DAMS
AND HYDROPOWER
Over the past 70 years, Artelia has been committed to the construction of water and energy infrastructure projects, in France and around the world, that promote regional development and contribute to meeting the basic needs of the population.

To this end, different types of services, from preliminary studies through to the supervision of construction works, are provided by our specialists, not just for dams and hydropower schemes, but also for water conveyance and power transmission structures.

Historically, Artelia has always had the capacity to combine the necessary expertise and technical resources to design and build structures that blend in with their natural and human environment.

Our environmentalists, civil engineers, geologists and geotechnical engineers, hydrologists and hydraulic engineers, mechanical and electrical engineers and contract experts are called upon to provide their know-how for a wide variety of projects, some of which can be on such a gigantic scale that they will shape the future for generations to come.

This photo book presents forty-or-so projects recently completed under the supervision of our teams. These projects would never have come to fruition without the development inspiration of our clients, to satisfy the multiple needs of mankind, and above all without the faith that they have placed in our capacity to accompany them in each of these true adventures.

We should like to take this opportunity to express our warmest thanks to our clients and also to acknowledge the valuable contribution made by the many partners who collaborated with us on certain projects.

From America to Asia, through Africa, we hope you will enjoy the round-the-world journey described in these pages, covering projects implemented over the past decade in which Artelia’s teams have been proud to make their contribution.

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Construction of a concrete dam and a 180 MW hydropower plant. Located in Loja Province in southern Ecuador, this project contributes to the overall development of the country by improving its energy independence and by diversifying its resources.

**DELSITANISAGUA**

- 35 m high, 200 m long concrete dam comprising a gated flood spillway (discharge = 1600 m³/s)
- Bottom outlet (5 m x 5 m gates)
- 20 m high water intake (capacity = 42 m³/s)
- 10 km long headrace tunnel with a surge tank
- 180 MW power plant (three 60 MW Pelton units).
La Sarcelle low-head hydropower scheme is part of the James Bay development programme and is one of the components of the Eastmain 1-A Rupert project (Quebec Province).

150 MW hydropower plant
(three 50 MW bulb units)
Headrace channel: deep channel excavated in the Opinaca reservoir
1 km long outlet channel into lake Boyd.
Construction of a new dam designed to supply drinking water to the town of Saint-Pierre.

10 m high, 180 long conventional concrete dam.

Downstream fill for thermal protection and landscaping integration purposes.

Pumping station between the Goeland and Vigie reservoirs.

Supervision of reservoir filling operations.

6000 inhabitants concerned.
Raising the height of the sill at the Saut Maman Valentin low-head hydropower plant on the river Mana, located in the heart of the Amazon Forest. Artemis provided design and works supervision services on site in the context of the project to raise the height of the existing weir and the fish pass and the dugout canoe pass in order to ensure unhindered passage for the population.

<table>
<thead>
<tr>
<th>Item</th>
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<tr>
<td>Raising the height of the sill by 1.11 m</td>
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<tr>
<td>Raising the height and reinforcement on the downstream side of the sill</td>
<td>h = 5.20 m / l = 200 m</td>
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<td>Extension of the fish pass: 9 new basins</td>
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<td>Raising the height of the protection embankments</td>
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<td>Raising the height of the power plant sealing system</td>
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</table>
Rehabilitation of a weir and construction of a low-head hydropower scheme (replacing a hydropower plant built in 1927) in Felou, on the left bank of the river Senegal, benefiting from the controlled flow rate obtained thanks to Manantali dam. The power generated has a low cost and does not have any environmental impact because the diversion weir used to feed the headrace already exists.
Rehabilitation of the Sélingué hydropower plant located in the Sikasso region, 140 km from Bamako and in the vicinity of the Guinean border, on the river Sankarani (a tributary of the river Niger).
SOTUBA

Rehabilitation of the Sotuba hydropower plant located on the river Niger, 5 km from the centre of Bamako.

Dam consisting of two 1800 m wide weir-type structures
Run-of-the-river hydropower plant fed by a 1984 m long headrace channel
Two 2.5 MW vertical Kaplan-type turbines, 3.4 MVA generators
Two 3.4 MVA transformers – 2 kV / 30 kV.
Reconstruction of a new gated-structure navigation dam with flap gates designed to replace the existing dam with Aubert shutters, on the river Seine, upstream of Paris, in the Essonne department.

Two navigable channels equipped with 32 m wide, 6 m high gates.
A small channel equipped with a 13 m wide, 6 m high gate
Floating maintenance stoplogs
Control room
Fish pass
Footbridge.
COUDRAY: positioning of flap gates
Dry reconstruction of a gated-structure dam on the river Seine, upstream of Paris, without interrupting navigation. Vives-Eaux dam was initially built in 1928. It is used to regulate the river level upstream and downstream of the structure to allow navigation on the river thanks to a head of 2.70 m. Combined with a lock on the left bank, which allows ships to pass through, the dam becomes completely invisible during flood periods.

Construction of three 30.20 wide, 4.40 high bays equipped with flap gates

Fish pass with 12 successive basins

Control room

Footbridge open to the public

Jetty and maintenance stoplogs.
Rehabilitation of a dam that was built in 1981, originally designed to supply fire-fighting water and for tourist activities. The ultimate objective for the Owner is to use the reservoir water for additional drinking water supplies.

Regauging of the flood spillway: design floods from 80 to 240 m³/s
Earthworks representing 50,000 m³ of material to be excavated
Construction of a reinforced-concrete weir: L = 44.4 m – H = 2 m
630 m³ of concrete placed during the works
Reconstruction of the bottom outlet: maximum capacity: 2 m³/s
Construction of an outlet tower at the upstream toe of the dam, which houses two bottom outlet gates
Access from the bank via a walkway.
Restoration of the historic hydropower functions of a listed building: design and construction of a hydropower plant next to a former water mill (“Moulin Saulnier”), which used to have hydropower functions and is now listed as a national heritage site. Search for a low-profile solution allowing the seamless integration of the structure at this historic monument, which is also a workplace for several thousand employees, as it houses the Nestlé France headquarters.

400 kW low-head hydropower plant
Average yearly power generation: 2300 MWh, i.e. 25% of the site power consumption
Located next to the “Moulin Saulnier” water mill, a listed historic monument.
Reinforced concrete sluice.
ROANNE

Construction of a low-head hydropower plant.

Three Kaplan turbines
Each turbine has a capacity of 833 kW
Total capacity of the plant: 2500 kW
Head: 2.70 m.

NEUVILLE-SUR-AIN

Rehabilitation of the hydropower plant.

Replacement of two old units with a single more efficient unit
Integration of the new equipment in an old building without modifying the external envelope
Capacity: 1360 kW.
Construction of a new high-head hydropower plant called “Frédet-Bergès» to replace three of the oldest hydropower plants in France, originally built by Messrs Frédet and Bergès, who were pioneers in the field of hydropower.

Discharge: 1.3 m³/s; head: 330 m
Single, buried 800 mm diameter, 2800 m long penstock
Total head = 336.51 m
Plant equipped with a vertical axis Pelton unit with an installed capacity of 3.5 MW.
The tailrace of the plant discharges into the underground channelled part of the stream in Laval.
VERUT

Built in 1891 to create a drinking water reservoir for the village of Saint-Galmier in the Loire department, this arch-gravity dam required rehabilitation works: regauging of the flood spillway, construction of a stilling basin, creation of a downstream consolidation embankment made of compacted rockfill, and replacement of some of the electromechanical equipment.

RIZZANESE

Working design study for the latest major dam in France, expert appraisal concerning sediment transport, study of the hydromechanical equipment for the temporary diversion equipped with a sediment flushing gate.

RCC gravity dam (concrete volume: 75,000 m³)
- Maximum height: 60 m
- Crest length: 140 m
- Reservoir capacity: 1.2 Mm³
- 6 km long, 4 m diameter headrace tunnel
- Hydropower plant: 2 x 26 MW (two Pelton units)
- Flood spillway: three 17 m long sluiceways with fixed overspill sills
- 5 m diameter diversion tunnel equipped with a sediment transport gate
- 1.8 m diameter mid-level steel-lined outlet passing through the dam
- Water intake tower (h = 30 m) with a design discharge of 15 m³/s.
The Charleville-Mézières urban area is highly prone to river Meuse floods. Works were carried out in 1995 but they were insufficient. A flood protection and management strategy covering the French part of the Meuse river basin was drawn up, in coordination with the authorities responsible for the area downstream.

Development study involving nine sites: enlarging the flap gates on three diversion channels (including one at a hydropower plant site), dry cutoff, flow-channel regauging under three bridges, elimination of an embanked area in the high-water bed, improvement of a tributary outlet.

Flap gates: 10, 15 and 20 m wide, 3 and 2 m heads
Operating devices: hydraulic cylinders
Total volume of earthworks: about 100,000 m³
Use of the river to evacuate excavation material.
In north-east Tunisia, in a challenging geotechnical environment, construction of an earthfill dam and its ancillary structures (water intake tower, culvert under the fill, flood spillway, outfall structures) designed to create water reservoirs and transfer structures for irrigation and drinking water supply purposes towards less irrigated areas in Tunisia.

**DOUIMIS**

Homogeneous earthfill dam
- Maximum height above ground: 50 m
- Crest length: 487 m
- Fill volume: 3 Mm³
- Reservoir volume: 46 Mm³

Free-surface flood spillway:
- Length of overflow sill: 10 m
- Maximum flow rate: 128 m³/s

Water intake/bottom outlet:
- Multi-stage water intake tower (three intake levels including one for the bottom outlet); water removal through a 320 m long culvert under the dam, also used as a temporary diversion (water outflow rate = 103 m³/s when used as diversion, 12 m³/s for controlled water releases)

Transfer:
- 1.4 m diameter, 5 km long pipe.
This dam is a flood control and aquifer recharge structure located on the wadi Sficifa, 13 km upstream of the town of Sbeitla. The aim of the scheme is to store flood inflows temporarily with a view to final reinfiltration into the Sbeitla aquifer.

**SFICIFA**

- 31 m high, 640 m long earthfill dam with impervious core
- 240 m long secondary embankment
- Free-surface lateral spillway with a capacity of 1200 m³/s.
- Diversion, transfer and bottom outlet structure comprising: a 25 m high intake and outlet tower, a 125 m long reinforced concrete culvert with a cross-section of 3.00 x 3.50 m, and an outlet structure.
The aim of the Kebir scheme is to create a reservoir to enable water to be transferred to Sidi El Barrak reservoir. The dam is situated near the town of Tabarka. Kebir is 8 km to the south of the town on the wadi Kebir.

Zoned earthfill (alluvium) dam with impervious core
Maximum height above foundations: 80 m
Crest length: 560 m
Fill volume: 3.65 Mm³
Volume of the reservoir at full supply level: 64.4 Mm³
Diversions structure, water intake, bottom outlet, flood spillway: 80 m high water intake tower used as a water intake and flood spillway (morning glory spillway with a discharge capacity of 300 m³/s), 350 m long, 7.00 m diameter tunnel, outlet structure.
35 km long, 1.4 m diameter water transfer pipelines with a pumping station.

Début du chantier en 2006
MELAH

In north-east Tunisia, construction of an earthfill dam and its ancillary structures, in order to create a water reservoir and transfer structures for irrigation and drinking water supply purposes towards less irrigated areas in Tunisia.

Earthfill dam with impervious core
- Maximum height above ground: 50 m
- Crest length: 260 m
- Fill volume: 1.3 Mm³
- Reservoir volume: 41 Mm³.

Ancillary structures:
- Water intake tower
- Culvert under the fill
- Flood spillway
- Transfer pipes.
In order to allow the Inga hydropower scheme, located on the river Congo, 200 km south-west of Kinshasa, to operate at full capacity (1630 MW in total), a new water intake needed to be constructed and an additional headrace excavated.

**INGA 1 & 2**

In order to allow the Inga hydropower scheme, located on the river Congo, 200 km south-west of Kinshasa, to operate at full capacity (1630 MW in total), a new water intake needed to be constructed and an additional headrace excavated.

<table>
<thead>
<tr>
<th>Excavation of an additional headrace canal parallel to the existing headrace</th>
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<tbody>
<tr>
<td>Length: 1200 m</td>
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<td>Height: 25 m</td>
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<td>Width: 30 m</td>
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<td>Discharge: 3340 m³/s</td>
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<td>Cofferdams built in the river Congo</td>
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<td>Reinforced concrete bridge with three spans</td>
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<td>Underwater rock removal works</td>
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<td>Grout curtain to improve watertightness</td>
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</table>

The two hydropower plants will continue to operate throughout the works:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Turbines</th>
<th>Discharge</th>
<th>Height</th>
<th>Capacity</th>
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<tbody>
<tr>
<td>Inga I</td>
<td>6</td>
<td>780 m³/s</td>
<td>50 m</td>
<td>330 MW</td>
</tr>
<tr>
<td>Inga II</td>
<td>8</td>
<td>2560 m³/s</td>
<td>56 m</td>
<td>1300 MW</td>
</tr>
</tbody>
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RÉPUBLIQUE DÉMOCRATIQUE DU CONGO

INGA 1 & 2
Cross-border hydropower project: located on the border between Rwanda and Tanzania, the scheme also provides electricity to Burundi, which is involved in the project.
12 m high, 200 m long concrete dam equipped with radial gates
11 m wide, 14 m high, 700 m long water intake and headrace tunnel
with a support system made of shotcrete and anchor bolts
Hydropower plant with three vertical Kaplan turbines (3 x 27.2 MW)
250 m long, 40 m wide tailrace
220 kV substation.
The earthfill dam designed for irrigation will be 40 m high and 150 m long. Initially, it will have a storage capacity of 5.6 million m$^3$. The design takes into account the possibility of raising the height of the dam by 20 m in order to increase its storage capacity to 31.5 million m$^3$. 

**BWANJE**

Storage capacity: 5.6 Mm$^3$ (phase 1) / 31.5 Mm$^3$ (phase 2)  
Maximum dam height: 40.1 m (phase 1) / 60 m (phase 2)  
Crest length: 150 m  
Crest width: 8.0 m
Construction of a new dam on the river Nile downstream of the existing dam in the city of Assiut, comprising a hydropower plant and two navigation locks. Rehabilitation of the Ibrahima canal head regulator built in 1902 for irrigation.

Flood spillway with eight 17 m wide bays equipped with radial gates.
Low-head hydropower plant with four bulb units and a total installed capacity of 43.2 MW.
Two 120 x 17 m navigation locks and renovation of the existing 80 x 16 m lock.
Replacement and rehabilitation of the Ibrahima canal head regulator.
Closure dam and road bridge.
The Naga Hammadi project is a multipurpose scheme (irrigation, navigation and energy production) located on the river Nile, 360 km downstream of Aswan dam. The project involves, in particular, the construction of a new dam 3.5 km downstream of the existing barrage that was built in 1927, comprising a low-head hydropower plant and two navigation locks.
Flood spillway with seven 17 m wide bays equipped with 13.5 m high radial gates with hinged flaps (design capacity: 5700 m³/s, emergency flood discharge: 7000 m³/s)
Closure dam made of rockfill and sandfill with a central diaphragm wall. Maximum height: 17 m, crest length: 200 m
Hydropower plant with four bulb units and a total installed capacity of 64 MW, with a head ranging from 2.4 to 8 m, for a total flow rate of 1280 m³/s.
Two 170 m x 17 m navigation locks (Lock No. 1 with two mitre gates, Lock No. 2 with a downstream sector gate and a mitre gate also used as an emergency spillway.
This pumped-storage hydropower scheme is a new-generation hydropower plant designed to store intermittent renewable energy sources (photovoltaic and wind power) and to stabilise the power distribution network.

Upstream and downstream man-made reservoirs with a capacity of 2.4 Mm³
High-pressure vertical shaft (h = 500 m – diameter: 4.5 m) and high-pressure horizontal tunnel (L = 950 m – diameter: 4 m)
Underground power plant with a capacity of 2 x 150 MW
Surge shafts (h = 10 m – diameter: 5 m and h = 76 m – diameter: 10 m)
Low-pressure tunnel (L = 1400 m – diameter: 4.5 m, of which 300 m excavated in clay)
The Janneh site forms one of the only geographical locations along the river Nahr Ibrahim (the third largest water resource in Lebanon) where considerable quantities of water can be stored (38 Mm³). The reservoir and dam are also used for the following purposes:
- Production of electricity by exploiting a head of over 300 m (100 MW),
- Water supply to the coastal areas of Jubail and Keserwan Caza and the northern districts of Beirut,
- Supply of new irrigation areas downstream.

RCC dam of the following dimensions:
- 165 m height above the foundations
- 345 m crest length
The dam is equipped with a surface spillway (2830 m³/s capacity), an intake tower for water supplies (0.5 m³/s) and an intake for the hydropower plant (32 m³/s).
This project is designed to make up for shortage of drinking water in the upper Batroun District and to use the remaining static storage to compensate for the shortage of irrigation water. Given that the Balaa reservoir and dam site are located in a karstic zone, watertightness was achieved by placing a bituminous concrete membrane.

Rockfill dam with a bituminous concrete upstream facing
Maximum height above ground: 45 m
Crest length: 499 m
Normal reservoir capacity: 1.5 Mm³
Rockfill volume: 470,000 m³
Flood spillway capacity: 80 m³/s.
The project involves the construction of a storage dam with a capacity of 30 million m³ in a secondary valley, on the Vedi and Khosrov rivers, to provide gravity irrigation for approximately 3200 hectares of land in the fertile Ararat Plain. The project’s ultimate aim is to contribute to the sustainability of irrigated agriculture in the Ararat Plain. The zone is earthquake prone and the dam is built partly on a thick layer of alluvium.

85 m high rockfill dam with a clay core
14.3 m high secondary dam
Reservoir storage capacity: 29.4 Mm³
11.5 km long fiberglass-reinforced polyester pipe network (discharge: 5 m³/s).
The town of Sur, situated in an area with a desert climate (80 mm of rainfall per year on average) was severely affected by two cyclones in 2007 and 2010, receiving more than 400 mm of rain in 24 hours.

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**NEW FULAIJ**

Barrage en enrochements avec noyau en asphalts (H = 26,50 m ; L = 1 100 m)
Evacuateur de crues en béton (H = 30 m ; L = 140 m)
4 grandes vannes de dévaseement (4,60 m x 3,60 m) et une prise d’eau
Canalisation du lit principal du cours d’eau (excavation, protection, digues) sur un tronçon de 9 km, soit 3 000 000 m³ de terrassements.
Construction of an aquifer recharge dam on Wadi Um ti, in the Wilayat of Izki, using an innovative material: hardfill. This mix consists of only 60 kg/m³ of cement and aggregates taken from the bed of the Wadi. In similar fashion to Roller Compacted Concrete (RCC), 30 to 40 cm thick layers are placed using conventional construction machines (bulldozer, grader), which are then compacted using a vibrating roller.

Gravity fill dam
Height: 23 m
Slope: 0.7 h / 1 v
Dam body hardfill volume: 38,000 m³
Crest elevation: 647 m
Full supply level: 641 m

Reservoir volume: 610,000 m³
Spillway width: 100 m
Skilling basin length: 19 m
Dam design flood: 2700 m³/s
Spillway design flood: 1660 m³/s.

WADI UMTI
The Al Amerat dam is one of the seven dams built to protect capital city Muscat from floods on Wadi Aday. The ambitious objective is to store flood volumes generated by 500-year floods.

AL AMERAT HEIGHTS DAM (B15)

Earthfill dam with a plastic concrete core
Length: 5 km
Height: 22 m
V = 22 x 106 m³.
AL AMERAT HEIGHTS DAM (B15)

OMAN
The tailings dams at the Ambatovy mining facility in Madagascar are designed to store mining sediments in order to protect the downstream environment. In total, seven earthfill dams are planned at the open-air mining facility, including the Analamay South dam, which is under construction.

Lateritic fill dam with drainage shafts and blankets
Maximum height above ground: 34 m
Crest length: 106 m
Fill volume: 450,000 m³
Excavated material volume: 300,000 m³
Gabion spillway with a capacity of 60 m³/s.
Dam designed to create a 14 Mm³ reservoir with a view to improving the reliability of water supply to the city of Port Louis and neighbouring areas for the next 50 years.

2.5 km long dam with a diaphragm wall in the foundations:
- Earthfill section (clay core and random fill) for the low section of the dam (H: 30 m approx.) located on both banks
- Rockfill section with central clay core (H: 47 m approx.) in the central part of the dam
- Concrete tower integrating all appurtenant structures such as the intake, the bottom outlet and a morning glory spillway (capacity 450 m³/s) with a gallery under the rockfill dam
- Water transfer from the Cascade River including:
  - diversion weir in the river cascade
  - 2 km culvert with aqueducts.
Artelia (Sogreah) was previously the Owner’s Engineer for the Nam Leuk hydropower scheme, located in a mountainous region 130 km north of Ventiane. The dam height was subsequently raised by installing fusegates on the flood spillways.

NAM LEUK

50 m high rockfill dam with an RCC spillway
3 km long tunnel and penstock, 60 MW power plant (two Francis units), 110 kV transmission line.
Adaptation of the main flood spillway and installation of 12 straight-crest fusegates (H = 1.10 m, L = 5 m) fed by stainless steel water supply shafts.
Demolition of the secondary flood spillway and construction of a new spillway involving the installation of 20 labyrinth-crest fusegates (H = 2.40 m, L = 3.75 m) fed by protected water supply shafts installed in a water intake tower.

NAM MANG III

Works to raise the height of the dam by installing fusegates on the main flood spillway. Artelia (Sogreah) had previously worked as Owner’s Engineer.

30 m high RCC dam and 20 m high earthfill dam
1 km long tunnel and penstock, 35 MW hydropower plant (Pelton unit), 110 kV transmission line.
Adaptation of the main flood spillway and installation of 24 labyrinth-crest fusegates (H = 1 m, L = 2 m) fed by stainless steel water supply shafts.

LAOS
Located on the river Nam Ngum (a tributary of the river Mekong), 265 km North of Vientiane, the Nam Ngum III and IV hydropower schemes are part of major programme comprising fifty other projects designed to provide electricity for the entire country and thus support its economic development.

**Nam Ngum III**
- 210 m high concrete face rockfill dam (CFRD)
- Crest length: 730 m
- Reservoir capacity: approximately 1.4 billion m³
- Tunnel: 11 km long and 7.6 m diameter
- Installed capacity (three 160 MW Francis units): 480 MW
- Average annual capacity: 2345 GWh
- 130 km of 230 kV transmission lines.

**Nam Ngum IV**
- 74 m high concrete gravity dam
- Crest length: 252 m
- Reservoir capacity: 110 Mm³
- Tunnel: 17 km long and 8 m diameter
- Installed capacity (three 80 MW Francis units): 240 MW
- Average annual capacity: 872 GWh
- 50 km of 230 kV transmission lines.
We should like to convey our warmest thanks to our clients, partners and members of staff who, together, have contributed so much to all of the projects described in this book.