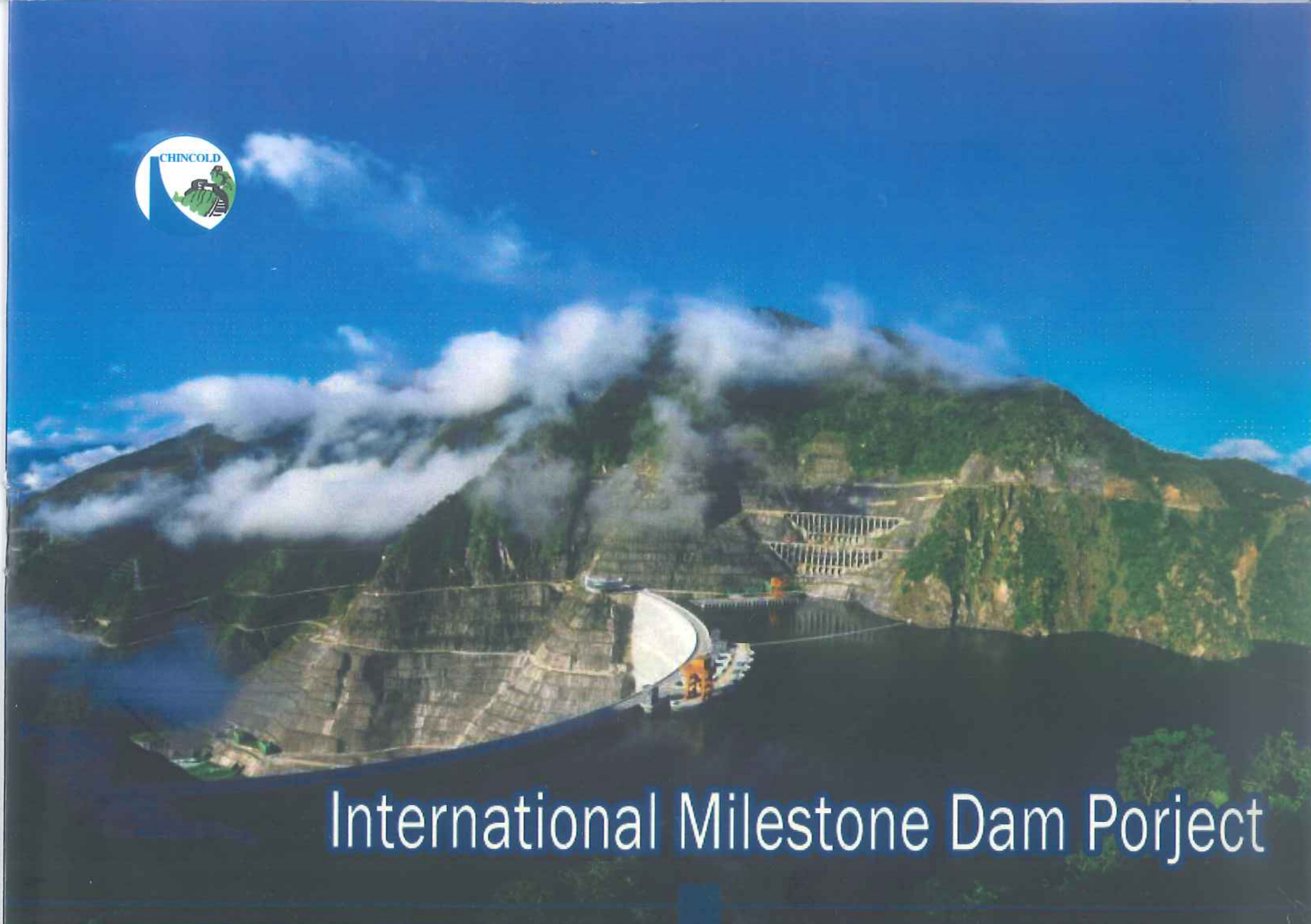


International Milestone Dam Porject

CHINESE
NATIONAL COMMITTEE
ON LARGE DAMS

Chinese National Committee on Large Dams
October 2016 Xi' an · China

| Table of Content

I.The 2nd International Milestone High Concrete Dam Projects

Dams and reservoirs have strategic importance in supporting economic and social development on the aspects of flood control, water supply, energy security and food security. The role of dams and reservoirs is fundamental along with the further development of urbanization and modernization, as well as increasing concerns about the impacts of climate change. It is necessary to continue to develop new dam technology, paying more attention to safety, rehabilitation, environmental protection and etc., so as to make a greater contribution to the benefits of human beings.

To recognize major achievements of high concrete dam technology and define milestone projects, Chinese National Committee on Large Dams (CHINCOLD) and US Society on Dams (USSD) jointly organized the appraisal of the 2rd International Milestone High Concrete Projects with wide support from international dam society.

The milestone projects awarded are the representatives of the main achievements in high concrete dam fields (excluded RCC dams) according to the following criteria, which can be used as valuable references for the future development.

- Outstanding technical innovation in design, construction, operation or other aspects;
- Good performance after completion;
- Much attention has been paid during the construction and operation stages to environmental protection and social aspects;
- Attention paid to raising awareness of technical achievements and advanced experience.

Recommend projects have been examined and assessed by the Special Experts Group consisted of ten experts from eight countries, who are representatives of ICOLD national committees, ICOLD Technical Committee of Concrete and international experts in fields of high concrete dam technologies. Four dam projects namely XiaowanDam, Dworshak Dam, Ridracoli dam and Karun III project have gained 2/3 votes and approved by Mr. Anton Schleiss, President of ICOLD, Mr. Jiao Yong, President of CHINCOLD and Mr. John Wolfhope President of USSD as this year's International Milestone Projects. The introduction of each project can be found in this brochure for your reference.

1)Xiaowan dam

General Information of Project

<table>
<tr><td colspan="2">roject name</td><td colspan="3">Xiaowan Hydropower Project</td></tr>
<tr><td colspan="2">Location</td><td colspan="3">Lancang River in Yunnan Province, China</td></tr>
<tr><td colspan="2">Main purpose</td><td colspan="3">Power generation, irrigation, flood control, navigation</td></tr>
<tr><td colspan="2">Reservoir capacity (million m^3)</td><td colspan="3">15,000</td></tr>
<tr><td rowspan="4">Dam project Participants</td><td>Owner</td><td colspan="3">HuanengLancang River Hydropower Inc.</td></tr>
<tr><td>Designer</td><td colspan="3">PowerChina Kunming Engineering Corporation Limited</td></tr>
<tr><td>Construction company</td><td colspan="3">Sinohydro Bureau 1 Co., Ltd.
Sinohydro Bureau 3 Co., Ltd.
Sinohydro Bureau 4 Co., Ltd.
Sinohydro Bureau 7 Co., Ltd.
Sinohydro Bureau 8 Co., Ltd.
Sinohydro Bureau 14 Co., Ltd.
China Gezhouba Group Co., Ltd.</td></tr>
<tr><td>Supervision company</td><td colspan="3">China Northwest Water Conservancy & Hydropower Engineering Consulting Co., Ltd
Zhejiang Huadong Engineering Consulting Co., Ltd.</td></tr>
<tr><td colspan="2" rowspan="9">Concrete dam</td><td colspan="2">Type</td><td>Arch dam</td></tr>
<tr><td colspan="2">Height (m)</td><td>294.5</td></tr>
<tr><td colspan="2">Crest / Base width (m)</td><td>12/73.12</td></tr>
<tr><td colspan="2">Crest length (m)</td><td>892.786</td></tr>
<tr><td colspan="2">Concrete volume (million m^3)</td><td>8.4</td></tr>
<tr><td colspan="2">Design flood</td><td>500-year flood</td></tr>
<tr><td rowspan="3">Water release structure</td><td>Type</td><td>5 surface outlets + 6 mid-level outlets + 1 flood discharging tunnel on the left bank</td></tr>
<tr><td>Discharge capacity (m^3/s)</td><td>16,700</td></tr>
<tr><td>Energy dissipation type</td><td>Flows collision of surface outlets and mid-level outlets, with a plunge pool after dam</td></tr>
<tr><td colspan="2" rowspan="4">Hydropower station</td><td colspan="2">Type</td><td>Underground powerhouse</td></tr>
<tr><td colspan="2">Size (L/W/H, m)</td><td>298.4×30.6×79.38</td></tr>
<tr><td colspan="2">Installed capacity (MW)</td><td>4,200</td></tr>
<tr><td colspan="2">Annual energy output (TWh)</td><td>19</td></tr>
<tr><td colspan="2" rowspan="5">Construction</td><td colspan="2">Project started</td><td>January 20, 2002</td></tr>
<tr><td colspan="2">Date of impoundment</td><td>December 16, 2008</td></tr>
<tr><td colspan="2">Project Finished</td><td>October 31, 2011</td></tr>
<tr><td colspan="2">Maximum daily concrete pouring intensity (m^3/d)</td><td>11,130</td></tr>
<tr><td colspan="2">Maximum monthly concrete pouring intensity (m^3/m)</td><td>222,400</td></tr>
<tr><td colspan="2" rowspan="5">Operation status</td><td colspan="2">Normal water level (m)</td><td>1240</td></tr>
<tr><td colspan="2">Date of first normal high water level</td><td>October 31, 2012</td></tr>
<tr><td colspan="2">Maximum water level after commissioning (m)</td><td>1240</td></tr>
<tr><td colspan="2">Dam crest displacement of latest normal water level (mm)</td><td>124.1</td></tr>
<tr><td colspan="2">Seepage (total seepage/seepage of dam body, L/s)</td><td>2.78/0.64</td></tr>
</table>

Innovative technologies

1.Introduction of The Project

Xiaowan Hydropower Project acts as the controlling reservoir station for the mid and lower reaches of Lancang River. The project is designed for a major purpose of power generation, combing flood prevention, irrigation, sediment retention and navigation. The total reservoir volume is 15 billion m3. The installed capacity is 4,200MW and the annual average generation is 19 TWh.

Xiaowan Hydropower Project consists of the double-curvature concrete dam, energy dissipation protective facilities, a flood discharging tunnel on the left bank, power generation system on the right bank and the power transmission system. The dam is a parabolic arch dam with the maximum dam height of 294.5m, crest length of 892.786m, the bottom width of the crown cantilever 73.124m, the ratio of arc length to height 3.035, the ratio of thickness to height 0.248, the flexibility coefficient 12.46, and the largest hydrostatic load about 18 million t. The dam is arranged with 5 surface outlets, 6 mid-level outlets and 2 bottom diversion outlets.

The main works of Xiaowan commenced on January 20, 2002, followed by river closure in October 2004, impoundment in December 16, 2008, and the operation of first unit in September 2009. Concrete placing of the dam was finished in March 2010, and total construction was completed in October 2011. Impounding to the normal water level of 1240m for the first time was on October 31, 2012, and another two times, on October 11, 2013 and September 30, 2014 respectively. The units have been in safe operation for 2,583 days up to September 30, 2016, with total electricity generation of over 100 TWh.

2. Main Technical Innovation

The Xiaowan arch dam, 294.5m in height, was the highest of the same type in the world by the time when finished. The dam has maximum flood discharging capacity and bearing the highest water load among arch dams in the world, with the complicated topographic & geological conditions and high seismic intensity. Main innovations are as following:

(1) Innovation on high arch dam structure

The shape of the arch dam has been optimized and designed rationally. Many new structure measures have been developed and applied, including the upstream seepage prevention system, comprehensive anti-seismic measures, such as mounting arch and beam bidirectional anti-seismic reinforcements combining with the damper, fillet anchor on the dam toe, reinforcement measures for arch dam resistance block,

(2) Treatment of 700-meter-high slope

The excavation support procedures and principles are proposed and then the combined twist drilling, drilling with casing, load-dispersion anchor cable and complete set of anchor cable grouting construction technology are developed for unloaded broken rock masses and deposits, solving the problems of being difficult to form pores and thread the rope, as well as high in grout amount. Various processing technologies, such as pre-anchoring, excavating while anchoring, mechanically dredging, strengthening consolidation grouting and increasing anchor piles, are proposed to successfully solve the dam safety problem resulted from the dam foundation unloading relaxation.

(3) Real-time Safety Evaluation Technology

A safe and advanced monitoring system of ultra-high arch dam is established, and the basic principle of stage impounding is proposed. In addition, a statistical model and a mixed model for the analysis of the working condition of the ultra-high arch dam are established, realizing the real time safety evaluation during the whole dam working process. A computing method for dam heel stress of high arch dam based on actual data is initiated.

(4) Foundation Treatment

The geological condition, grouting results and contrast effect etc. are detected by applying the digital imaging and acoustic testing technology in the hole, intuitively judging whether the quality of grouting meets the standards specified in the technical requirements. For many grout hole connected parts are developed by fissure, wind-water joint flushing and high-low pressure pulse flushing of holes are innovatively applied, effectively cleaning the drilling rock powder and slag in the connected cracks. Thegrouting automatic recorder is applied, ensuring the grouting quality and treatment effect.

3.Operation Status and Performance of The Project

Since completion, the Project has impounded to normal water level for three times. The test results of observed data on dam deformation, seepage, temperature, stress and strain revealed a normal condition and regular cycles. The test value on displacement of arch dam foundation and stress is below the pre-set standard value. In addition, the amount of seepage flow from the dam and dam foundation is scarce, and the slopes on both banks have become quite stable. On overall, the arch dam is operating in perfect condition. On October 22, 2015, Xiaowan Hydropower Project passed the special acceptance review.

4. Prizes Achieved

The Project has made major breakthroughs on a series of key technologies for building ultra-high arch dams and has greatly contributed to the development of world's high arch dam technology. The achievements have been highlighted by academicians of Chinese Academy of Engineering including Mr. Pan Jiazheng, Mr. Zhang Chaoran, Mr. ZhengShouren, Mr. Niu Xinqiang and ect..So far, dozens of awards such as China Electric Power Quality Awards have been achieved for the construction of Xiaowan Hydropower Project.

5.Environmental and Social Benefits and Local Contributions

(1) Environmental benefits

The annual generation of the Project is 19TWh, an equivalence of 6.86 million tons of standard coal saved each year, and a reduction of 13.48 million tons of CO_2.

(2) Social and economic benefits

Power generation. The annual average generation is up to19TWh, thus the social and economic benefits are quite remarkable. Electricity generated from Xiaowan has effectively eased the power shortage in Yunnan and Guangdong Province, which makes major contributions to the development of national economy in China. In addition, Xiaowan Hydropower Project also has strong ability for water compensation for downstream cascades, which can effectively improve whole-cascade power generation performance during flood and dry seasons, and overall generation efficiency.An increase of 1,100MW guaranteed output has been achieved in Manwan, Dachaoshan, Jinghong which are located downstream, and the net increase of the effective power is about 6.2TWh each year.

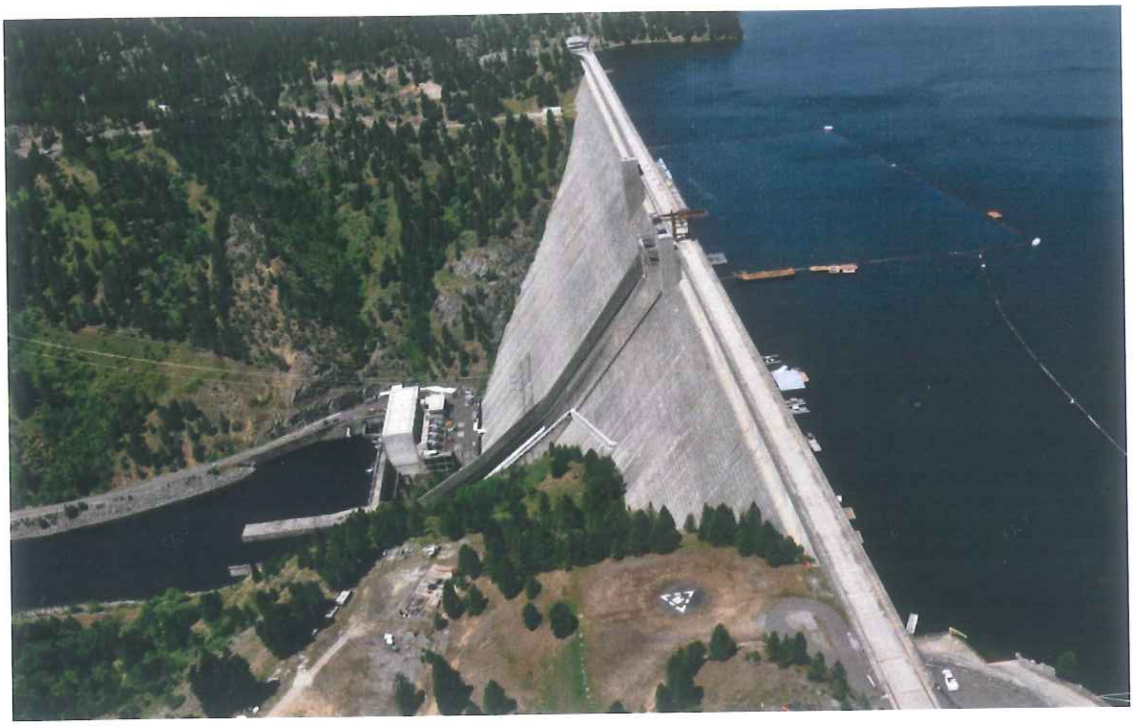
Flood control. Xiaowan Reservoir can provide a flood regulation storage capacity of 1.318 billion m^3 in combination of the utilizable capacity, and the flood regulation can reduce the flood peak by 12%.

Navigation.Xiaowan Reservoir can form 178km deep-water channel in trunk stream reservoir area, and 123km deep-water channel in tributary Heihui River reservoir area, which creates the conditions for developing navigation in reservoir areas.

2)Dworshak dam

General Information of Project

<table>
<tr><td colspan="3">Name of project</td><td>Dworshak Dam</td></tr>
<tr><td colspan="3">Location</td><td>North Fork Clearwater River, Idaho, USA</td></tr>
<tr><td colspan="3">Main purpose</td><td>Flood Risk Management</td></tr>
<tr><td colspan="3">Reservoir Capacity (10^6m^3)</td><td>4,278</td></tr>
<tr><td rowspan="5">Companies involved</td><td colspan="2">Owner</td><td>United States Army Corps of Engineers</td></tr>
<tr><td colspan="2">Designer</td><td>United States Army Corps of Engineers</td></tr>
<tr><td colspan="2">Dam project contractor</td><td>Dworshak Dam Constructors</td></tr>
<tr><td colspan="2">Consultant</td><td></td></tr>
<tr><td colspan="2">Manufactures and assembly firms</td><td></td></tr>
<tr><td rowspan="11">Dam</td><td colspan="2">Type</td><td>Gravity dam</td></tr>
<tr><td colspan="2">Height(m)</td><td>219 meters (717 feet)</td></tr>
<tr><td colspan="2">Crest width(m)</td><td>13.4 meters (44 feet)</td></tr>
<tr><td colspan="2">Crest length(m)</td><td>1,002 meters (3,287 feet)</td></tr>
<tr><td colspan="2">Crest elevation (m)</td><td>492 meters (1613 feet)</td></tr>
<tr><td colspan="2">Bottom width (m)</td><td></td></tr>
<tr><td colspan="2">Volume (10^6m^3)</td><td>4.969</td></tr>
<tr><td colspan="2">Design flood</td><td>6,228 cubic meters per second</td></tr>
<tr><td rowspan="3">Discharge structures</td><td>Type</td><td>spillway: Two Tainter gates with stilling basin, 5,097 cubic meters per second
Others: Three regulating outlets, 1,133 cubic meters per second (total)</td></tr>
<tr><td>Discharge (m^3)</td><td></td></tr>
<tr><td>Energy dissipation</td><td></td></tr>
<tr><td rowspan="4">Powerhouse</td><td colspan="2">Type</td><td>Francis turbine</td></tr>
<tr><td colspan="2">Size (L/W/H, m)</td><td></td></tr>
<tr><td colspan="2">Installed Capacity (MW)</td><td>400 megawatts</td></tr>
<tr><td colspan="2">Annual power generation</td><td>1,536,000,000 kilowatt hours (average from 2008-2012)</td></tr>
<tr><td rowspan="4">Construction</td><td colspan="2">Project Started</td><td>1966</td></tr>
<tr><td colspan="2">Project Finished</td><td>1973</td></tr>
<tr><td colspan="2">The maximum daily intensity of construction (m^3)</td><td></td></tr>
<tr><td colspan="2">The maximum monthly intensity of construction</td><td></td></tr>
</table>



Innovative technologies

1.Introduction of the project

Dworshak Dam is a straight axis gravity dam located in Clearwater County of Idaho. Construction began in 1966, and was completed in 1973 with the powerhouse also coming online in 1973. The dam is named to honor U.S. Senator Henry C. Dworshak.

Dworshak is a multipurpose dam that controls water from the 2,440 square-mile drainage area above the dam. The project is operated for flood risk management, power generation, recreation, water quality, and fish and wildlife uses.The development of recreational facilities along the reservoir is complete, and all facilities are operational.

The spillway, located on the dam towards the left abutment, consists of a concrete chute on the downstream face of the dam from an ogee crest elevation of 1545 feet (mean sea level datum) to the stilling basin floor at elevation 931 feet (mean sea level datum). The spillway crest width is 122 feet, consisting of two 50-foot bays and one 22-foot center pier. Discharge over the spillway is regulated by two 50-foot-wide x 56.4-foot-high Tainter gates. The stilling basin founded in excavated bedrock and is lined with reinforced concrete. Three lower level regulating outlets are available for evacuation of reservoir storage below the spillway crest (elevation 1545mean sea level datum). The regulated probable maximum flood discharge is 220,000 cubic feet per second. Regulated discharges into the stilling basin would be approximately 180,000 cubic feet per second from the spillway and 40,000 cubic feet per second from the three lower level regulating outlet conduits.

Dworshak Reservoir has a gross storage capacity of 3,468,000 acre-feet, of which about 2 million acre-feet is used for local and regional flood control; and for at-site and downstream power generation. At elevation 1,600 feet (mean sea level datum), the reservoir is about 54 miles long, has a surface area of about 20,000 acres and extends into the Bitterroot Mountains.

2.Major innovative technologies used in the project

Design considerations unique to 1960's technology included early finite element analysis (FEA), which is now common to all mass concrete design today. Control of internal curing temperatures was extremely important as well control of creep and shrinkage. FEA was used to determine the structures response to earthquakes, as well as determine response to changes in internal and external temperatures. The analysis resulted in concrete placed in 5-foot lifts in monoliths generally 65 feet wide. The longest monolith lift was about 530 feet long. The maximum differential height between monoliths was maintained at 15-20 feet.

Construction of the dam had a stringent temperature requirement of placing 45 °F concrete, as measured 20 minutes after mixing. Multiple methods were used to achieve this requirement and minimize concrete temperatures, including a low heat of hydration cement, incorporating pozzolans as part of the cementitious materials, pre-cooling the aggregates, using ice in the mix, and post cooling with chilled water in pipes. Precooling of aggregate was achieved by circulating chilled air into the aggregate storage bins and by spraying the aggregate with cold (40 °F) water when it was conveyed on the metering belt. To provide post cooling, 1-inch outside diameter aluminum pipe was installed on the foundation and at the bottom of each lift of concrete in the lower portions of the dam. Each pipe formed a loop from the downstream face of the dam to near the upstream face and return. Pipes were spaced on approximately 5-ft centers horizontally. Water at an inlet temperature of 41 °F was circulated through the pipes, generally for 21 days without interruption. The total length of cooling pipe installed was 2.9 million ft.

To reduce uplift below the dam a grout curtain was constructed in the bedrock foundation and foundation pressure relief drains were installed. The Dam recently had two waterstops repaired using cylinders composed of a new urethane material. This material has gained international interest as a potential waterstop repair. Information from the construction of Dworshak has been used to verify or enhance code criteria for massive concrete structures.

3.Performance of the project

On an annual basis, Dworshak generally experiences a pool within approximately 5 ft of the probable maximum flood without significant distress. To date, the average annual damages prevented since the project has been in operation is $3.5 million. However, Dworshak also contributes to flood risk management (FRM) benefits much farther downstream; these benefits have not historically been calculated for Dworshak. Currently, the average annual benefits within the Columbia River system attributed to Dworshak are estimated to be $40 million. This gives total annual FRM benefits of $43.5 million.

4.Technical achievements and Prizes ever achieved

Dworshak Dam is the highest straight-axis concrete dam in the Western Hemisphere, and the 22nd highest dam in the world. There are only two other dams in the United States that exceed it in height.

5.Environmental and social aspects andlocal contributions of the project

There are about 30,000 acres of project lands surrounding the reservoir for public recreation purposes, wildlife habitat, wildlife mitigation and log-handling facilities. These include federally owned lands managed by the Corps, as well as easement lands managed by the U.S. Forest Service to which the Corps has flowage easement rights. Surrounded by lush forested mountains, the 54 mile long reservoir offers a myriad of recreation opportunities for the entire family. Recreation opportunities include boating, water-skiing, fishing, developed and primitive camping, picnicking, hiking and hunting.Average annual recreation benefits were valued at $1,592,358.

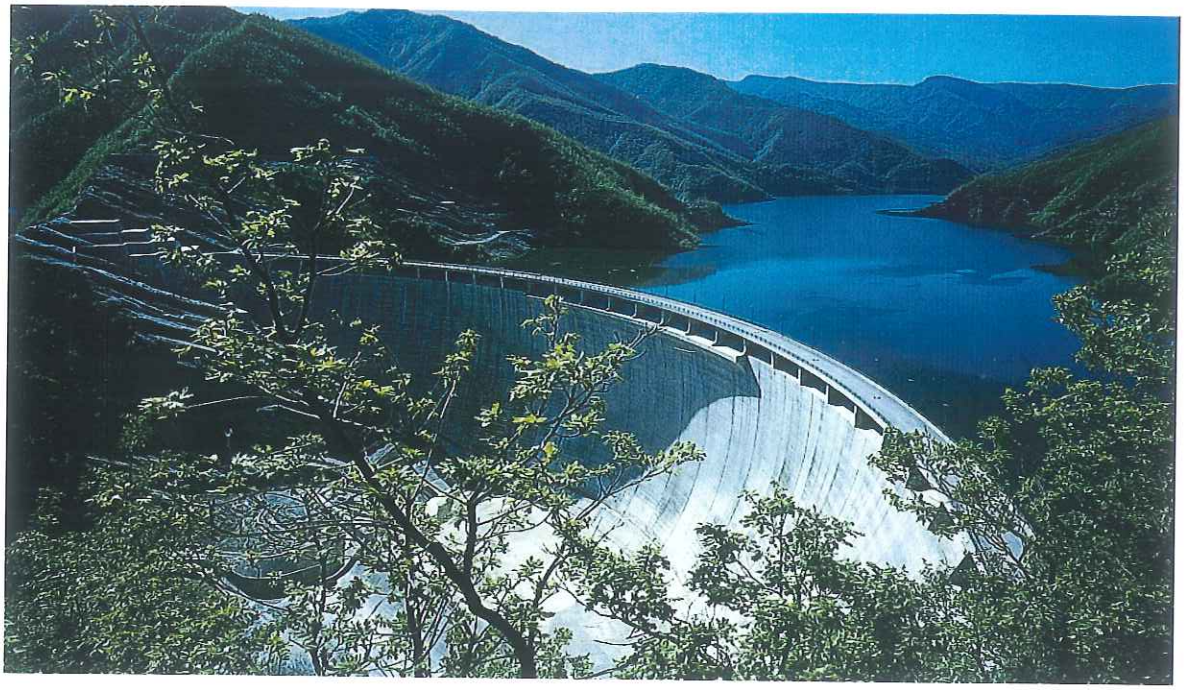
The construction of Dworshak Dam resulted in blocking anadromous steelhead trout, and converting a river habitat to a reservoir. Mitigation for fish losses led to construction of the Dworshak National Fish Hatchery, constructed and maintained by the Corps and operated by the U.S. Fish and Wildlife Service. The Dworshak hatchery is the largest steelhead hatchery in the world. After filling Dworshak Reservoir, kokanee salmon and smallmouth bass were stocked and became self-sustaining in the reservoir. The abundance of kokanee salmon in the reservoir has made it the favored sport species in the reservoir. The operating power intakes are equipped with adjustable gates for selective withdrawal of water from full pool elevation 1600 feet to minimum pool elevation 1445 feet. The selective withdrawal system duplicates natural river water temperatures downstream to support migratory fish runs.

The filling of the reservoir also resulted in the loss of about 15,000 acres of terrestrial habitat. The greatest loss of wildlife habitat was the winter range for Rocky Mountain elk and white-tailed deer. To offset this loss, mitigation lands have been developed, and are managed for winter range. About 7,000 acres were purchased and are managed specifically for elk mitigation.

3)Ridracoli dam

General Information of Project

Name of Project	Ridracoli dam		
Location	Ridracoli /S.Sofia and Bagno di Romagna Municipalities / Forlì Province		
Main Purpose	Water Supply		
Reservoir Capacity ($10^6 m^3$)	33,06		
Companies Involved	Owner		Romagna Acque - SocietàdelleFontiS.p.A.
	Designer		Alpina - Ing. A. Rebaudi e Ing. G. Oberti
	Dam Project contractor		
	Consultant		Ismes- Elettroconsult(ELC)
	Manufacture and Assembly firms		CORIDRA (Cogefar, CMC, Lodigiani)
Dam	Type		Arch - Gravity dam
	Height (m)		103,5
	Crest width (m)		6,62
	Crest length (m)		432
	Crest elevation (m)		561,0 m a.s.l.
	Bottom width(m)		36,46
	Volume ($10^6 m^3$)		0,6
	Design flood		600 m^3/sec
	Discharge Structures	Type	Spillway: free 730 m^3/sec
			middle level outlet: 135 m^3/ sec
			bottom outlet: 173 m^3/sec
		Discharge (m^3)	≈ 900 m^3/sec
		Energy dissipation	Stilling basin
Powerhouse	Type		
	Size		
	Installed capacity		
	Annual power generation		
Construction	Project Started		1975
	Project Finished		1982
	The maximum daily intensity of construction (m^3)		
	The maximum monthly intensity of construction (m^3)		



Innovative technologies

1.Introduction of the project

Romagna is an Italian region when the earth is reach and generous but good potable water is scarce. A saying about this chronic shortage, that was old to travelers on the long road to the sea, was: "To find out where you are during your journey just ask for a drink. If you are given a glass of water you are in Emilia, when you get a glass of wine you have arrived in Romagna". Faced with the growth in population water was pumped from underground by thousands of wells. With growing demand for industry and intensive farming, groundwater abstractions became excessive, inducing ground subsidence problems in a large area and causing seawater to encroach into the water tables.
The Ridracoli Project was therefore realized to provide good quality water to the large population of the region, building a mountain reservoir.

The project consists of the following infrastructures:
•Dam and appurtenant works
•Water tunnels and channels diverting water from two mountain streams into the reservoir
•Diversion tunnel, surge chamber and pressure tunnel, 33 km pipeline
•Water treatment plants, control centre, remote control system
•Water distribution network to 43 municipalities.

2.Major innovative technologies used in the project

The main innovation introduced in the project concerned the commitment, resources and tools dedicated to the communication, interaction and discussion with the stakeholders potentially affected by the project, at all unusual at the time the project was developed.
In 1975, when construction started, there were strong reactions from conservationists and from the population living downstream of the dam.
Arguments focused on alleged dangers to the public. Opponents feared river depletion and geological and climate changes, predicting disasters for the environment, declining population, and deteriorating socio-economic conditions over a vast area in the mountains and foothills. Environmental organizations took the matter to courts to try to stop construction.

The dam owner (Romagna Acque) managed to overcome the legal problem by submitting studies from specialists and providing safety monitoring and strict control systems, and developed the interaction with stakeholders and opponents on the basis of three principles:
a) Careful project monitoring to control the environmental impact, with a commitment to give top priority to public safety;
b) Constructive, rigorous management of the dam, water resources, and land upstream and downstream;
c) Lively interest in social, cultural and local economic development by making the resources of the area a centre of attraction.
The project was developed with the objective of optimal management of water resources and regional development. Reforestation, soil conservation, promotion of social, cultural and economic development enabled the project to safeguard and enhance the area.

3.Performance of the Project

The performance of all the components of the projects were excellent, without any problem. The project demonstrated its capability to fulfill its ambitious targets.

The water demand from the Romagna area is finally satisfied, and water of excellent quality arrives punctually in the homes of more than one million people.

Furthermore, as an additional result, some 60 GWh energy is produced and saved, since water is brought to homes by gravity while previously it was pumped form depths up to 300 m.

The environmental problems (subsidence and salt water encroachment) which contributed to motivate the project has been solved, producing large benefits especially to the touristic coastal areas and historical and artistic heritage (as in the city of Ravenna).

4.Technical achievements and Prizes ever achieved

The Project received t strong interest from the ICOLD Technical Committee on the "Environment", which dedicated to the project a full ICOLD Bulletin: Bulletin n. 100, "DAMS AND ENVIRONMENT – Ridracoli: A model achievement".

This Bulletin is annexed to this document, for completeness of information.

5.Environmental and social aspects and local contributions

An extended scientific study was carried out to have an objective assessment of the environmental conservation efforts and quantify the impacts of the project.

An "environment quality index" (EQI) was used to quantify the impacts, by comparing the post project situation with the baseline before the project was built.

Also factors difficult to measure were included in the analysis (air quality, human health, cultural aspects). A non-monetary approach based on two-steps method (qualitative, quantitative) was adopted, and an assessment model incorporating multiple criteria was used.

The "pre-dam" EQI was set at 1000. In terms of general environmental conditions, the EQI rose from 1000 (pre-dam baseline) to 1219 "post-dam".

This global result derived from the assessment carried out for the ecological, physical and socio-economic domains: the post-dam index rose in all the three domains. For all the basic factors examined in the evaluation (63, in total) a positive balance between pre and post condition resulted, with only one exception ("natural zones" factor).

More details are reported in the annexed ICOLD Bulletin n. 100.

4)Karun III project

General Information of Project

Name of project	Karun 3		
Location	Iran, Khoozestan, Izeh		
Main purpose	Generating of clean electrical energy, controlling the frequency and increasing the stability of public electricity network controlling destructive floods		
Reservoir Capacity (10^6 m^3)	3000		
Companies involved	Owner		Iran Water and Power Resources Development Company (IWPC)
	Designer		Iranian-Canadian Corporation of Acres International-Mahabghodss
	Dam project contractor		Main parts of project implemented by Sabir and Tablieh
	Consultant		Acres International- Mahan ghodss
	Manufactures and assembly firms		Farab
Dam	Type		Arch dam
	Height (m)		205
	Crest width (m)		5.5
	Crest Length (m)		462
	Crest elevation (m)		840
	Bottom width (m)		29.5
	Volume (10^6 m^3)		1.3
	Design flood		10000 ys
	Discharge structures	Type	Gated Service Spillway Gated orifice Spillway Free crest spillway
		Discharge (m^3)	8710 m^3/s
		Energy dissipation	Plunge pool
Powerhouse	Type		underground
	Size (L/W/H,m)		250/25/48
	Installed Capacity (MW)		2000
	Annual power generation		4172 million kw/h
Construction	Project Started		1993
	Project Finished		2004
	The maximum daily intensity of construction (m^3)		2500
	The maximum monthly intensity of construction		45000

Innovative technologies

1. Introduction of the project

Karun3 dam and powerhouse are located in 28 km of Izeh City in north-east of Khuzestan Province. Aerial distance of Karun 3 project from Ahwaz is approximately 14 km. This project is located in western Zagros Mountains within sedimentary layer and in a rough, rocky and earthquake-prone area with calcareous stones.

Karun river is the most watery and the longest river of Iran. Length of Karun River is above 950 km and of its catchment area is 60000 km2. Karun River joins Arvandrud within Iraq borders and heads toward Persian Gulf.

Annual long term average discharge of this River in dam location is 300 m3/s as the greatest in Iran.

Karun 3 has the biggest reservoir among double arc concrete dams in Iran, one of the most volume of excavation and concrete placement among double arc dams and the biggest powerhouse cavern of the country.

The highly permeable limestone foundation was sealed with one of the largest grout curtains in the world.

2. Major innovative technologies used in the project

•Aside from the magnitude of the project, the challenges lay in the extremely complex foundation conditions. The presence of highly permeable limestone formations in Iran has a history of causing problems for impoundment projects.

For this reason, consultant undertook detailed geological investigations over a decade. The results showed that the project could be constructed on the downstream limb of the Keyf-Malek anticline. However, this formation had many adverse features such as joints, some filled with weak clays, well defined discontinuities up to 300 meters deep, and cavities to depths of 200 meters below the river bed. In the dam abutments these features formed large wedges which could become unstable after impoundment.

Using state-of-the-art tools and software designed to simulate the stresses on the foundation and seismic loadings, detailed designs were formulated to deal with each potential problem.

•Due to some purchase limitation and installation difficulty, the contractor was instructed to use anchorage instead of tendons. Maximum usage of double protected 63.5 mm anchors was carried out during construction phase in plunge pool to support uplift pressure and trust block foundation.

3.Performance of the project

•During impounding phase, the biggest compensatory outlets among country's dams did its job.

•During road relocation phase, two of the biggest beautiful arched bridges in the country have been used.

•Power house in the 10th greatest world's cavern has done its job very well. The plant is generating the expected quantities of electricity.

•Post construction seepage from the dam is within 10% of the quantities estimated.

4. Technical achievements and Prizes ever achieved

Canadian Consulting Engineering Awards in 2008 by Mahabghodss& Acres JV.

5. Environmental and social aspects and local contributions of the project

•Social aspects: In construction period, workshop has 7000 local staffs manpower at the peak of activities. The created accupational opportunities in Karun 3 project were more than 22000 jobs. In boundary of reservoir about 63 small and big villages were located. 39 villages lost their lands. There was a project in 2001 and 2002 for studying social, economic and natural consequences of Karun 3 project. The aim of this job was finding the ways of reducing or avoiding social problems relevant to resident population translocation in upstream villages. Results of these studies include opportunities in the region leading to some recommendations.

•Constructing the exhibition and recreation complex in vicinity of Karun 3 dam site.

•Constructing administrative and educational facilities in rural region.

•Repairing roads and rural paths.

•Activities related to archeology studies and deliver some valuable ancient cases in the reservoir

•Translocation of ImamzadehShahpir Shrine

•Environmental aspects: Environmental results of project coming from not using fossil fuels and elimination of greenhouse gas in the energy generation process.

II. International Milestone Projects since 2007

Longtan Dam in China

Miel 1 Dam in Columbia

Miyagase Dam in Japan

Olivenhain Dam in USA

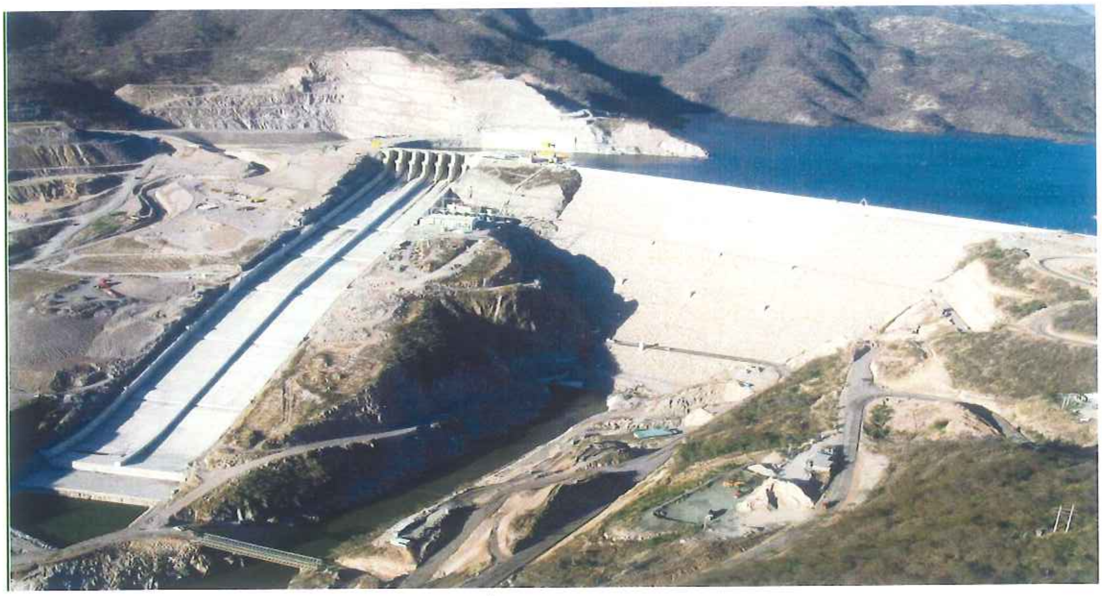
Ralco Dam in Chile

Rialb Dam in Spain

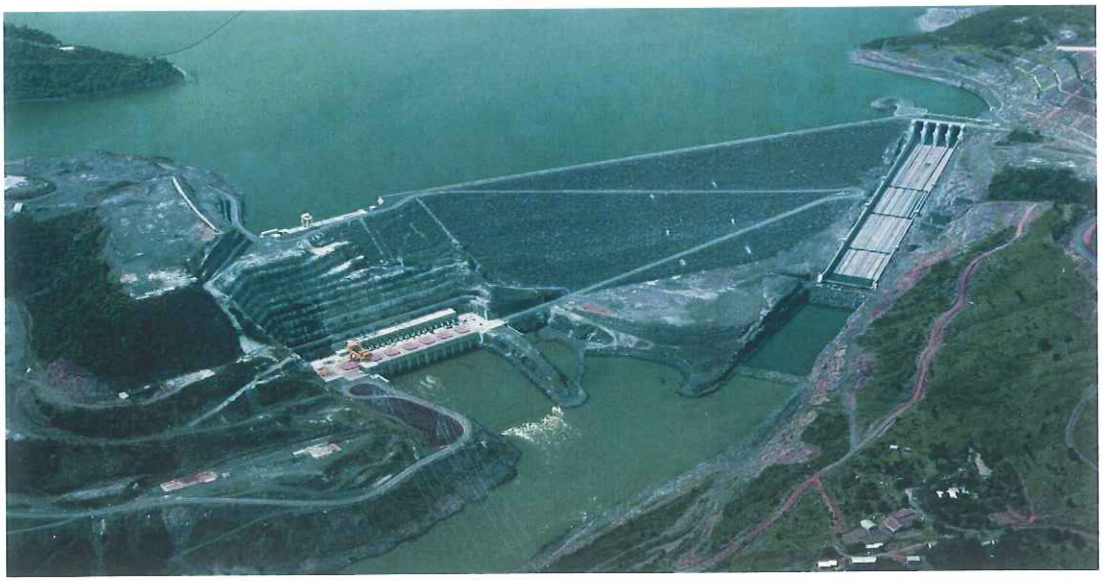
Salto Caxias Dam in Brazil

Wolwedans Dam in South Africa

El Cajon Dam in Mexico



Foz Do Areia Dam in Brazil



Karahnjukar Dam in Iceland

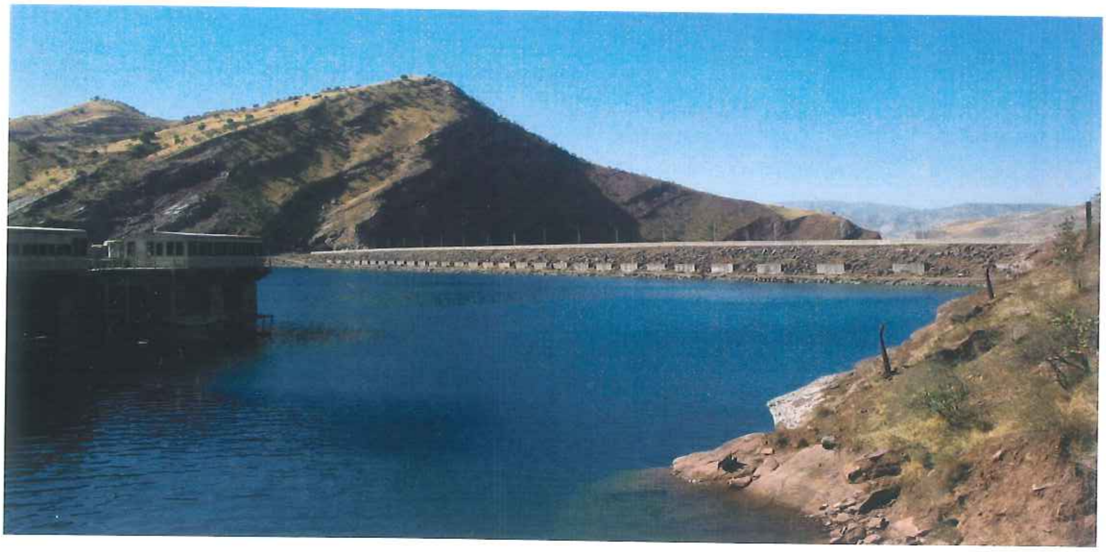
Santa Juana Dam in Chile

Shuibuya Dam in China

Chicoasen Dam in Mexico

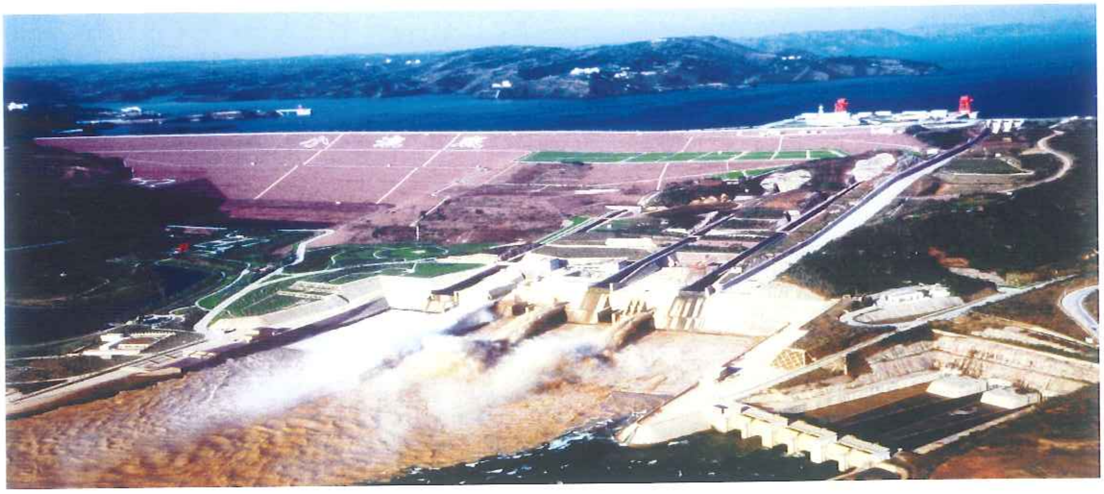
Irape Dam in Brazil

Nurek Dam in Tajikistan



Tehri Dam in India

Xiaolangdi Dam in China



Finstertal Dam in Austria

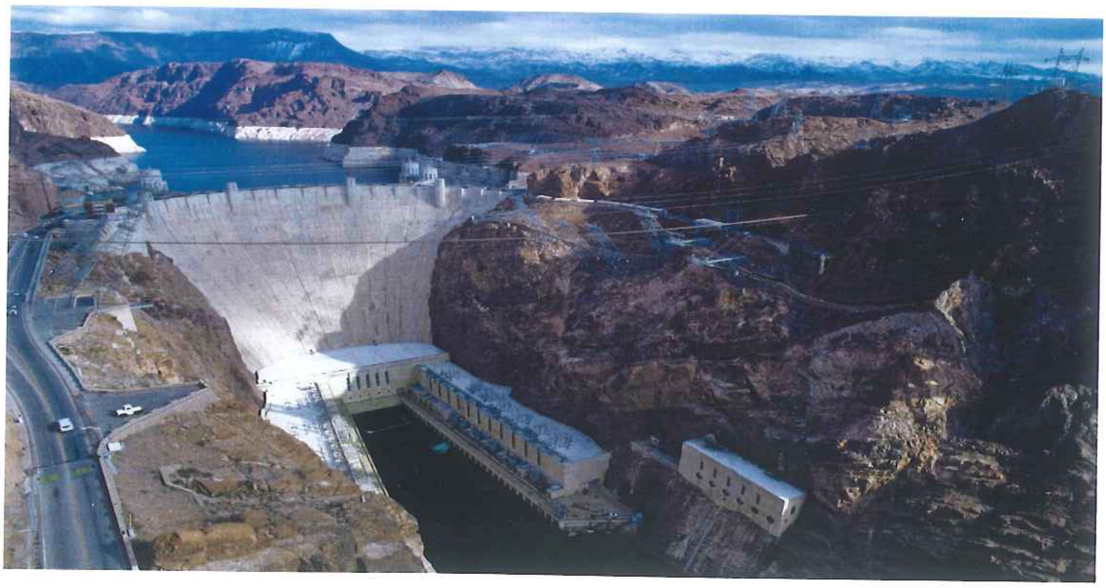
Yashio Dam in Japan

Zipingpu Dam in China

Ertan Dam in China

Grand Dixence Dam in Switzerland

Hoover Dam in USA



Itapu Dam in Brazil and Paraguay

Three Gorges Dam in China

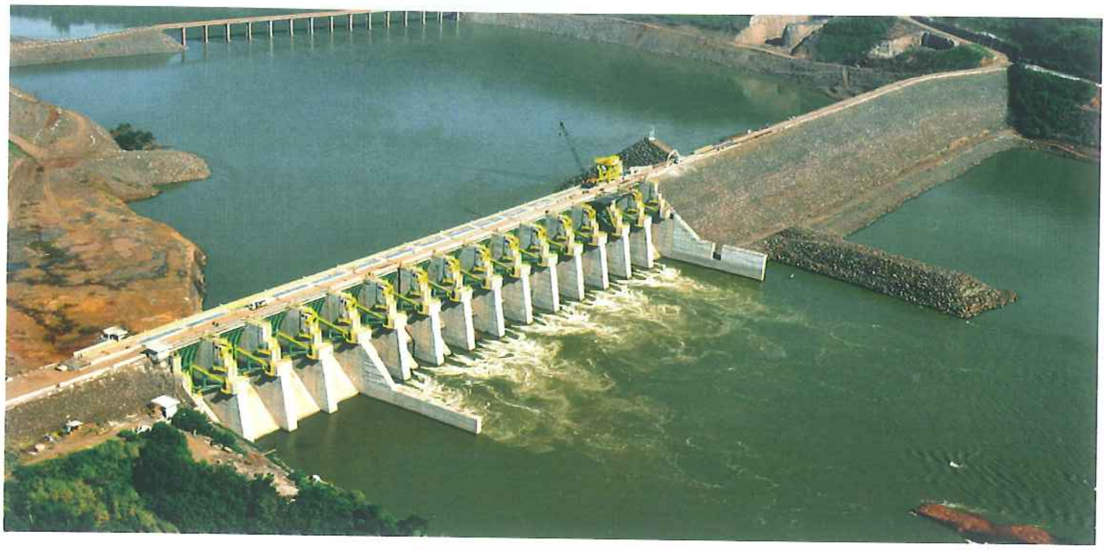
Hongjiadu Dam in China

Xingo Dam in Brazil

Pubugou Dam in China

Serra da Mesa Dam in Brazil

Foz do Chapeco Dam in Brazil



Guangzhao Dam in China

La Brea II Dam in Spain

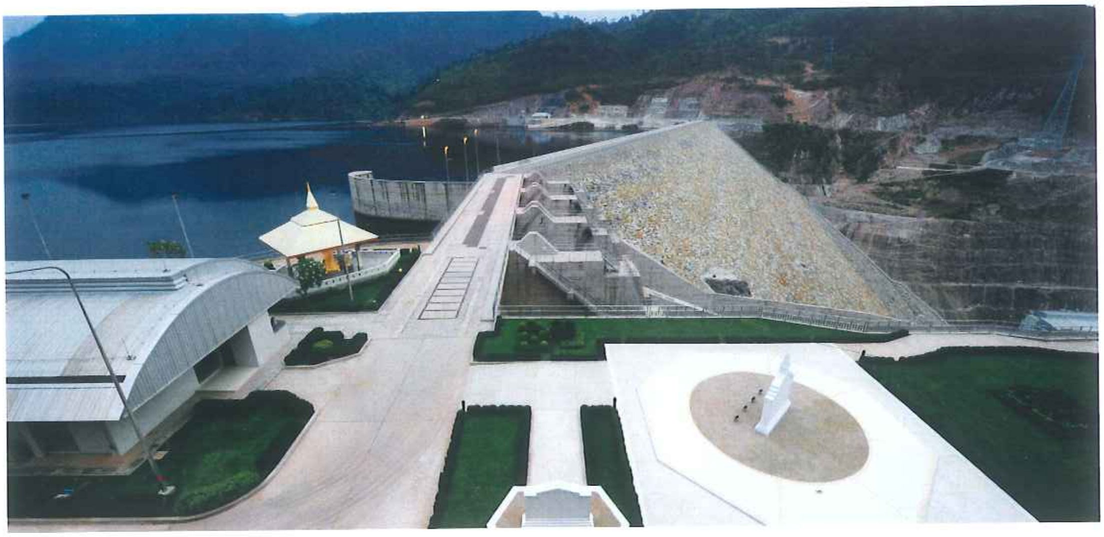
Taum Sauk Dam in USA

Bakun Dam in Malaysia

Jiudianxia Dam in China

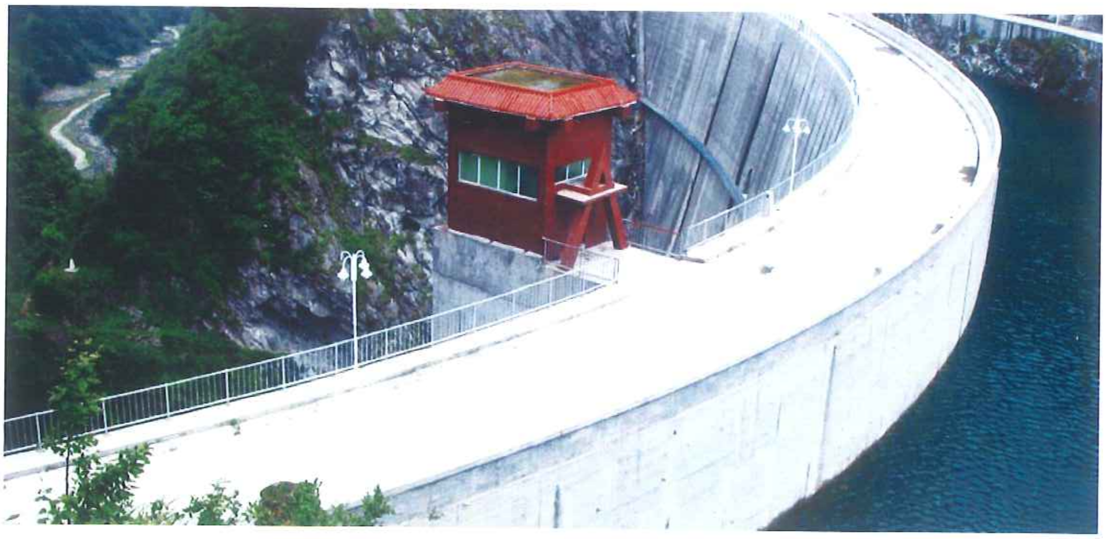
La Yesca Dam in Mexico

Nam Ngum 2 Dam in Laos



Sao Simao Dam in Brazil

Shapai Dam in China



Murum Dam in Malaysia

Changuinola I Dam in Panama

Portugues Dam in USA

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