on the eastern border of the state of Minas Gerais, Brazil.

The catchment area of the dam is 62,167 km^2. The long term mean flow is 292 m^3/s. The reservoir covers 30.9 km^2 at the maximum normal water level at El. 90.0 and holds 184.6 x 10^6 m^3 of water.

Various studies by different entities were carried out on the Doce river for hydroelectricity development and other purposes as follows:

• During the period 1963/65 Canambra and Cemig made an inventory of the Doce river as part of an overall study of hydro-energy potential in the state of Minas Gerais.

• DAG-MME hired SERVIX Eng. that made a feasibility study in 1963/64, using a different concept than that by Canambra.

• Cemig made further investigations and studies from 1975 to 1980 to update Canambra's studies.

• The federal port authority, Portobrás, hired Themag/ Montreal to study the feasibility of navigation and energy possibilities of the Doce river, which were finalized in 1978.

• Government agencies established a task force that made a study for prevention and control of floods on the Doce River, that was concluded in 1982.

• Eletrobrás hired IESA and Fundação João Pinheiro to make an overall review of Canambra/Cemig's studies due to changes of criteria by the federal government for electric power planning and multiple use of power reservoirs. These studies were done in the period from 1985 to 1989.

• Cemig and CVRD hired Monasa in 1992 for pre-feasibility studies reviewing the cost of Cemig's 1976 alternative, and moved the dam further upstream away from the city of Aimorés, and lowering the reservoir levels to reduce the impact on the cities of Aimorés, Itueta and the railway.

• Feasibility studies in 1996 and the preliminary design in 1997 were done by Promon/SPEC.

• Final design was carried out by SPEC.

The works were carried out according to the following time schedule:

1. Start of works to river diversion: 5 months
2. River diversion to 1st Phase closure: 22 months
3. Closure of diversion structure to start of power generation (1st unit): 3 months

The first generating unit was put in commercial operation in February 2006.

The civil works were carried out by Queiroz Galvão.

2. LAYOUT

Aimorés project can be considered as two separate parts (Figure 1):

1. A main earthfill dam forming the reservoir on the right bank, 18 m high and 565.0 m long at the crest, adjoining a ten gate 15,000 m^3/s capacity spillway located across the river valley that ends at the Lorena Rock, about 5 km upstream from the city of Aimorés.
2. A hydraulic power circuit, that includes a long 12 km open channel partly excavated on the left bank, and at the end a low head monolithic intake/powerhouse structure housing three turbine/generators that discharge back into the Doce river.

The power structure is just across the city of Baixo Guandu in the state of Espírito Santo, which is the sister city of Aimorés and about 5 km downstream.

Figure 1 shows the general layout of the Aimorés hydroelectric development.

3. MORPHOLOGY, GEOLOGY AND GEOTECHNICS OF THE FOUNDATIONS

The hydroelectric development is located in an area where, over time, the geological features were eroded away, resulting in the valleys of the Doce and Manhuaçu rivers (see Figure 2). Tectonic activity and intense fluvial dissection of the rock formations created various forms of relief, such as: hills and elevations between 50 and 250 m; mountain size formations around 400 m high; low flat valleys and alluvial plains with heights between 70 and 90 m. A main feature of the region is a round flat plateau circled by large mountain sized rock outcrops called "Aimorés Circular Structure" which is mentioned further on in more detail.

The rock formation geology is basically precambrian granite-gneisses of the Barbacena-Paraíba do Sul Association and includes the Charnockitic, Gneissic-Migmatic and Granitoid complexes. Of these three:

• The "Aimorés Circular Structure" is part of the first rock complex.

• Most of the reservoir area is part of the second rock

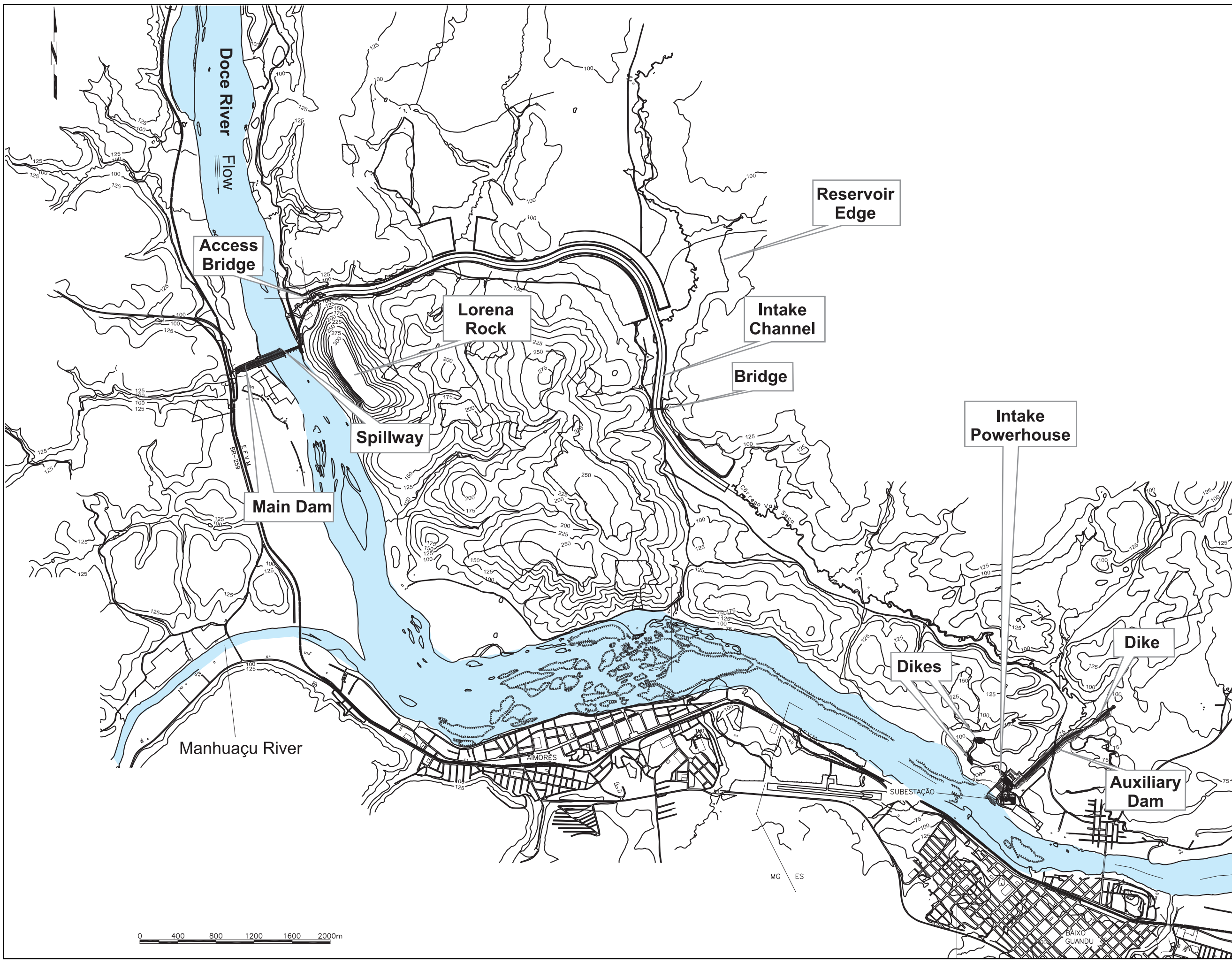


Figure 1 - General Layout

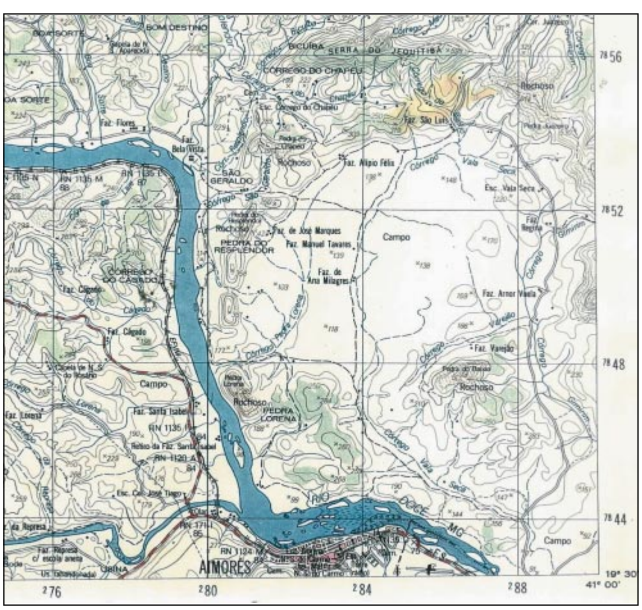


Figure 2 - Map of the Project Area

complex.

• The right bank of the main dam and a small section between the upstream towns of Itueta and Resplendor are part of the third rock complex.

These rock formations did not reveal any foundation permeability problem for impounding the reservoir.

3.1. Main Dam and Spillway

In the main dam and spillway area there are two distinct characteristics:

1. On the left bank there is a tall (El. 389) mountain outcrop named "The Lorena Rock", which is 299 m above the reservoir (Photo 1). It makes part of the "Aimorés Circular Structure", and is an important feature as it closes the main dam on the left bank;

2. On the right side there is an extensive alluvial plain 300 m wide before reaching the right river bank.

The main dam river bed had a very good foundation quality as the rock was sound, very consistent, occasionally fractured and impervious; in some places it outcropped or was covered with a thin layer of sand. Towards the right bank there was large alluvium soil plateau about four to five meters thick. The loose to moderate

Photo 1 - Lorena Rock Seen from the Right Bank at a Distance

fine silty sand of the alluvium was low in permeability. Where the spillway and stilling basin are located, which is in the riverbed by the left bank, there was a thick layer (7.5 m) of alluvial sand covering the sound bedrock which had to be completely removed. The foundation rock was considered sound and not very decomposed, consistent, and lightly fractured and had a low to medium permeability. All spillway structures, including walls and stilling basin were founded on solid rock.

3.2. Intake/Powerhouse and Tailrace Channel

The intake/powerhouse structure and tailrace channel were founded on sound rock. Soil excavations were on average 6.5 m thick and excavations in sound granite-gneiss rock reached 39 m deep in the powerhouse down to El. 31.6 and were the deepest excavations carried out. In the discharge channel area excavations reached 30 m deep mainly in sound granite-gneiss, lightly fractured and with very good geo-mechanical qualities. Soil excavations reached maximum depths of 7 m.

3.3. Auxiliary Dam and Dikes

The foundation of the auxiliary dam was in a low area with rounded hills, and alluvium soil in between, of which one is the Vala Seca stream that crosses the dam axis. This created two separate foundation conditions: the first was with low plain alluvium soils up to 8 m thick, made up of loose to moderate well graded material from sand to clay, and low permeability; the second condition was the small elevations that had a thin top layer, with up to 3 m, of porous and permeable colluvium. Underlying this top layer was altered rock which in some places was 11 m thick. The sound rock surface was quite irregular, and outcropped in some places and in others was buried below the layers of altered rock.

The excavation of the auxiliary dam and dike 1 foundation was on average about 2 m deep but increased to 4 m where the thickness of the alluvium layers were greater, and a cut-off trench 2 x 3 m was dug beneath the dam core to intercept the saprolite layer. Dikes 2 and 3 were built on the topographic saddles where the foundation is sound, with rock outcropping in dike 2 and shallow soil overburden in dike 3. The soil above was colluvium and residual soil. Only one meter of the spongy colluvium was removed for these foundations.

3.4. Intake Channel

The mouth of the 12 km intake channel is located on the left bank of the Doce river and situated in the valley between the upper side of the "Lorena Rock" and the "Resplendor Rock", where the Lorena stream bed used to flow into the Doce river. The channel topography is generally quite plane and the rock profile is irregular with a number of undulations.

The first half of the channel was excavated, while the second half was in the natural valley of the Vala Seca stream (Figure 1). Four types of rock were identified during blasting along the channel: microcline, granite-gneiss, granitoid and gabbro. The solid rock surface was covered with a layer of altered rock (residual saprolite) with thicknesses between one to nine meters.

The excavations of the intake channel were carried out in the low plateau of what is called "Aimorés Circular Structure" following part of the courses of the Lorena and Vala Seca valleys and through the higher elevations of the watershed between them. The plateau has an average elevation between 120 and 140 m, and surrounding it are hilly elevations on average around 300 m high and about half this towards the city of Baixo Guandu; the tallest peak is 779 m (Serra do Jequitibá - in the north direction). Recent investigations and satellite photographs have suggested that it is an ancient crater of about 10 km in diameter caused by a meteor, that could have displaced the Doce river bed. The Lorena Rock is part of the left side of the crater ridge. (see Photo 2 below by courtesy of Embrapa Monitoramento por Satélite).

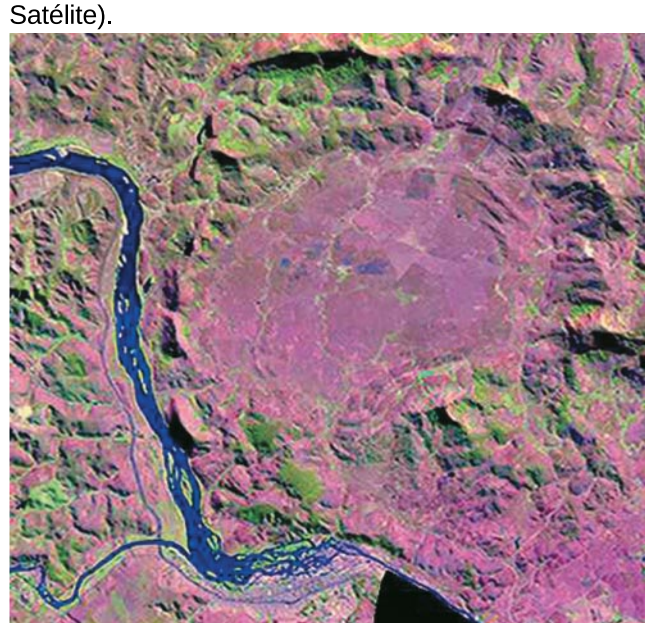


Photo 2 - Aimorés Circular Structure or Meteorite Crater

The overall length of the intake channel between the beginning at the upstream confluence with the Doce river and the intake structure at the end of the channel is 11,904 m. The first half (6,604 m) of the channel was excavated in soil and rock, and the second half (5,300 m) was part of the natural terrain.

- In the first 500 m of the channel, excavations were not necessary as over time erosions had worn away the terrain that is part of the Lorena Stream outlet valley.
- In the next 800 m section, slope excavations were on average 5 m deep in wet alluvium soil.
- In the subsequent 300 m section, slope excavations were 4 m deep in alluvium, residual soil, and saprolite.
- Most of the excavations were done below the water table. In the next 600 m section, excavations also included rock, about 7 m deep, and in soil they were deeper (10 m) than the previous section.
- The 100 m next section had no rock excavations, only common excavation in alluvium and residual/saprolite soil.
- The following, 2,000 m long channel section, had the lower part excavated in rock by blasting; excavation depths reaching 13 m, intercepting various soils, decomposed and sound rock. In this section a 1,100 m long seam of decomposed/fractured rock varying from one to five meters thick was found along the middle half of the section, which required surface treatment of anchored gunite for protection.

From ¾ of the 2,000 m section up to the end of the channel (2,700 m), excavations were mainly in soil and depths became continuously shallower, diminishing from about four meters deep to two meters at the end. Some rock excavations had to be carried out in smaller sections near the end.

The channel excavations were carried out in difficult conditions because of the high water table and the topography of the terrain, that was mostly plane, and required a program for dewatering the excavation areas. The channel bottom slope is linear and followed the design requirements of: El. 81.00 at a distance of 400 m from the beginning of the channel and El. 79.94 at the excavation end of the first half of the channel.

The Table 1 lists the volumes of excavation and construction material for each of the structures. Most of the excavations were for the intake channel: 75% of the common excavations and 73% of the rock excavations.

4. DESCRIPTION OF THE MAIN STRUCTURES

4.1. River Diversion

The river diversion was carried out in a normal two stage solution. Hydrological studies showed that the Doce river watershed has a very regular seasonal water flow: a dry and wet season. So the diversion flow, for a 25 year recurrence, was determined as 1,750 m^3/s for the dry season and 6,500 m^3/s for the flood period .

4.1.1. First stage Cofferdam Construction:

During this stage the river bed was widened towards the right bank by excavation, opening a 140 m diversion channel, and Cofferdam "A" was built on the left bank for the spillway structures, diverting the river through the new diversion channel.

The 1st stage construction of cofferdam "A" was done in two steps.

In step 1 the cofferdam crest reached El. 81.50 and had the exterior layer of large size rockfill that was covered with impervious dumped soil with a fine rockfill transition in between. All dam materials were dumped up to a meter above the surrounding water level. The longitudinal stretch of the cofferdam close to the river flow was protected with rockfill placed over the soil blanket for protection.

In step 2 the cofferdam was raised to El. 85.50 with soil sealing the outside surface on both the upstream and downstream side, and the latter raised to El. 83.50. The outside slopes were then protected with rip-rap. During this stage care was taken to keep the river level below the railway and roads on the right bank.

As there was a layer of alluvium soil with coarse sand in the riverbed near the left bank, it became necessary

VOLUMES OF CONSTRUCTION MATERIALS (1000 m^3)						
STRUCTURES	**Common Excavation**	**Rock Excavation**	**Compacted Earth/Cores**	**Filters and Transitions**	**Rockfill**	**Concrete**
Diversion Channel	174.8	7.6	228.3			
Main Dam	43.3		272.1	33.5	39.8	
AuxiliaryDam	258.1		138.6	119.4	483.5	
Right Wing Dam	4.5		26.3	6.8	22.2	
Dike 1	18.7		11.5	15.1	35.3	
Dike 2	4.2		11.3	2.6	2.1	
Dike 3	3.2		7.7	2.6	1.8	
Spillway		19.5				39.1
Intake Channel	2067.2	1171.1				
Intake	80.1	95.4				37.3
Powerhouse	42.6	110.1				75.5
Discharge Channel	51.2	194.9				
Switchyard	24.1		79.5			0.5
Totals	**2772.0**	**1598.6**	**775.3**	**180.0**	**584.7**	**152.4**

Table 1 - The Volumes of Excavation and Construction Material for each of the Structures

to dredge the material and fill it in with soil dumped straight into the river on the upstream and downstream side of the cofferdam area, that then became cutoff trenches.

4.1.2. Second stage Cofferdam Construction:

After construction of the spillway, cofferdam "A" was removed, and the second stage cofferdams were built. These were cofferdam "B" on the upstream side, and "C" on the downstream side, that bridged the river and diverted it through the spillway. Between the cofferdam arms the area was then able to be dewatered for construction of the main earthfill dam.

In this construction stage the upstream cofferdam was built up to El. 81.40 and the downstream to El. 80.50. The cofferdams were built with rings of large size rockfill and sealed on the outside with dumped soil and a layer of transition between both.

The sources of materials for the cofferdams were mainly from the excavations of the intake and diversion channels.

4.2. Main Earthfill Dam

The main dam bridges the river together with the spillway structure on the left side where it meets the Lorena Rock (Figure 3 and Photo 3), along a common straight axis. It has a cross section typical of earthfill dams with a maximum height of 18.0 m above the foundation, a volume of about 350,000 m^3 of compacted earthfill and a length of 565.0 m along the crest (Figure 4).

The dam slopes are 1V : 2.5H on both sides for the typical main section, but on the right bank and at the left side (earth/rockfill) they are respectively 1V : 2H and 1V : 1.6H. To drain the seepage through the compacted earthfill of the dam, there is a vertical 0.60 m wide sand filter/drain with a horizontal 1.0 m blanket laid straight on the dam foundation. The dam crest is at El. 93.0 with a 10.0 m wide roadway for access to the spillway structures.

The composite section near the spillway has an impervious core of compacted earthfill and the sides are rockfill with a transition on the upstream side and filters and transition downstream.

4.3. Spillway

The spillway structure (Figure 5) consists of nine blocks with 10 bays, an overall length of 168.0 m, and radial gates 13.5 m wide and 15.3 m high, hydraulically operated and mounted on 3.0 m thick concrete piers held in place by post tensioned cables. The two end blocks include one and a half bay, while the middle blocks are regular one bay ones with half widths and a central pier. The spillway is designed for the 10,000 year

Photo 3 - Spillway and Main Dam from upstream

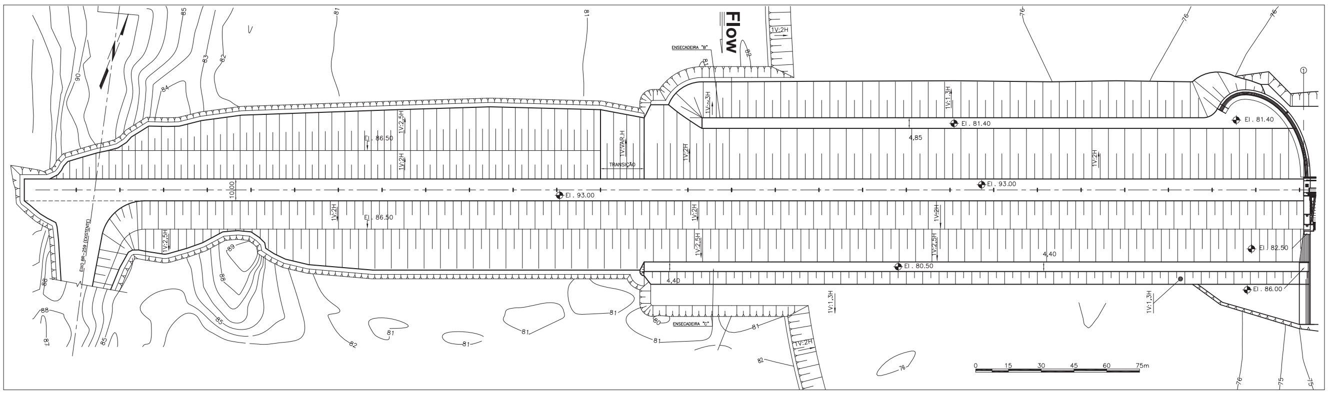
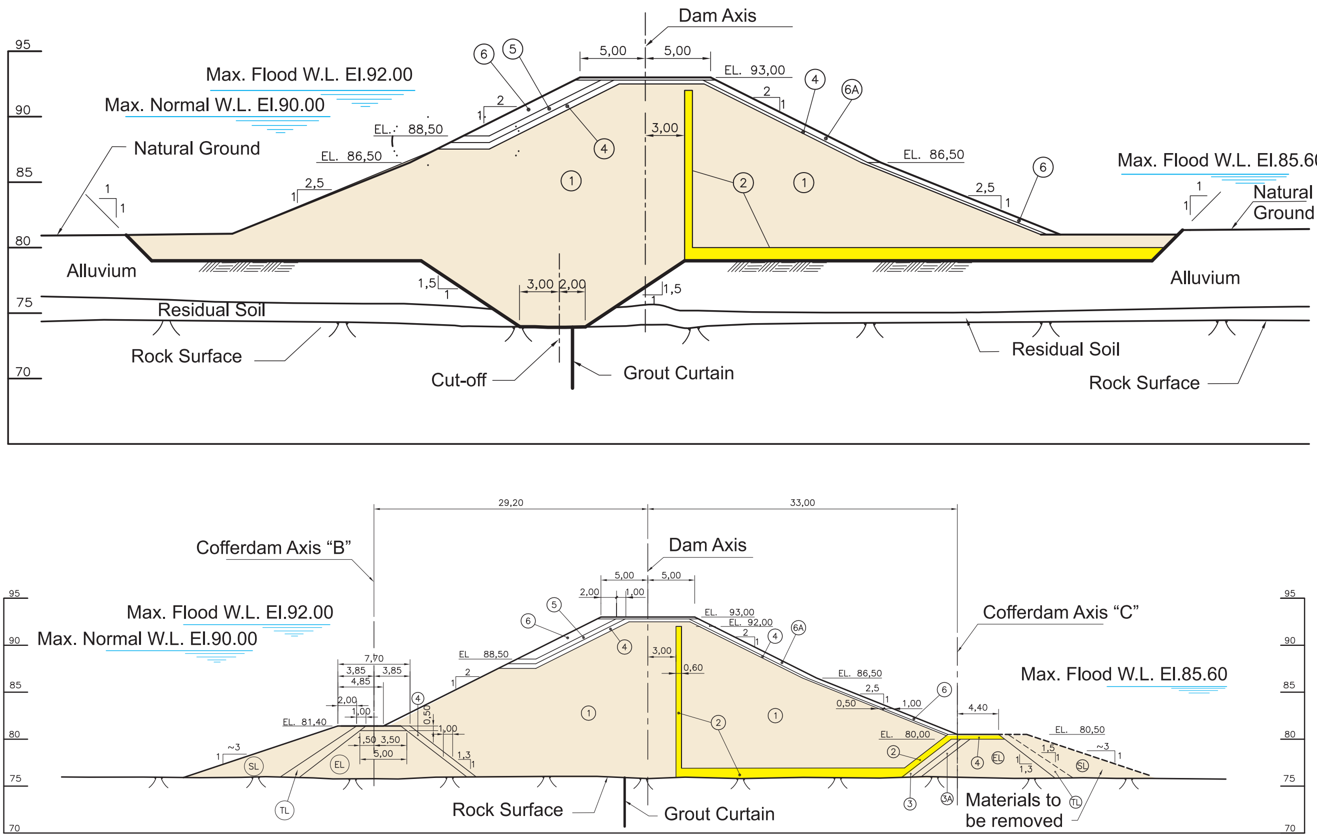


Figure 3 - Main Earthfill Dam - Plan



Legend of Materials

Zone	Material	Zone	Material
1	Clayey Soil from Borrow areas A, B & C	6A	Selected Rockfill
2	Processed Washed Sand	SL	Dumped Soil
3	Fine Transition	SC	Compacted Soil
3A	Coarse Transition	EL	Dumped Rockfill
4	Single Transition	TC	Compacted Transition
5	Rockfill	TL	Dumped Transition
6	Rip-rap	RP	Primary Lining

Figure 4 - Main Earthfill Dam - Sections

recurrence flood of 15,000 m³/s. For the maximum probable flood of 16,800 m³/s the reservoir level will be allowed to rise to El. 92.0 m which is the Maximum Flood Level.

The structure is located in the river bed by the left bank, with the main earthfill dam on the right side and the left guide wall on the left. The blocks are 24.5 m above the foundation and transversally are 22.65 m long and the ogee crest is at El. 76.0 m. The 2.5 x 3.0 m drainage gallery is at El. 70.85 m on the upstream side from which both the drainage and grout curtain were drilled.

The stilling basin is 156.0 m wide and has an overall length of 162.0 m in two sections. The first one adjoining the spillway ogee is 15.0 m in length and consists of a 0.4 m concrete slab anchored to the foundation rock with a slight upward slope in the downstream direction. The second section is a 28.3 m horizontal stretch of sound rock. To confine the discharge flow when only a few gates would be operating, the pier ends of every two bays were extended and tapered the length of the 15.0 m basin section.

The side walls of the stilling basin are 17.0 m high and are anchored on the inner side to the rock foundation to strengthen the rock mass against undercutting by flow erosion and increasing wall stability. On the upstream side, the right guide wall is heavier and "L" shaped to withstand the end load of the main dam. The wall crest varies between El. 91.0 and 93.0 and has a 40.0 x 30.0 m ellipse curve design for the approach channel.

The left upstream guide wall adjoins the spillway and the Lorena Rock on the left bank (see Photo 4). The structure is made of two concrete blocks with a length of 54.5 m, vertical walls on both sides and 8.45 m in width and a maximum height of 17.80 m above the foundation. The wall has four storage shafts for the stoplog sections and a lifting beam when they are not in use, and has an access to the drainage gallery.

The bridge over the spillway is the usual type made up of precast concrete girders that span the bays and are supported by the piers. The access road over the bridge is at El. 92.5. Photo 5 depicts the spillway seen from the Lorena Rock on the left bank.

Photo 4 - The Lorena Rock along the Main Dam Axis Seen from the Spillway

Photo 5 - Spillway Seen from the Lorena Rock on the left Bank

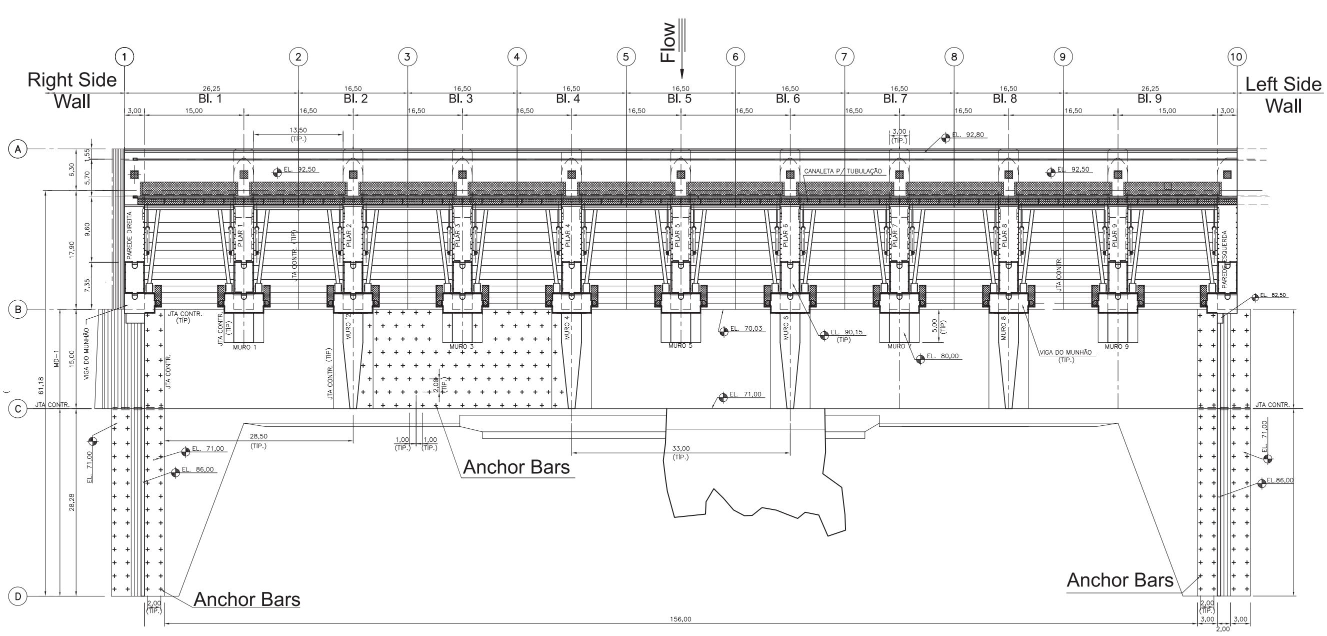


Figure 5 - Spillway - Plan

4.4. Intake Channel

To carry water from the reservoir that was created by the main dam it was necessary to excavate part of the 12 km channel that leads to the intake/powerhouse structure. The excavated channel is 80 m wide and 6,600 m long and joins with the 5,300 m of the natural valley of the Vala seca stream, which is parallel to the Doce river. The channel mouth is located about 200 m upstream from the main dam on the left bank, beside the "Lorena Rock" which is on the right side of the entrance to the channel. The topography of the area is basically flat and the channel maintains a constant width of 80.0 m at the bottom with the side slopes having variable angles depending on the excavated material: 1V:1.5H in alluvium soil, 1V:1H in saprolite or residual soil and 1V: 0.1H in rock.

The channel was studied to reach an optimum design and reduce rock and soil excavations which are a large part of the development. With this in mind and with the available data from geological and geotechnical investigations, it was possible to reduce the channel depth in about 1.0 m. The channel has a constant downward slope at the bottom just under 2% (0.017857 % = 1:56) all along its length starting at the upstream side, 400 m from the Doce river where the channel bottom is at El. 81.0, and ending at the end of the excavations 6,200 m downstream.

Surface treatments of the excavated channel walls were:

• Soil slopes: 0.50 m graded transition overlayed with 1.50 m of rockfill up to El. 93.0; higher up - protection is with a finer grade of rockfill.

• Anchored gunite with simple reinforcement in residual soil/saprolite

• Anchored gunite with double reinforcement in decomposed or very fractured rock

• Gunite treated slopes with emerging water to be drained by 1½" x 0.30 m holes in 3 x 3 m grid net.

• Large unstable rock wedges were to have a specific anchor design.

To be able to cross the channel and have access to the dam and the island that was formed by the reservoir and the channel in the area of the Lorena Rock, two bridges were built, one at the upstream end, 300 m from the Doce river and the channel mouth, and the other half way to the powerhouse and 5,080 m, from the first bridge.

A 3 m high underwater dike was built across the channel mouth with a crest at El.84.0 so that silt from the Doce river would not spill into the intake channel. One of the reasons for the location of the spillway on the left bank, near the mouth of the intake channel, was that its operation would help clear silting up to the channel entrance; later studies confirmed that even during the dry season this is possible with a minimum discharge of 1,500 m^3/s through the spillway.

The Table 2 shows the head losses in the intake channel:

Head Losses in the Intake Channel (m)			
Generator Units In Operation	Channel Flow Per Unit (m^3/s)	Head Loss with Reservoir at El. 90.0	Head Loss with Reservoir at El. 89.0
0.50	237.5	0.03	0.04
1.00	475	0.10	0.15
1.26	600	0.17	0.25
1.68	800	0.31	0.46
2.00	950	0.45	0.68
2.32	1,100	0.62	0.98
2.74	1,300	0.93	1.51
3.00	1,425	1.18	1.97

Table 2 - Head losses in the intake channel

Studies showed that the maximum head loss with all three units under full load is 1.18 m which was considered small considering the overall channel length of 12 km. With the reservoir decreasing 1.0 m, the head losses rise to 1.97 m which was still acceptable. Average flow speeds along the channel reach a maximum of 1.8 m/s in the smaller sections that were excavated in rock at the normal reservoir level of 90.0 and rise to over 2.0 m/s in the critical sections with the reservoir at El. 89.0.

This 1.0 m reservoir drawdown can become convenient or necessary to reduce flood water levels at the upstream town of Resplendor 27 km from the dam, or even to increase flow velocity along the reservoir to mitigate silting.

4.5. Intake and Powerhouse Structure

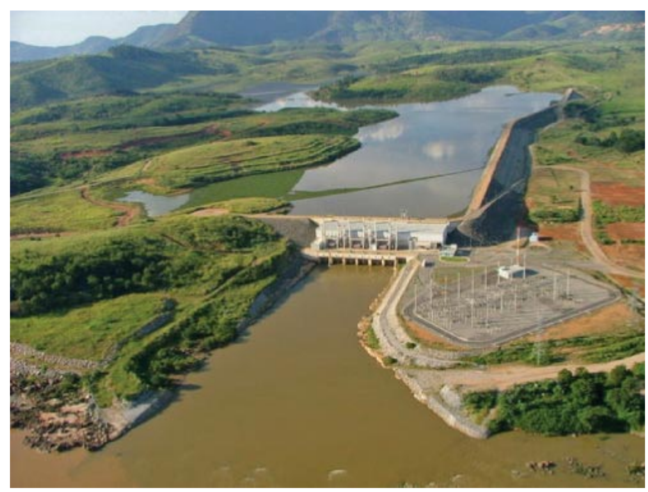


Photo 6 - The Intake/Powerhouse and Auxiliary Dam

The intake/powerhouse structure is an indoor design with a total length of 115.45 m and includes three unit blocks of 25,65 m each, and two erection/service bays: 20.5 and 18.0 m (see Photo 6). On the left side it joins with the auxiliary dam and on the right side with the right wing dam (Figure 6, 7 and 8). It is equipped with three generating units, rated at 110 MW each. The turbines are of the Kaplan type and operate between net heads of 18.75 m and 29.35 m. The emergency hydraulic operated wheel gates are located at the downstream end of the draft tubes and at the intake there are vertical slots for stoplogs for maintenance of the upstream end of the hydraulic circuit.

The crest of the intake part of the power structure is at El. 93.0 and is a conventional low head design with two columns that divide the water passage into three sluiceways 5.5 x 13.95 m. The stoplog sills in the sluiceways are at El 50.82 and there are removable trashracks on the upstream side. Four storage slots were built into the service bay blocks for storage of the stoplog sections when not in use. There is a 150 kN gantry crane on the crest for operating the stoplogs and removing the trash racks for maintenance. On the crest at El. 92.5 a road provides access between the auxiliary dam and the right wing dam.

The intake/powerhouse block is 61.0 m high above the foundation and 64.3 m long between the upstream intake and the draft tube (Figure 8). There is a 2.5 x 3.0 m drainage gallery at the upstream side under the intake at El. 49.0 where the grout and drainage curtains were drilled. The generator floor in the powerhouse is at El. 64.3 and is 18.76 m wide and 22.7 m high up to the roof. The overhead travelling crane is 16.7 m above the floor at El. 81.0, spans 18.1 m and is rated at 3,200 kN and 300 kN for the main and auxiliary hooks. The electrical gallery is located next to the downstream side of the generator room and the mechanical gallery is on the floor below at El. 56.0.

The draft tube of each unit is divided by a 2.0 m vertical column where two 10.52 wide openings have slots for the emergency wheeled gates. For maintenance a 1,000 kN gantry crane travels between the units on 7.5 m rail centers at El. 73.0 above the draft tube.

In order to join the power structure with the earth dams on both sides, concrete walls were built on either side of the intake as abutments for the dam cores. On the right side the wall has a rectangular base 23 m wide angled 30º upstream and 20 m long; the height of the wall reaches up to the road at El. 93.0. The right wall is 30 m long, tapered from 25 to 15 m at the base and the end faces 15º upstream and also reaches the crest.

On the right and protruding out of the side of Unit 3 powerhouse are located the three pump sumps, 5.8 m square; two are the draft tube dewatering sumps and one the plant drainage sump, furthest downstream, with bottoms at El. 27.0 and 34.0; the sump pump room is at El. 58.0. The upper projections of the sumps were incorporated into space in the generator hall.

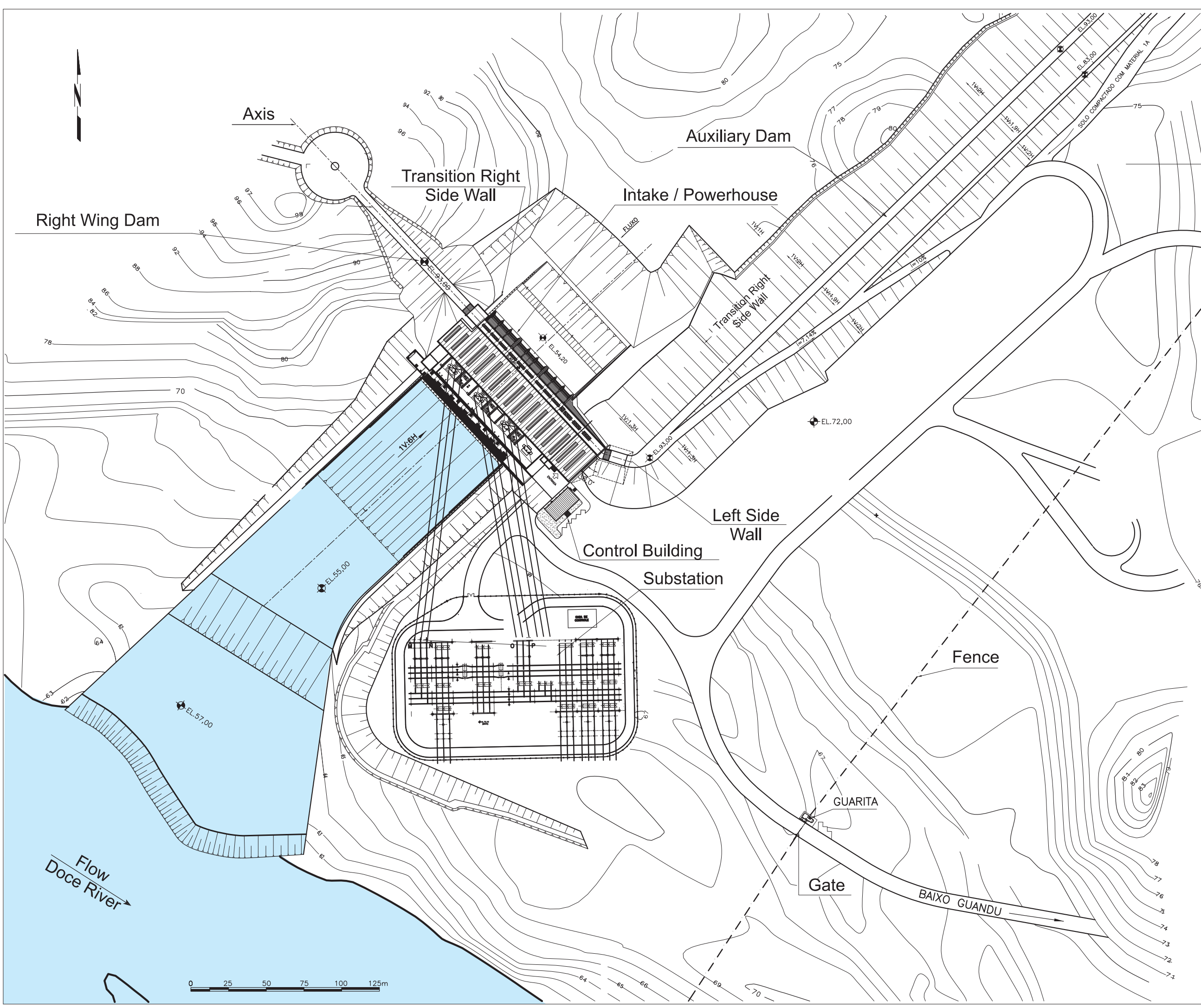


Figure 6 - Intake/Powerhouse - Plan

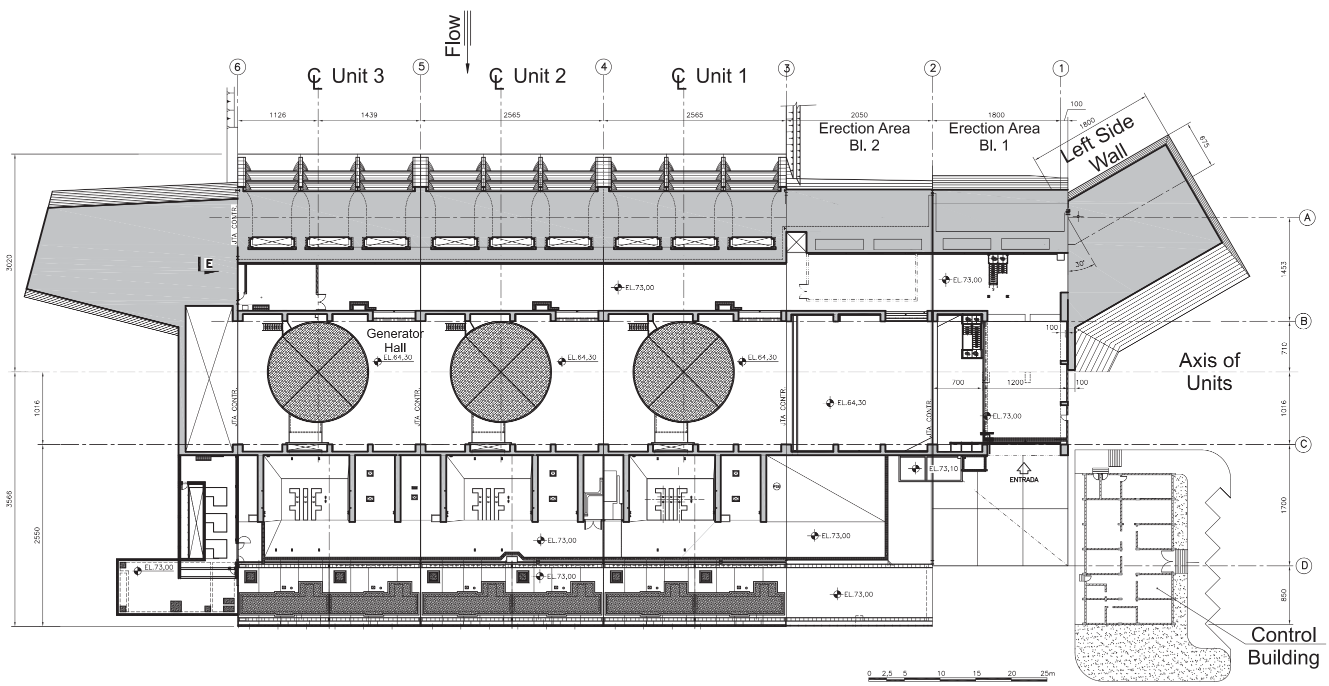


Figure 7 - Powerhouse - Plan

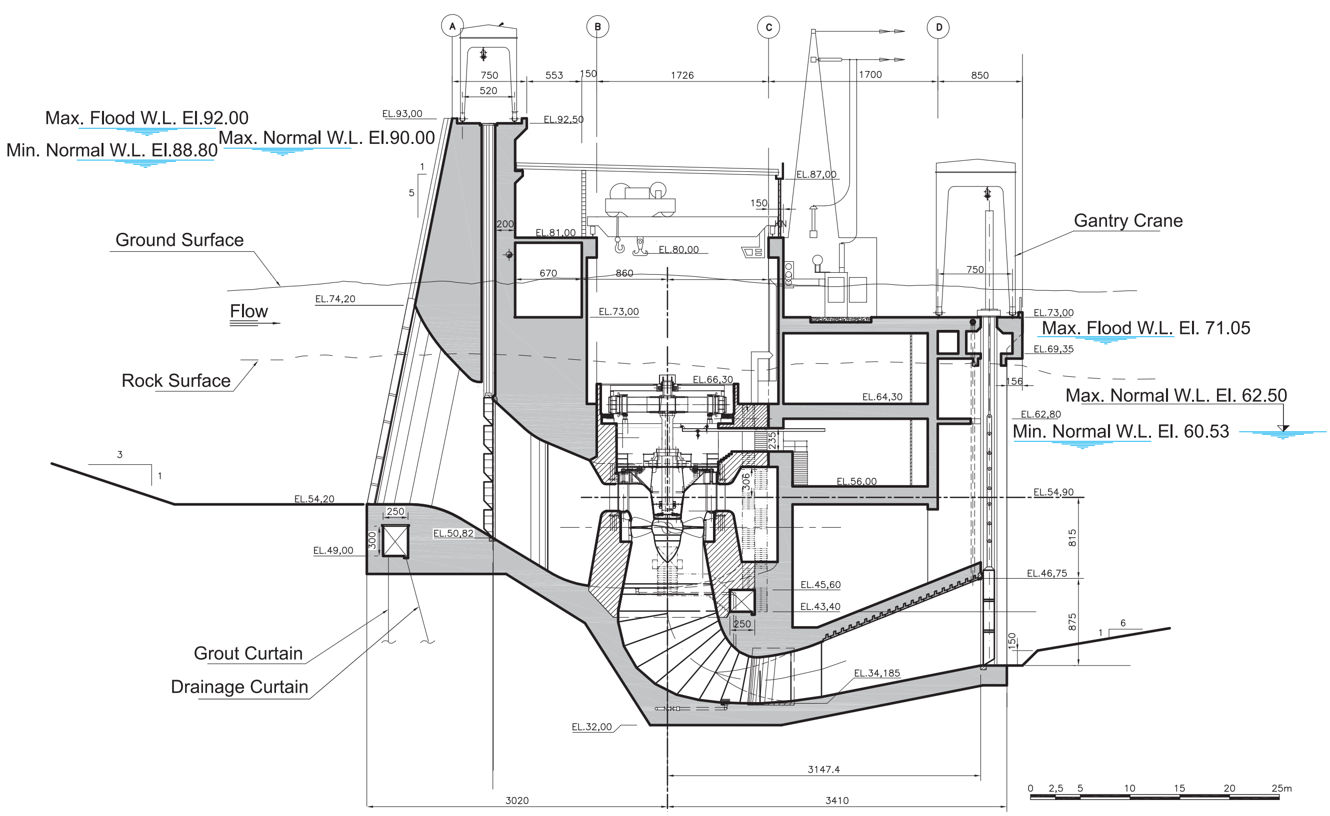


Figure 8 - Intake/Powerhouse - Generation Circuit

4.6. Tailrace

The tailrace starts at the end of the powerhouse draft tubes and goes all the way to the Doce riverbed. The channel is 77.0 m wide and is about 200 m long (see Photo 7). It was excavated in soil and rock with side slopes of 1.0V:2,0H and 10.0V:1.0H.; the soil slopes were protected with 1.5 m of rip-rap and a 0.5 m transition to contain soil particles.

The channel excavations are in three sections, starting at the end of the draft tube at El. 39.5 and proceeding roughly 90 m with an upward slope of 1.0V:6.0H until reaching a flat horizontal section at El. 55.0 for a distance

Photo 7 - Tailrace Channel with Powerhouse on the Background

of another 90 m. The end section is about 20 m long and slopes upward at a small angle of 1.0V:10.0H. This last section is angled 15º towards the river flow.

4.7. Auxiliary and Right Wing Dam

The auxiliary dam is located on the left side of the intake structure and is part of the left bank of the intake channel where it ends at the power structure (Figure 6). It is a rockfill dam with an earth compacted core and transitions of sand and compacted crushed rock. The sand was excavated from the river bed and the graded rock was obtained from the plant crushers. The crest is at El. 93.0, 6.0 m wide, 1015 m long and the maximum height above the foundation is 25.0 m. The upstream slope is 1.0V: 1.6H and the downstream is 1.0V: 1.5H.

The right wing dam is located on the right side of the intake structure and joins the concrete wall from the foundation up to the crest where it is 10 m wide for the access roadway between the right bank and the powerhouse. It is a composite structure with one section of homogeneous compacted earthfill 61.0 m long, and a second section of rockfill with an earth core and 35.0 m long. Upstream and downstream slopes are the same, and the earthfill slopes are 1V:2H and the rockfill ones are 1V:1,6H.

4.8. Dikes

To close three topographical saddles that were below the reservoir level, three dikes numbered 1 to 3 were built, some distance from the intake structure. Dike 1 is actually an extension of the auxiliary dam on the left bank, and has the same section, made of rockfill with an earth core, 276 m long, 19 m above the foundation; the upstream slope is 1V:1.6H and 1V:1.5H on the downstream side; the crest is at El. 93 and is 6 m wide.

Dikes 2 and 3 close two small saddles on the right bank of the intake structure. They are homogeneous earth dams with L shaped filters/drains, each 112 and 130 m long and 10 and 8 m high. There is an access road to these dikes from the power structure and right wing dam.

4.9. Switchyard

The switchyard is a conventional 230 KV station on a plateau on the left bank of the discharge channel. The 159 x 104 m area was excavated and planed for construction of the yard. Three lines come from the powerhouse transformers of each generator unit to the switchyard, and there are two lines that connect to CEMIG's transmission line and Aimorés' switchyard and the other connects to ESCELSA's transmission line and to Mascarenhas Powerplant in the nearby State of Espírito Santo.

4.10. Fish Ladder

As prescribed by the Brazilian federal environmental agency IBAMA, Aimorés Hydroelectric Powerplant was obliged to release 16 m^3/s so that the downstream quality of water between the main dam and the dike below the Manhuaçu river would improve.

Based on this premise, the fish ladder design was elaborated considering the 16 m^3/s flow going through a 2,000 mm pipe between the stoplog storage shaft and the spillway. Another auxiliary 1,200 mm pipe for a 3 m^3/s flow was installed downstream from the channel outlet, to guarantee an "attractive flow velocity", even with variations of reservoir levels. The ladder channel was designed for flows between 0.5 and 1.5 m^3/s and the vertical slot type was chosen which is the same used at the Igarapava dam. There are 60 steps, 2.60 x 3.00 m wide, a 10 % slope with two resting tanks between three ladder sections.

4.11. Sociological - Environmental Issues

Environmental Impact Studies and the final Environmental Impact Report (EIA-RIMA) were issued to the State Environmental Agency (FEAM) according to the ongoing procedures to obtain the Preliminary License (LP). These studies were made between December 1996 and February 1998, considering the reservoir level at El.88.0. The studies were carried out by a group of multi-disciplinary professionals and were supported by Federal and State Legislations. The studies included physical, biotical, socio-economical and cultural studies of the development area.

The raising of 2.0 m in the reservoir level to El. 90.0 required specific studies to evaluate the environmental impact around the reservoir. As the seats of the municipalities of Ituêta, and part of Resplendor already had to be relocated at the lower reservoir level, the impact of the higher level was considerably less than it could have been. These studies also showed that there was little impact on the railway sections that already had to be displaced or on the reduced river flow below the main dam. The conclusions were that the main impact would be in the rural area with little effect on the physical or biotical features.

In July 2008 the State Department brokered an agreement between the owners and the Consortium that runs the Aimorés powerplant, and ended a public demand of compensation for the original indigenous Krenak people. The indians composed of 100 families live in the rural area of the municipality of Resplendor, in the reservoir area, and were not consulted or consented about the construction - and in fact not really knew there would be a hydroelectric development.

The value to be paid out is nearly R$ 12 million (US$ 7.5 million) which will be used in projects to help the families and protect 54 stream springs that are located in the Krenak area. The consortium is to spend R$ 4 million more in other projects for the Indian's development.

5. TECHNICAL FEATURES

HYDROMETEOROLOGICAL DATA

Catchment Area of the Reservoir	62,167 km^2
Peak Inflow (Feb/79); 1931-1994 Period	4,284 m^3/s
Reservoir Mean Yearly Rainfall	1,163 mm
Minimum Inflow (Oct/56)	162 m^3/s
Reservoir Mean Yearly Evaporation	1,224 mm
Design Flood (TR:10.000 Years)	15,000 m^3/s
Long Term Mean Flow (1931 To 1996)	770 m^3/s
Probable Maximum Flood (PMF)	16,800 m^3/s
Firm Flow - 95% of the time	292 m^3/s
River Diversion Flow (Tr: 25 Years)	6.524 m^3/s

Reservoir

Area at W.L. 90.00	30.9 km^2
Area at W.L. 92.00	36.6 km^2
Length	90 km
Total storage at W.L.90. 00	184.6 x 10^6 m^3
Maximum normal level	90.0 m
Maximum flood level	92.0 m
Average depth	5.0 m
Maximum depth	16.0 m

Tailwater

Maximum flood level	71.05 m
Normal level	62.50 m
Minimum exceptional level	60.53 m

Power Generation

Installed capacity	330 MW
Firm energy	191,6 MW
Turbine Rated Head	25,8 m
Turbine Design Head	26.9 m

Main Dam

Type	Earthfill
Length	565.0 m
Height	18 m
Crest Elevation	93.0 m
Compacted fill	272,093 m^3
Rockfill	39,791 m^3
Upstream slope	1V : 2.5H
Downstream slope	1V : 2.5H

Spillway

Length	168.0 m
Gate type and operation	Radial - Hydraulic
Size and number	13.5x15.3 m 10 un.
Design flood (10,000 years)	15,000 m^3/s
Intake	
Length	76.95 m
Gate type and sections/sluiceway	Stoplogs - 5
Number: 1 Intake (3 sluiceways x 5)	15
Size: (5.5 x 3.06 m)	3 sets of 2 = 6 un
Gantry crane capacity	150 kN

Powerhouse

Type	Indoor
Length	116.45 m
One - Overhead travelling crane	3,500/300 kN
Emergency gate type and operation	Wheel - Servo
Location	Draft Tube
Size and number(2 x 3 blocks)	10.5x5.78m 6 un
Draft tube gantry crane	1000 kN

Turbine

Type	Kaplan
Rated capacity	110 MW
Rated head	25,8 m
Operating speed	105. rpm
Rated Flow	475 m^3/s

Generator

Type	Vertical axis
Rated capacity	115 MVA
Voltage	14.4 kV
Frequency	60 Hz
Rotor diameter	9,610 mm