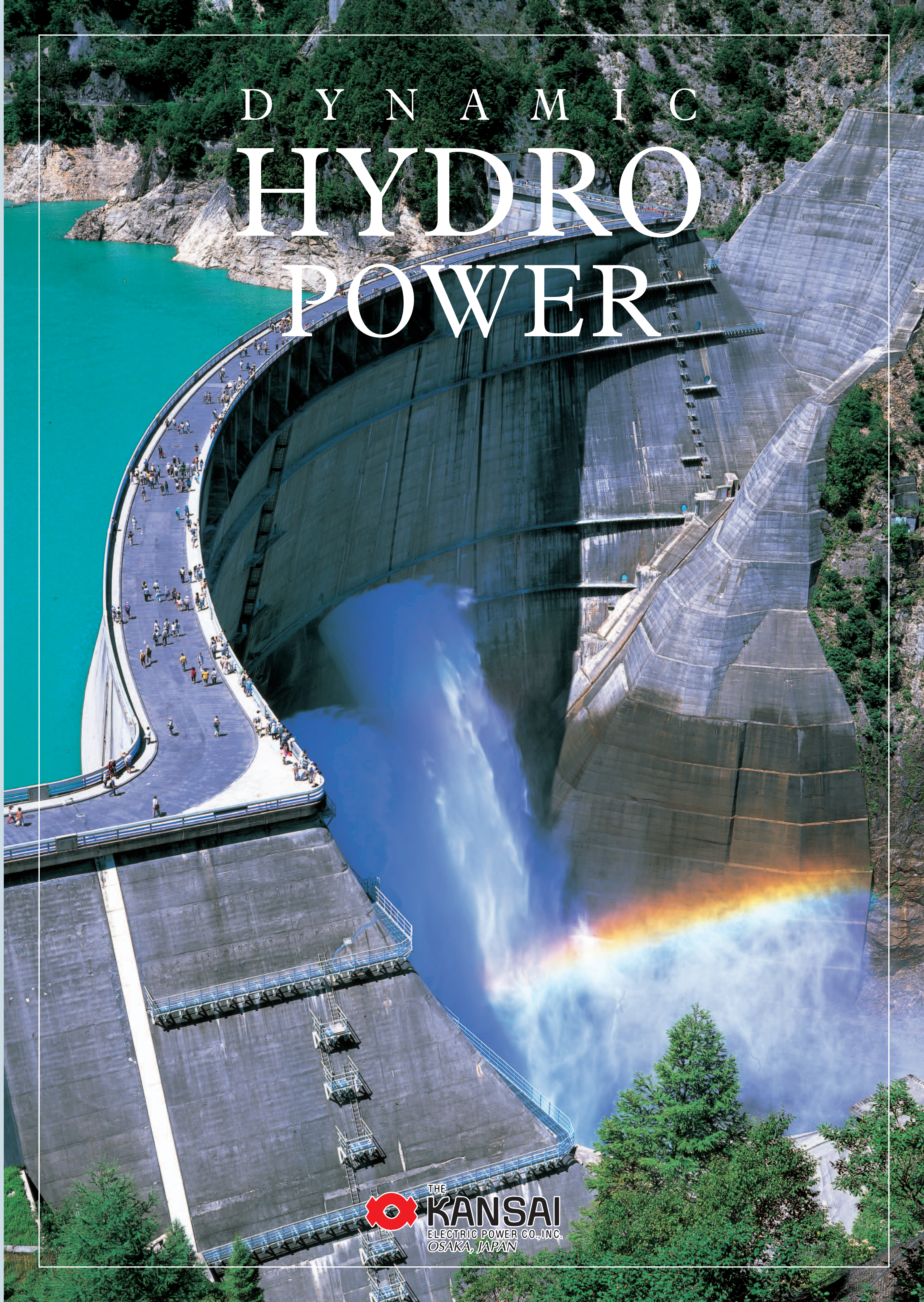
The KANSAI Electric Power Co., Inc.
Civil Engineering and Architecture Department
6-16 Nakanoshima 3-chome, Kita-ku, Osaka 530-8270, Japan
Tel : +81-6-6441-8821
Fax: +81-6-6446-6464
URL: http://www1.kepco.co.jp/english/

NEWJEC Inc.
3-20 Honjo-Higashi 2-chome, Kita-ku, Osaka 531-0074, Japan
Tel : +81-6-6374-4901
Fax: +81-6-6374-4633
URL: http://www.newjec.co.jp/e1kaisya/e0outlin

March 2013
Printed in Japan on recycled paper

DYNAMIC HYDRO POWER



THE KANSAI ELECTRIC POWER CO.,INC.
OSAKA, JAPAN

Taking pride in all its technologies, the KANSAI Electric Power Co., Inc. (KANSAI) opens up the future of hydropower technology.

The hydropower is an eco-friendly energy source, not emitting CO_2.
Over the course of a century, KANSAI has constructed numerous hydropower plants, such as the Keage Power Plant (1891), which was the Japan's first commercial hydropower plant, and the Kurobegawa No.4 Power Plant, one of the largest civil engineering projects ever undertaken in Japan.

Now KANSAI owns and operates 151 hydropower plants, of which capacity amounts to 8,199 MW, and produces high-quality electricity day and night.

KANSAI has been leading the hydropower technology in Japan, applying the newest knowledge of the times.
KANSAI stands No.1 in conventional hydropower output and generation, and No.2 in pumped-storage-type hydropower output, among 10 utility companies in Japan.

This report introduces KANSAI's reliable technologies and engineerings, which are substantiated by its long history and actual results over 100 years.

Kurobe Reservoir

CONTENTS

3-4	Company Profile
5-6	KANSAI's Hydropower
7-8	Beginning of Hydropower Development
9-10	Dam-type Hydropower Development
11-12	Large Dam Development
13-14	History of the Kurobe Dam
15-16	Consistent Development in Whole River System
17	Pumped-storage-type Hydropower Development
18	Main Player in the Low-carbon Society
19-20	Operation
21-22	Maintenance
23-24	Countermeasures against Sedimentation
25-26	Environmental Preservation
27-28	Overseas Activities
29-30	Corporate Data

Company Profile

KANSAI is an overall utility company, responsible for generation, transmission and distribution.

KANSAI is one of utility companies in Japan which were founded through the power industry reforming policy in 1951, and is a No.2 company in sales and capacity. KANSAI has been supplying electricity to Kansai area including Osaka, Kyoto, Kobe and Nara, which are well known worldwide as both historical and commercial places. The population of the Kansai area has reached 20 million.


Ohi Power Plant (Nuclear)


Ohkawachi Power Plant (Pumped-storage-type)


Kurokawa Power Plant (Wind power)


Hirakata Substation


Gobo Power Plant (Thermal)


Sannomiya Sales Office


Dai-Kurobe Trunk Line


Central Load Dispatching Center


Osaka Castle

Over 100 years, KANSAI has been developing, operating and maintaining hydropower plants.

Keage Power Plant

Yaotsu Power Plant

Ohi Dam

Komaki Dam

Sennindani Dam

Maruyama Dam

Tonoyama Dam

Yomikaki Dam

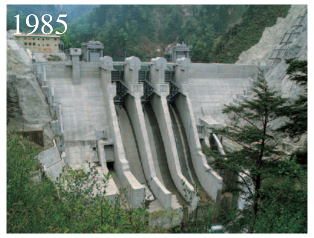
Kurobe Dam

Kiso Dam

Shimokotori Dam

Kurokawa Dam

Okuyoshino Power Plant

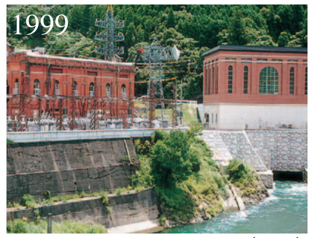


Dashidaira Dam

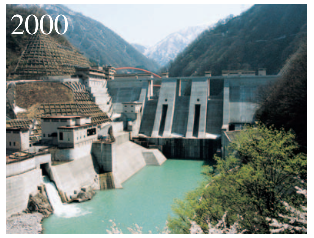
Ohkawachi Power Plant

Sakaigawa Power Plant

Shin-Yanagawara Power Plant



Shin-Takatsuo Power Plant (right)

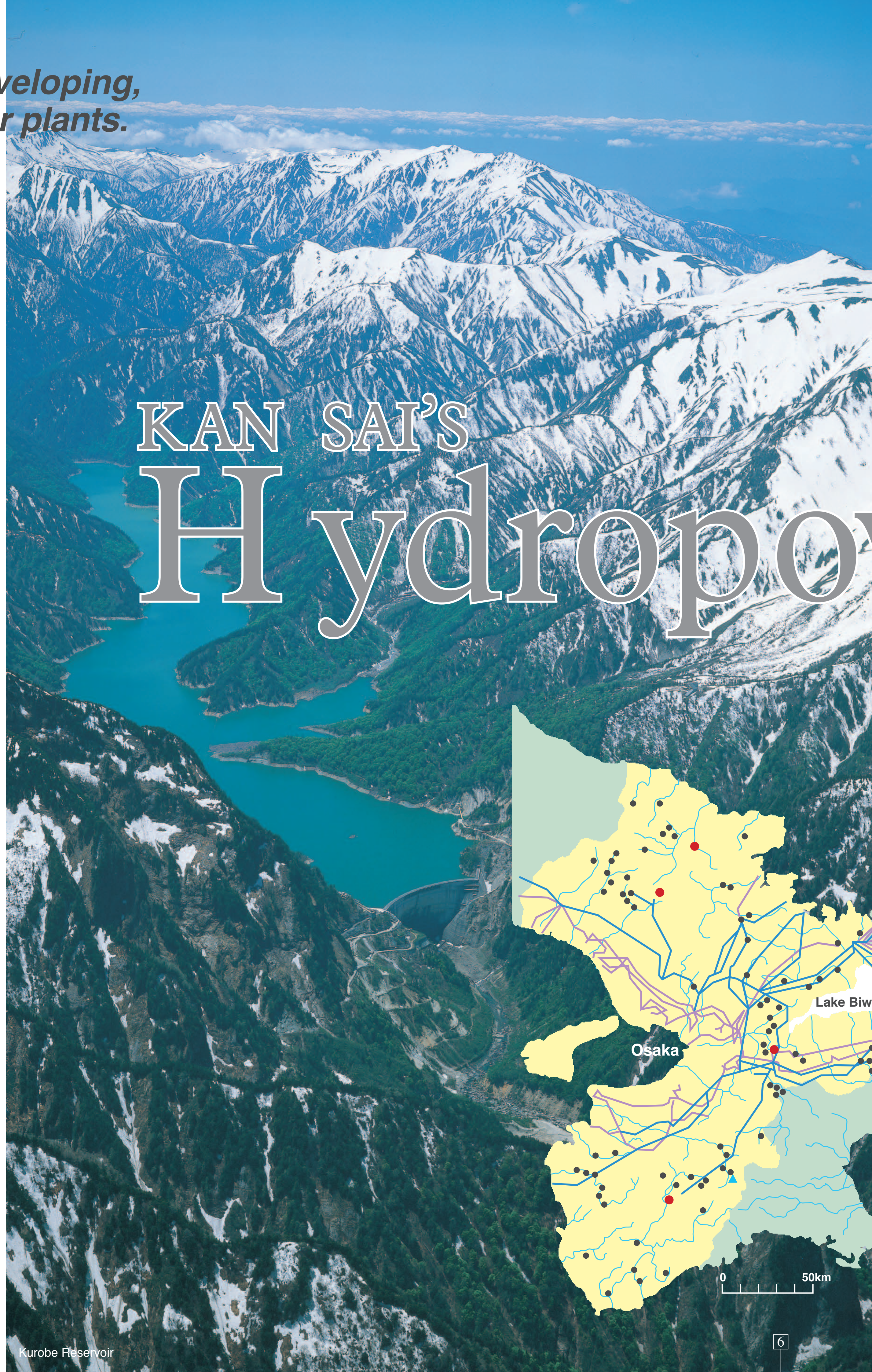


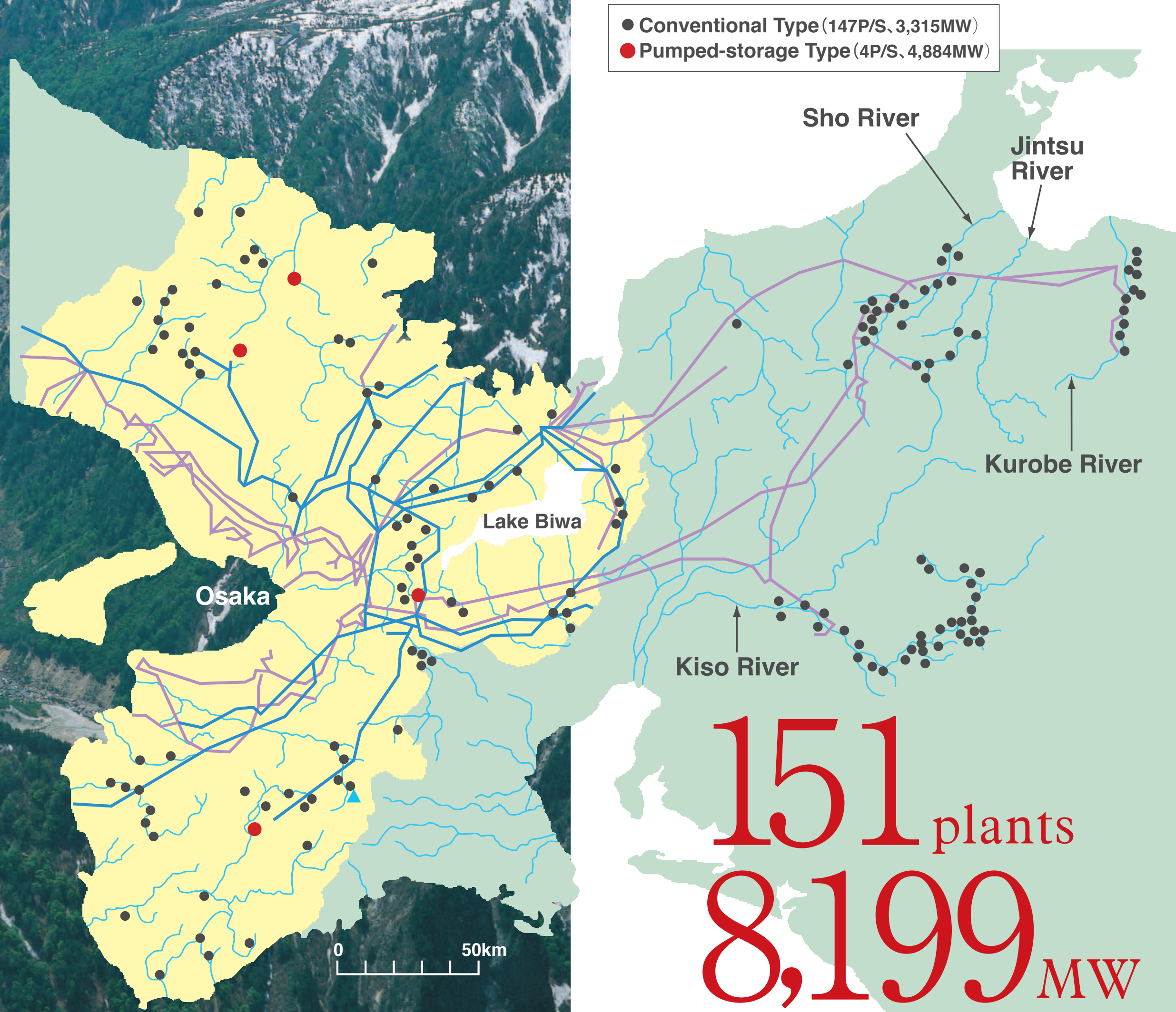
Unazuki Power Plant

Okuwa-Nojiri Power Plant

Shin-Kuronagi No.2 Power Plant

KANSAI'S Hydropower


Kurobe Reservoir



151 plants

8,199 MW

(As of March 31, 2013)

Japan's first commercial hydropower plant, Keage, All history began from here.

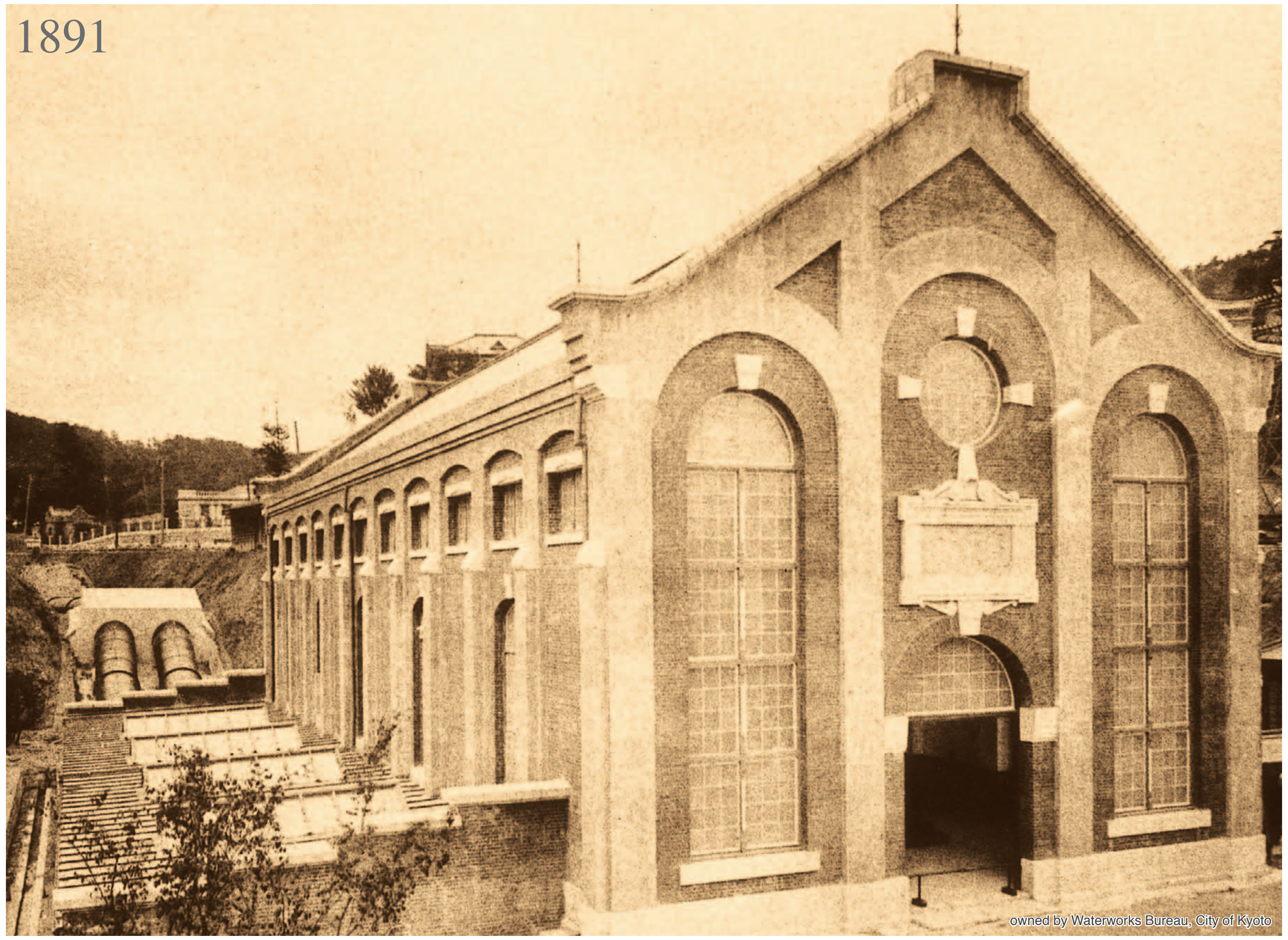
The commercial hydropower development in Japan started in 1891 at the Keage Power Plant in Kyoto.

Birth

Lake Biwa Canal（Keage Power Plant headrace）

Knit factory

Kyoto streetcar



Keage Power Plant Japan's first commercial hydropower plant−Installed capacity: 4,500kW Discharge: 16.7m³/s Effective head: 33.7m

For a few decades after the first commercial plant came into operation, all of the developed hydropower plants were run-of-river type due to small electricity demand and limited resources both technically and financially.

Direct current generator

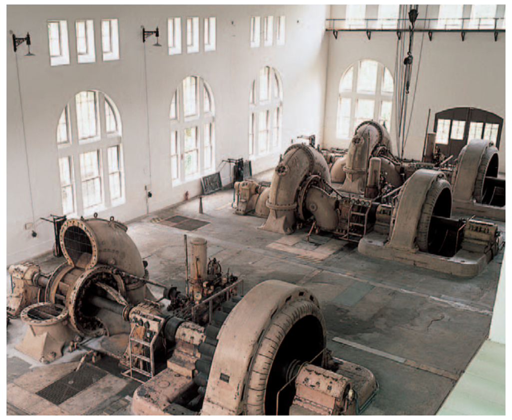
Penstock

Bird-view of Osaka in the 1890s

Birth

Stepping into Dam-type hydropower development Arrival of hydropower primary times

In 1920s, dam-type hydropower plants were lined up with the progress of civil engineering and transmission technology to meet increasing peak electricity demand.



Yaotsu Power Plant
First hydropower plant on the Kiso River System
Installed capacity: 9,600kW Discharge: 27.8m³/s Effective head: 46.2m

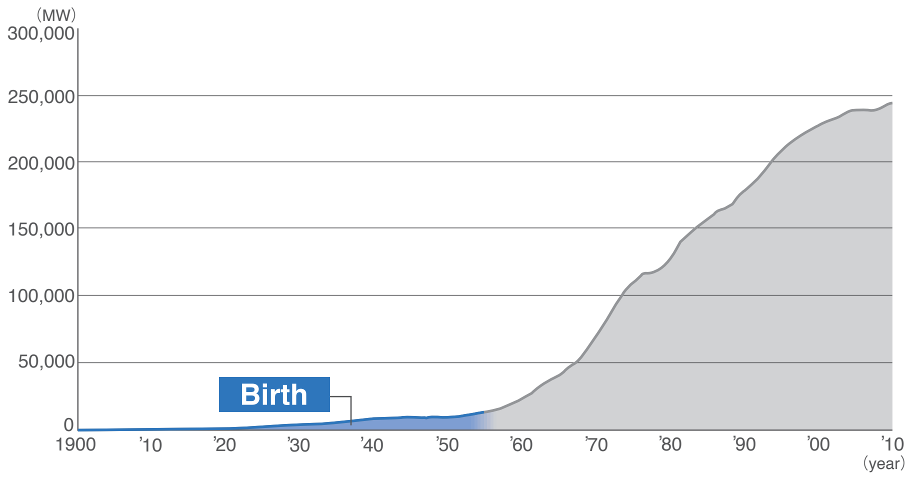
Ohi Dam
First full-scale dam higher than 15 m in Japan
Ohi Power Plant–Installed capacity: 48,000kW Discharge: 139.1m³/s Effective head: 42.4m

Soyama Dam
With auxiliary dam 26.8 m high on the left of the main dam 73.2 m high
Soyama Power Plant–Installed capacity: 54,000kW Discharge: 93.7m³/s
Effective head: 67.2m

Kasagi Dam
Kasagi Power Plant–Installed capacity: 41,700kW
Discharge: 165.8m³/s Effective head: 30.4m

Komaki Dam
Highest dam in the Far East at that time introducing U.S. technology
Komaki Power Plant–Installed capacity: 72,000kW Discharge: 138.7m³/s Effective head: 62.7m

■Electricity demand in Japan at the time



Kurobe Dam
Dam height: 186m Crest length: 492m Dam volume: 1,582,845 m³

Kurobegawa No.4 Power Plant
Installed capacity: 335,000kW Discharge: 72.0m³/s Effective head: 545.5m

An epock-making technology
Construction of Large-Dams

After 1940s, KANSAI built large dam-type hydropower plants, which improved the original river duration curve. The Kurobe Dam constructed in 1963 with the World Bank loan is typical one.

The construction work was so rare in that large arch-type dam was built at the unexplored Kurobe Gorge. The Kurobe Gorge has such steep topography and severe climate in winter that the construction had been expected to be difficult. KANSAI managed to finish the hard construction work, adopting and developing the latest knowledge and construction equipment at that time.

The Kurobe Dam is 186 m high and still highest in Japan.

Growth

Presentation Ceremony of IEEE Milestone

Kurobegawa No.4 Power Plant was awarded IEEE Milestone in 2010.

※IEEE: The Institute of Electrical and Electronics Engineers, Inc.

A high-economic-growth time of Japan, The life of the people improves by leaps and bounds.

Tokaido Shinkansen
It was one of the biggest projects of the day with technical innovation as well as the Kurobe Dam.

Courtesy of SANYO Electric Co.,Ltd   Courtesy of SHARP Corporation   Courtesy of Mitsubishi Electric Corporation

Three Sacred Treasures
(named after the symbol of the Japanese Imperial House)
The spread of electric appliances such as washing machine, television and refrigerator accelerated electricity demand.

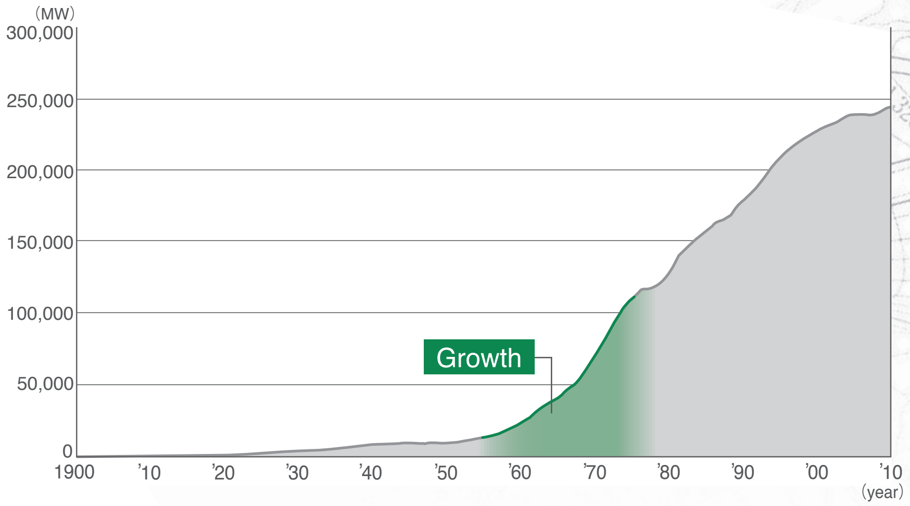
Growth

The symbol of KANSAI's challenging spirit "KUROYON" Project

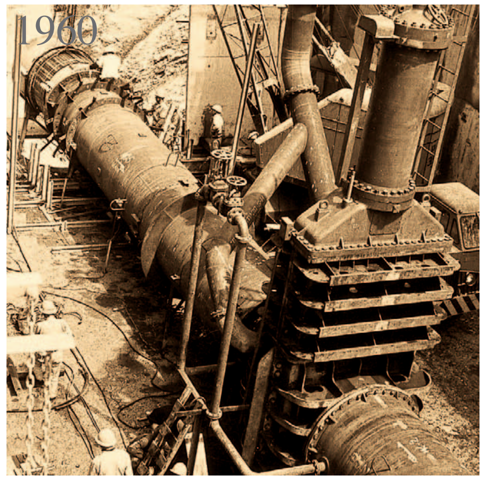
This honorable project is called “KUROYON” which is the abbreviation of the Kurobegawa No.4 Power Plant in Japanese.
“KUROYON” is one of epoch-making projects among civil works in Japan.
The “KUROYON” spirit which had been brewed through the project is kept in the employees’ mind.

Dam foundation excavation

■Electricity demand in Japan at the time

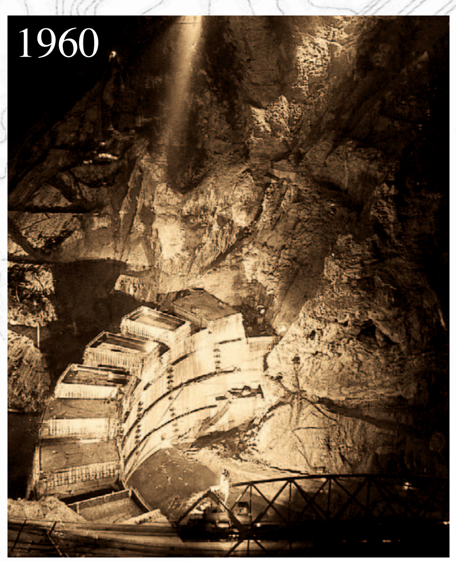


Penstock transportation

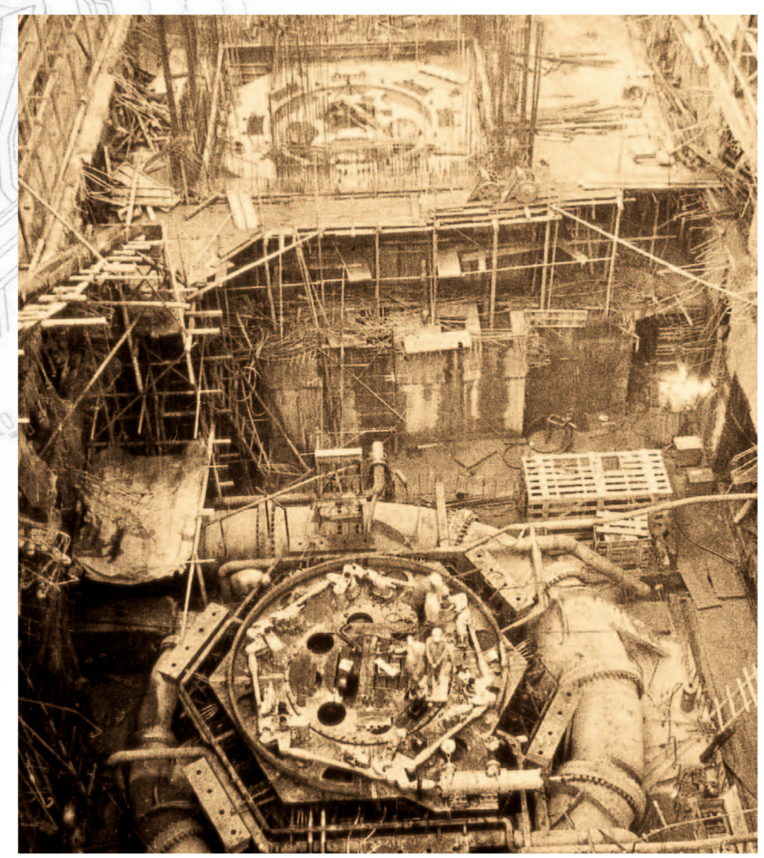


Dam outlet valve installation

Ohmachi-route fracture zone



Dam concrete placement in the night


Turbine installation

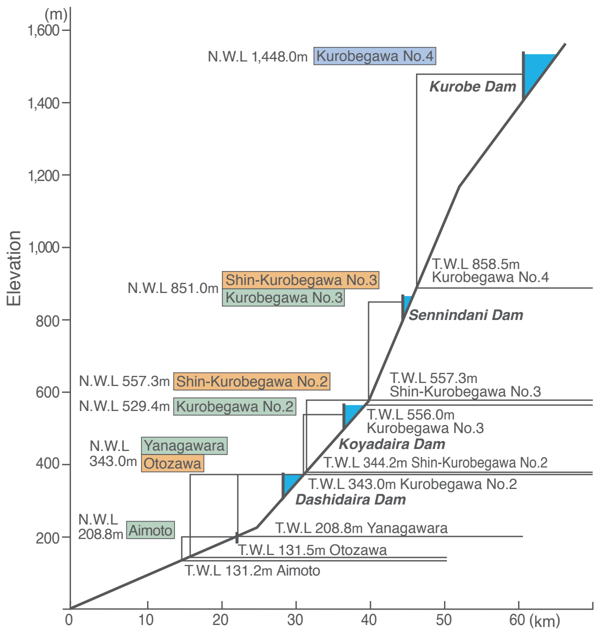
Consistent development in whole river system aiming at the maximum practical use of hydropower potential

In 1960s, Japan entered into a high economic growth period and electricity demand was increasing rapidly.
Large-scale thermal power plants and nuclear power plants were added to bear the base load.

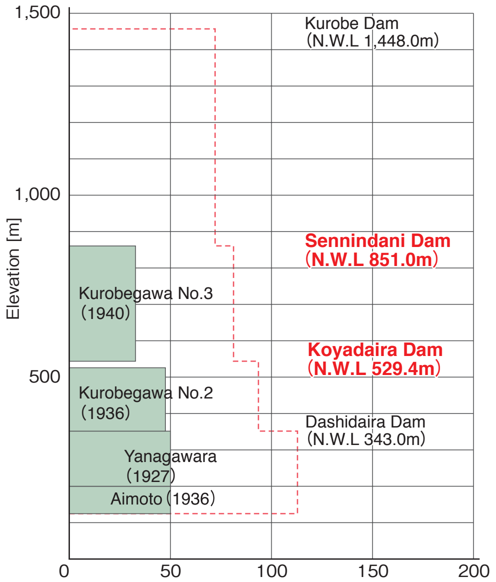
Hydropower plants, on the other hand, came to bear the peak load. Based on the concept of "consistent development in whole river system", a lot of peaking hydropower plants were developed. The concept is to construct a large reservoir in the uppermost reaches and to regulate the natural river flow.
Fully utilizing the head and flow of the river system, a series of hydropower plants along the river system operates like a single large peak power plant to provide peak output when needed.

The Kurobe River is one typical example of consistent development in whole river system as well as the Kiso River, the Sho River and the Jintsu River.
The development of the Kurobe River System began at the Yanagawara Power Plant in 1927, followed by Kurobe Dam in 1961 and ended at Otozawa Power Plant in 1985.

■Longitudinal Section of Kurobe River



1st period



Yanagawara Power Plant
Installed capacity: 54,000kW Discharge: 50.9m³/s
Effective head: 124.6m

Aimoto Power Plant
Installed capacity: 29,700kW Discharge: 50.1m³/s
Effective head: 71.5m

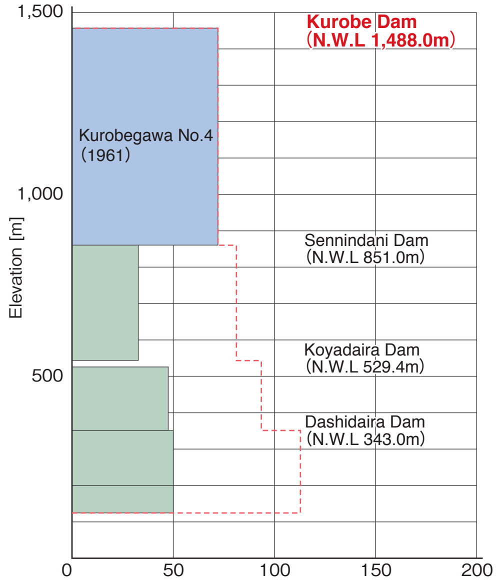
Kurobegawa No.2 Power Plant
Installed capacity: 72,000kW Discharge: 47.2m³/s
Effective head: 177.0m

Koyadaira Dam
Dam height: 51.5m

Sennindani Dam
Dam height: 43.5m

Kurobegawa No.3 Power Plant
Installed capacity: 81,000kW Discharge: 33.6m³/s
Effective head: 278.3m

2nd period

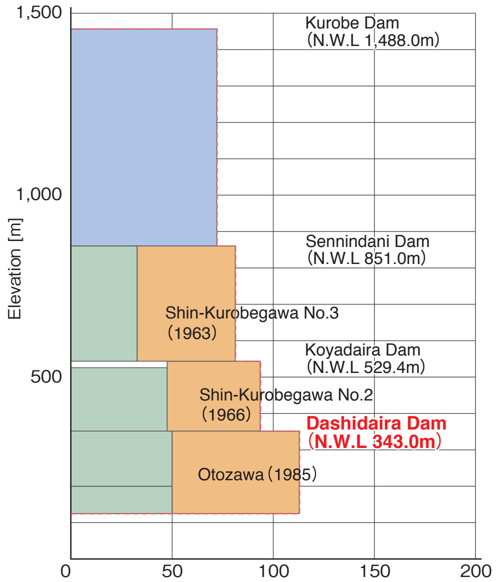


Kurobe Dam Dam height: 186.0m

Kurobegawa No.4 Power Plant
Installed capacity: 335,000kW
Discharge: 72.0m³/s
Effective head: 545.5m

Maturity

3rd period



Shin-Kurobegawa No.3 Power Plant
Installed capacity: 105,000kW Discharge: 46.0m³/s
Effective head: 269.0m

Shin-Kurobegawa No.2 Power Plant
Installed capacity: 74,200kW Discharge: 46.0m³/s
Effective head: 189.8m

Otozawa Power Plant
Installed capacity: 124,000kW Discharge: 74.0m³/s
Effective head: 193.5m

Dashidaira Dam
Dam height: 76.7m

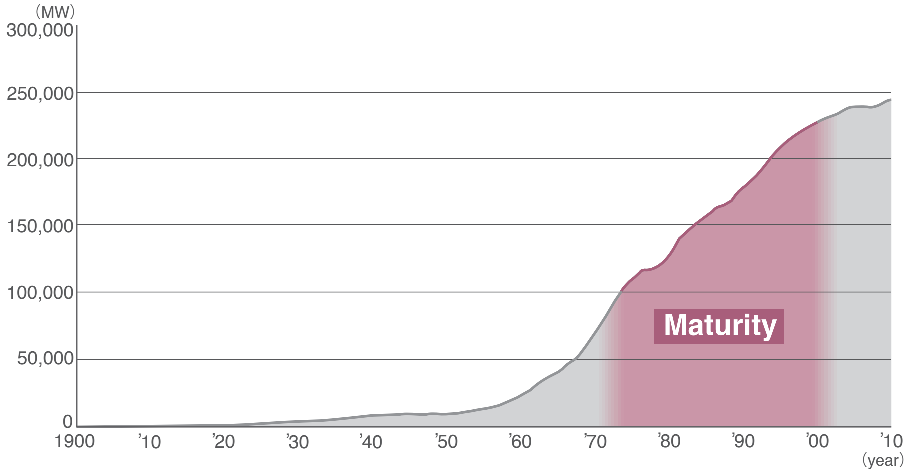
Maturity

Development of pumped-storage-type power plants to meet increasing peak demand

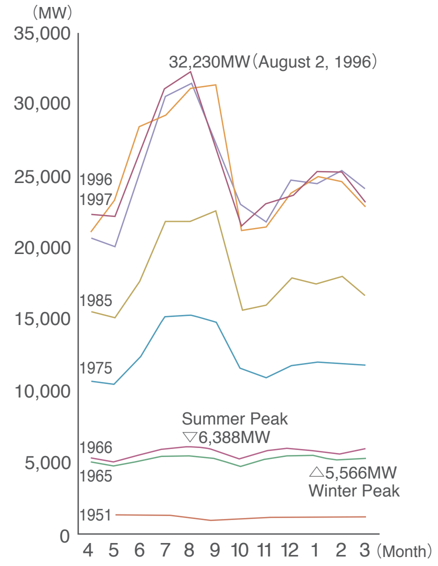
The daily demand curve of the day, especially at daytime in summer, became much sharper due to the prevalence of air conditioners.
This situation promoted the development of large pumped-storage-type hydropower plants.

Furthermore, the pumped-storage-type hydropower plants are essential for stabilizing the grid system in that they can immediately back up a system accident as well as can control system frequency.

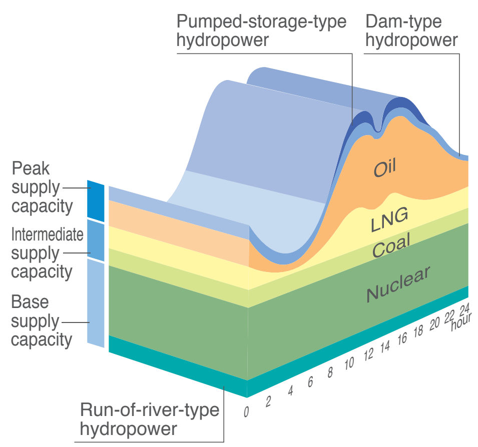
■Electricity demand in Japan at the time



■Annual load curve of KANSAI



■Daily load curve in a summer day



Ohkawachi Power Plant (Pumped-storage-type)
Installed capacity: 1,280,000kW Discharge: 382.0m³/s
Effective head: 394.7m

The Ohkawachi Power Plant has adopted adjustable speed function at pumping mode for the first time in Japan.

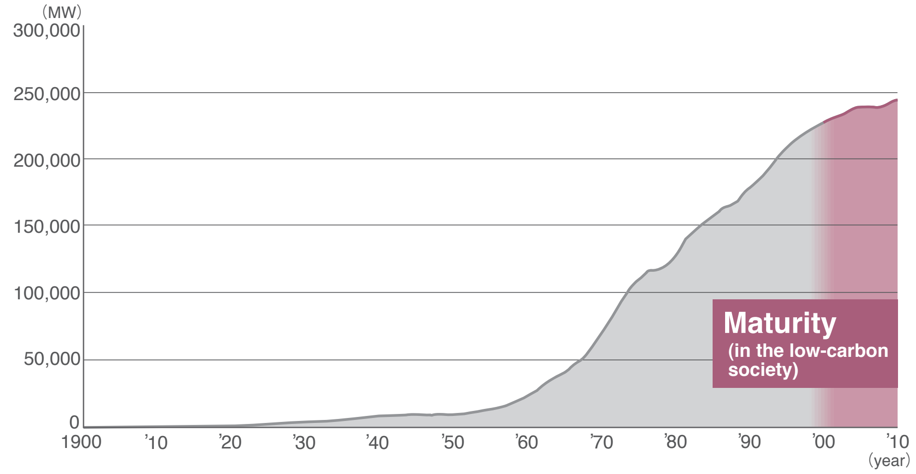
The function helps to stabilize system frequency, especially at night time.

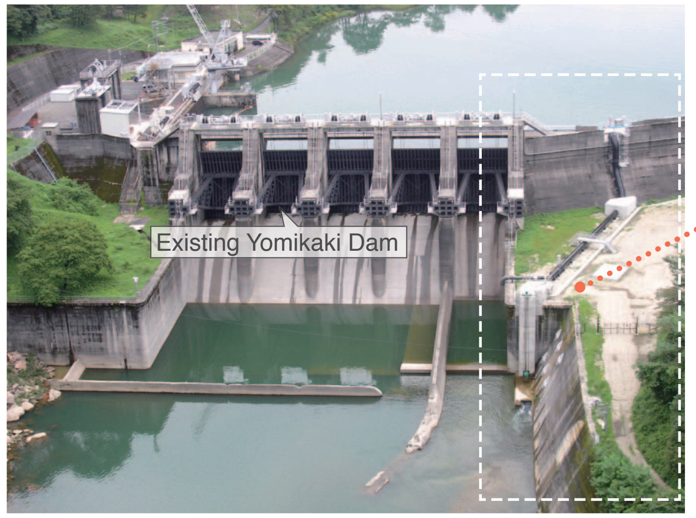
Kisenyama Power Plant (Pumped-storage-type)
Installed capacity: 466,000kW Discharge: 248.0m³/s
Effective head: 219.4m

Construction of small-scale hydropower plants as a main player in the low-carbon society

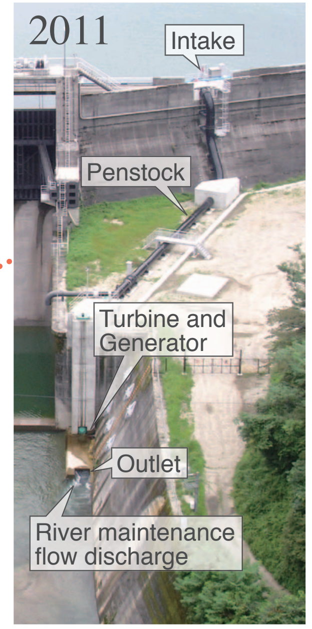
As hydropower potential was almost exhausted by 1980s, small-scale hydropower plants have been developed to correspond with the needs for clean and renewable energy as a main player in the low-carbon society.
Hydropower plants which utilize river maintenance flow discharged from dam and unused potential energy are being developed, and a construction project of hydropower plant which utilizes unused facility capacity such as sufficiently large section of existing headrace tunnel is implemented. The main concept among all projects is to utilize existing hydropower facilities effectively and efficiently.

■Electricity demand in Japan at the time

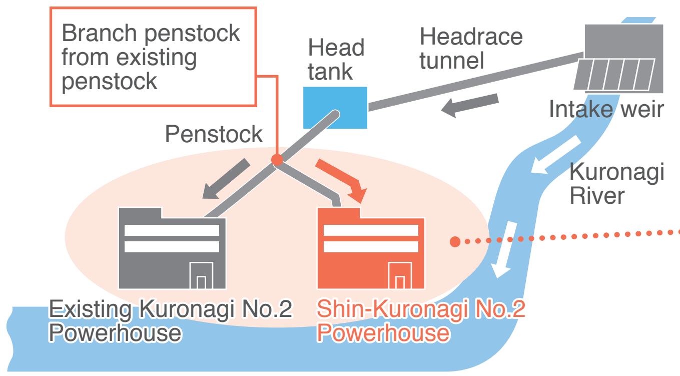




Okuwa-Nojiri Power Plant (using river maintenance flow discharge)
Installed capacity: 490kW Discharge:2.82m³/s
Effective head: 22.50m



The Okuwa-Nojiri Power Plant uses river maintenance flow discharge from the existing Yomikaki Dam reservoir and unused potential energy.



Shin-Kuronagi No.2 Power Plant utilizes the existing Kuronagi No.2 Power Plant facilities such as intake weir, head tank and headrace tunnel.

Shin-Kuronagi No.2 Power Plant
Installed capacity: 1,900kW Discharge:1.70m³/s
Effective head: 142.13m

Advanced power operation system, Reliable dam operation technology, Both support stable electricity supply.

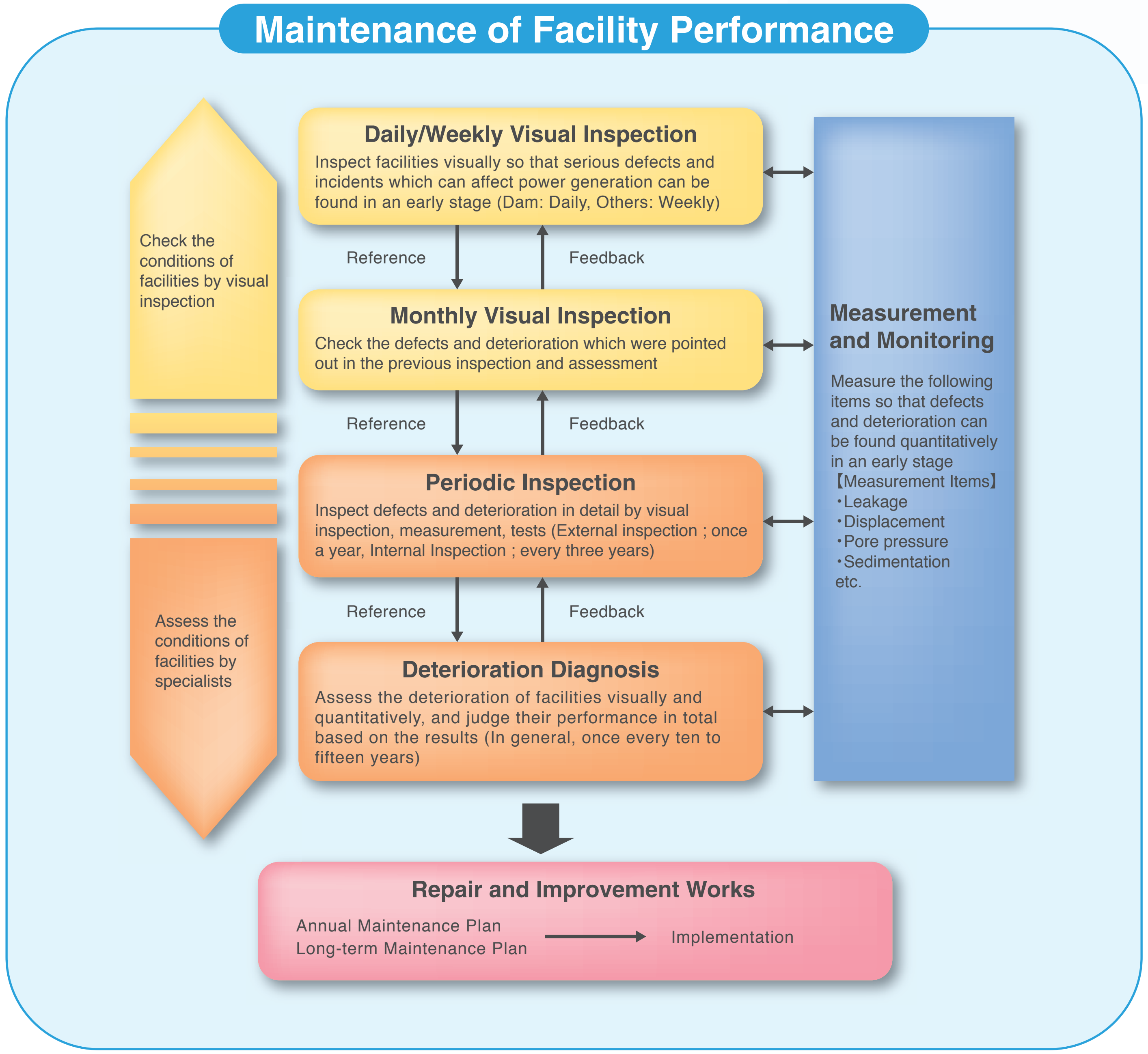
Large dams need careful operation because wrong operation might cause serious damage to the downstream area.
KANSAI has developed the unique dam operation system with advanced technology, which can make safe and sound operation of spillway gates.
KANSAI has distributed the system to 51 dams since 1992.

Yomikaki Dam Administration Office Computerized Control Board

Dam Operation Simulator of KANSAI

Features of Training with Dam Operation Simulator
・Simulation of actual dam operation
・Training program in accordance with the skill level of each trainee
・Simulation in case of mechanical trouble during gate operation

KANSAI developed a reasonable work flow regarding the maintenance of hydropower facility performance in order to ensure stable electricity supply. Inspection and assessment are conducted in accordance with this flow and repair and improvement works are implemented according to well-designed maintenance plan.

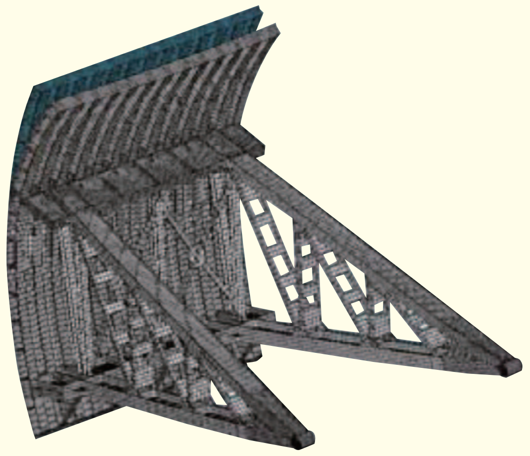


Operation

Maintenance

KANSAI's maintenance technology has sustained the hydropower history from 1891.

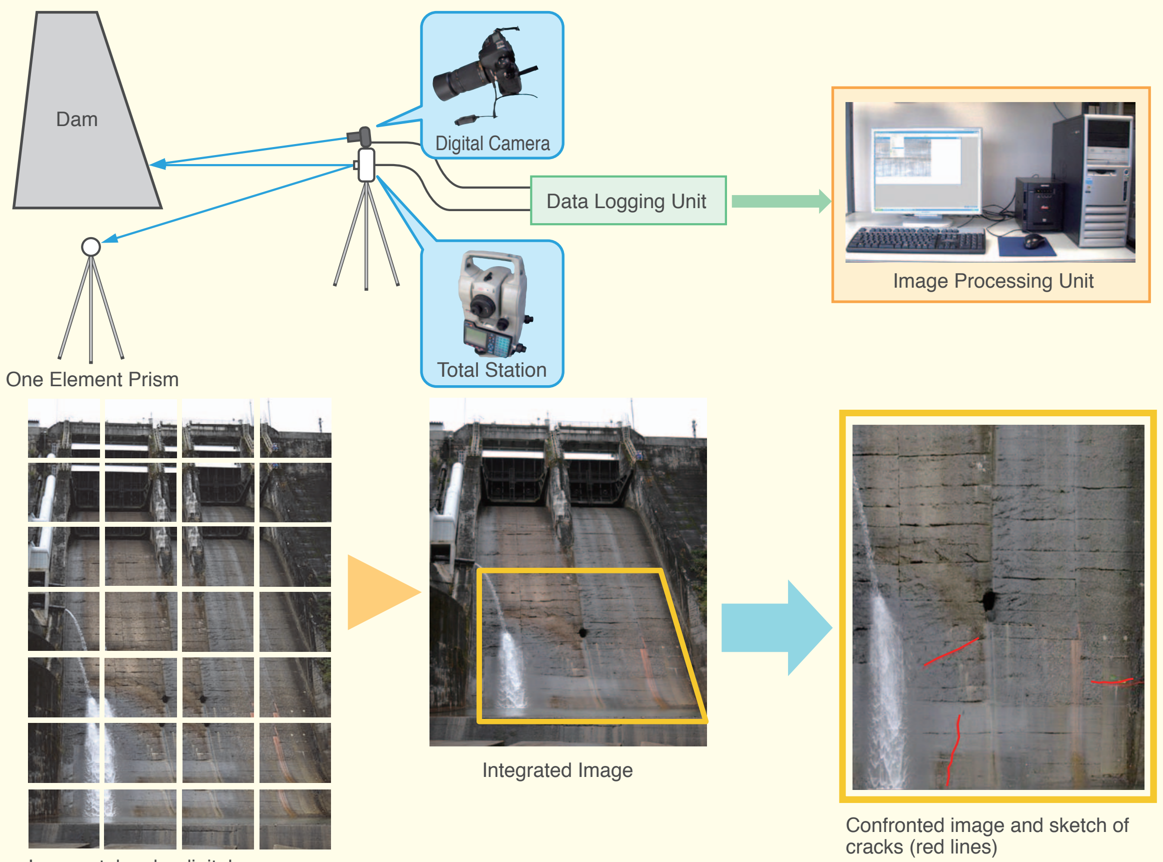
Proper maintenance work is indispensable to sustainable hydropower plant operation. KANSAI has put this important precept into practice. KANSAI's advantages lie in the accumulation of experiences and technologies.



Deformation Mode by Eigenvalue Analysis

Spillway gates are important facilities to keep the storage of water even in the event of an earthquake. KANSAI observed earthquakes at several points on an actual spillway gate and also conducted earthquake simulation experiments to identify the vibration characteristics. KANSAI prepared 3D-FEM model of the gate for eigenvalue analysis and confirmed that the series of predominant frequency from the analysis coincided with that from experiments.

The Investigation Method of Hydropower Facilities by using Digital Camera

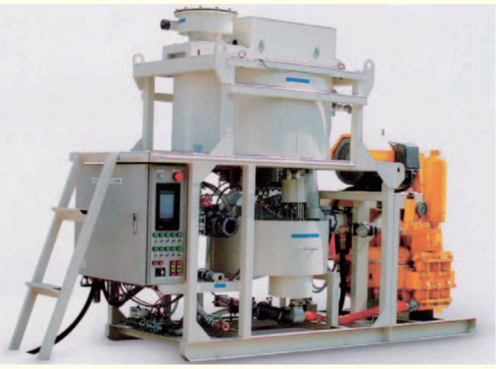


Images taken by digital camera

Integrated Image

Confronted image and sketch of cracks (red lines)

KANSAI has developed a image data acquisition system applying for such as surface of dams and concrete lining of tunnels and has confirmed the availability with a certain level of accuracy. KANSAI believes the new investigation method ensures the safety of field works and economic efficiency.

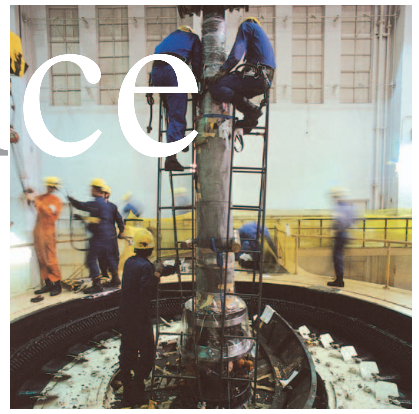


Automatic Grouting Control System on mix proportion

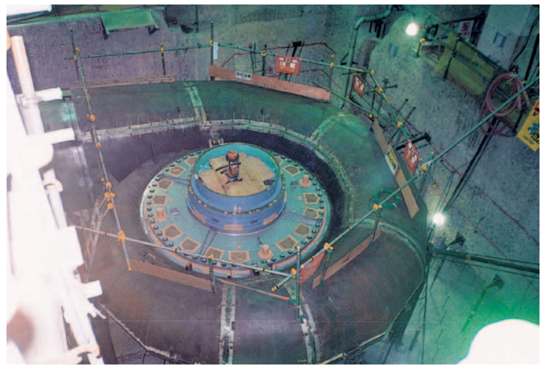
The system allows the user to reduce the grouting time and amount of cement fluid waste. Unlike the conventional batch change style, by changing the mix of cement fluid inside the grout mixer during grouting, the mixing proportion can be finely adjusted.

Frequency Domain Electromagnetic Method

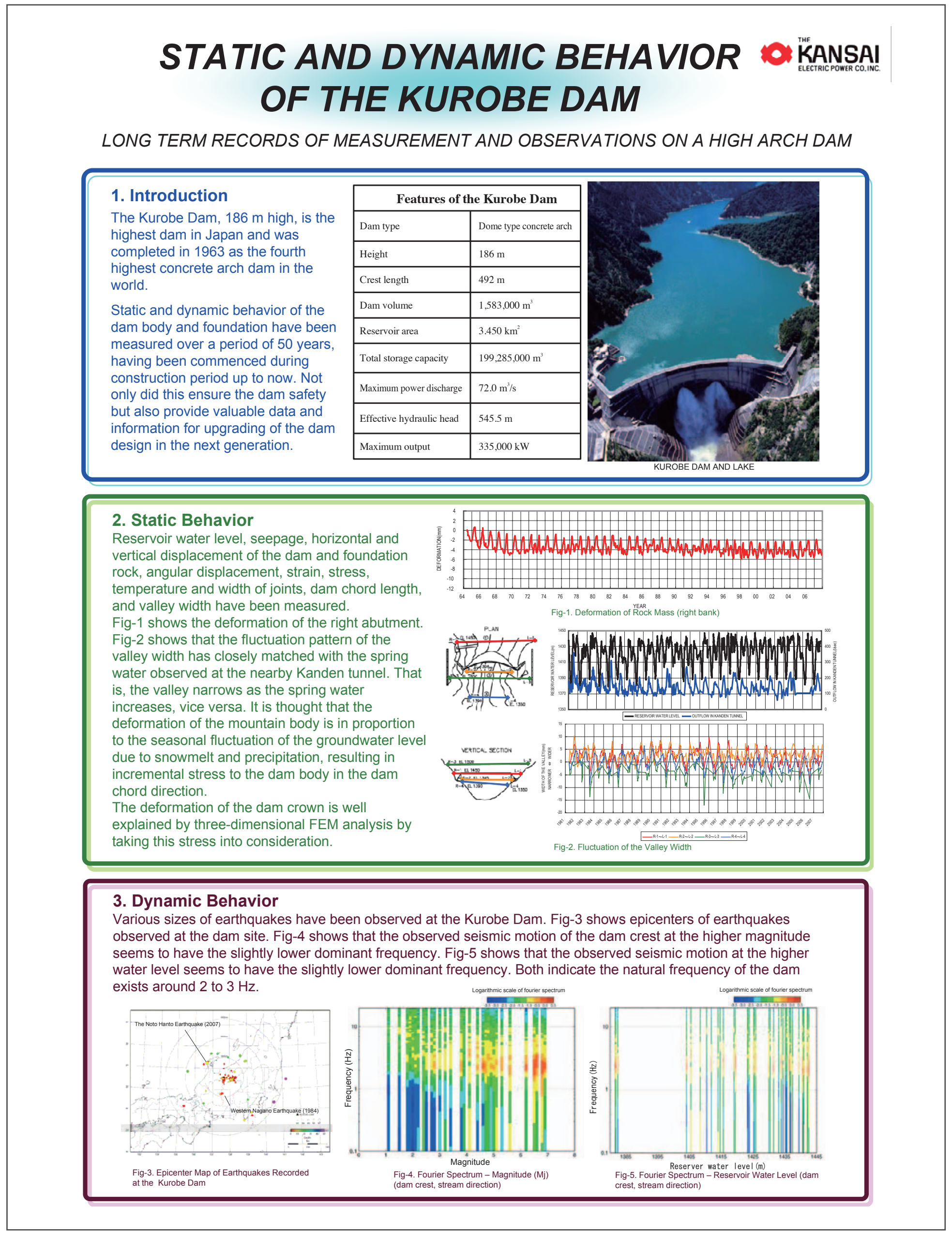
The compact FDEM system for the shallower sub-surface ground was developed. This system which is composed of a transmitter with 16 frequencies, a receiver and interpretation software is featured by its portability, speedy interpretation and applicability to the ground shallower than 20 to 30m.



Keage Power Plant
Turbine and Generator overhaul



Turbine and Generator replacement（Komaki Power Plant）
The turbines and generators which are more than 50 years old and which need large-scale repairing works have been replaced with new ones with additional output, by which the plant can enjoy the prolonged life.



STATIC AND DYNAMIC BEHAVIOR OF THE KUROBE DAM

LONG TERM RECORDS OF MEASUREMENT AND OBSERVATIONS ON A HIGH ARCH DAM

1. Introduction

The Kurobe Dam, 186 m high, is the highest dam in Japan and was completed in 1963 as the fourth highest concrete arch dam in the world.

Static and dynamic behavior of the dam body and foundation have been measured over a period of 50 years, having been commenced during construction period up to now. Not only did this ensure the dam safety but also provide valuable data and information for upgrading of the dam design in the next generation.

Features of the Kurobe Dam	
Dam type	Dome type concrete arch
Height	186 m
Crest length	492 m
Dam volume	1,583,000 m^3
Reservoir area	3.450 km^2
Total storage capacity	199,285,000 m^3
Maximum power discharge	72.0 m^3/s
Effective hydraulic head	545.5 m
Maximum output	335,000 kW

KUROBE DAM AND LAKE

2. Static Behavior

Reservoir water level, seepage, horizontal and vertical displacement of the dam and foundation rock, angular displacement, strain, stress, temperature and width of joints, dam chord length, and valley width have been measured.
Fig-1 shows the deformation of the right abutment. Fig-2 shows that the fluctuation pattern of the valley width has closely matched with the spring water observed at the nearby Kanden tunnel. That is, the valley narrows as the spring water increases, vice versa. It is thought that the deformation of the mountain body is in proportion to the seasonal fluctuation of the groundwater level due to snowmelt and precipitation, resulting in incremental stress to the dam body in the dam chord direction.
The deformation of the dam crown is well explained by three-dimensional FEM analysis by taking this stress into consideration.

Fig-1. Deformation of Rock Mass (right bank)

Fig-2. Fluctuation of the Valley Width

3. Dynamic Behavior

Various sizes of earthquakes have been observed at the Kurobe Dam. Fig-3 shows epicenters of earthquakes observed at the dam site. Fig-4 shows that the observed seismic motion of the dam crest at the higher magnitude seems to have the slightly lower dominant frequency. Fig-5 shows that the observed seismic motion at the higher water level seems to have the slightly lower dominant frequency. Both indicate the natural frequency of the dam exists around 2 to 3 Hz.

Fig-3. Epicenter Map of Earthquakes Recorded at the Kurobe Dam

Fig-4. Fourier Spectrum – Magnitude (Mj) (dam crest, stream direction)

Fig-5. Fourier Spectrum – Reservoir Water Level (dam crest, stream direction)

Panel displayed at ICOLD2012 in Kyoto

Static and dynamic behavior of the Kurobe Dam body and foundation rock has been measured during over half a century. Regular measurement and monitoring ensures the safety of the dam and provides valuable data and information for upgrading of the dam design in the next generation.

Flushing and Bypassing against sedimentation, KANSAI is a pioneer of these technologies.

The sedimentation problem is inevitable to the dam.

KANSAI moved flushing and bypassing to practical use for the first time in Japan
as a countermeasure against the sedimentation problem.

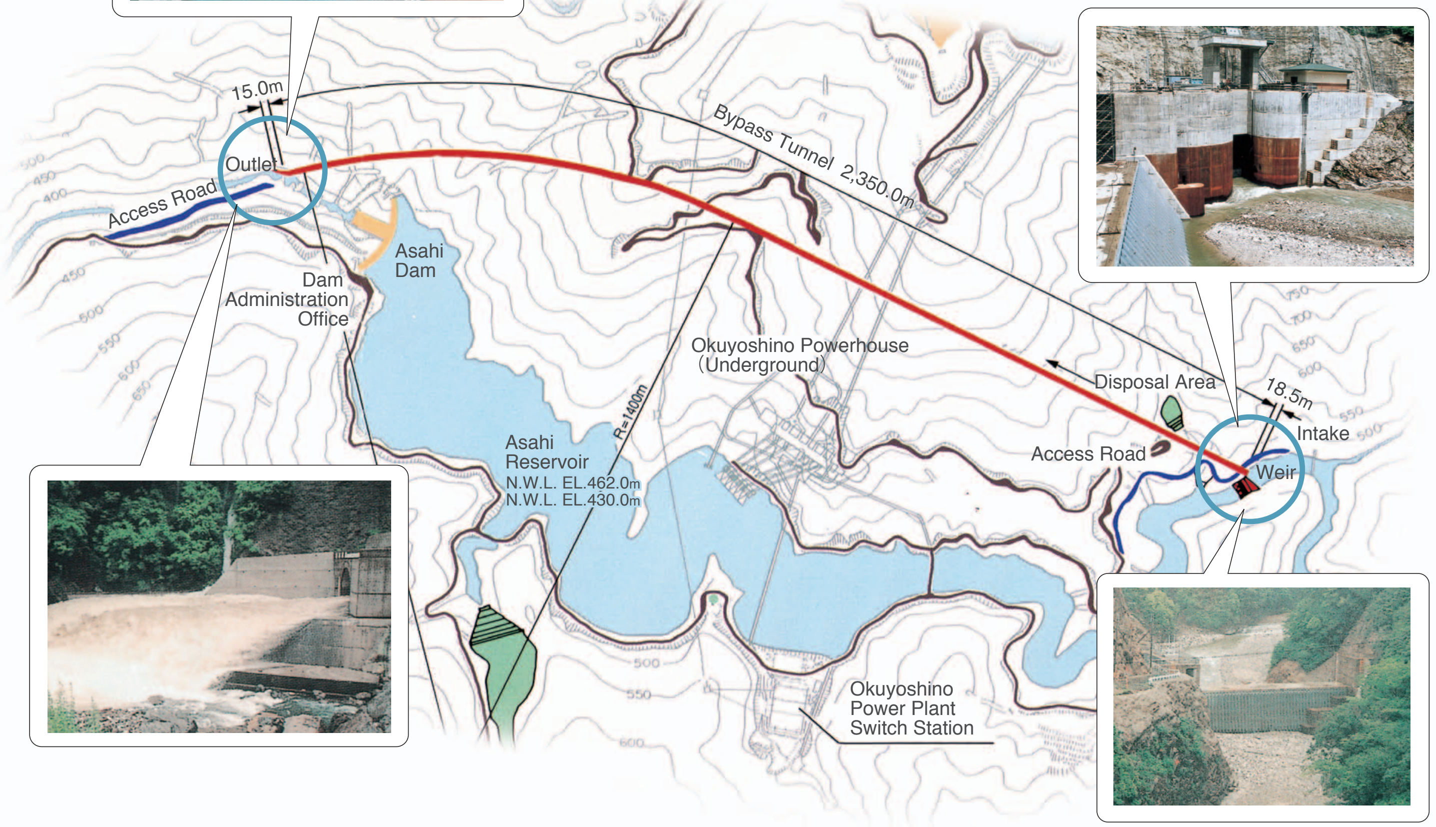
Now KANSAI has been accumulating variable data from
the Dashidaira Dam (flushing) and the Asahi Dam (bypassing).

Sediment

Dashidaira Dam under flushing

Bypassing at Asahi Dam

In 1998, bypassing equipment was additionally installed with the Asahi Dam constructed in 1978.
This was the first case in Japan.
This system resolves the problems of sedimentation and prolonged turbid water.
This technology is registered on the Register of the Japan Patent Office.
(PATENT NUMBER : No.3347104)



Before flushing

Under flushing

Flushing at Dashidaira Dam

About 500,000 m³ sediment per year is flushed through the flushing gates with tractive force at the end of flood.
The dam is equipped with two channels with 5 m wide and 5 m high for flushing. Each channel has 3 gates.
The sure operational procedure is supported by well-trained operators and numerical simulation results. KANSAI is also monitoring the downstream environment carefully.

KANSAI respects both "Energy" and "Environment".

The environmental preservation is vital for hydropower operation in recent years.
KANSAI makes much of the environment through the construction stage to the operational stage.

Tataragi Dam〈Lower dam of Okutataragi Power Plant〈Pumped-storage-type〉〉
Water pollution in a reservoir causes a big environmental problem to the downstream area as well as the reservoir itself.
KANSAI is conducting regular monitoring for water quality in reservoirs and observed data are compiled into a database for environmental assessment.

Imawatari Dam fishway
The Imawatari Dam on the Kiso River is equipped with a Denile-type fishway based on the experiment with real sweetfish.

Driftwood in reservoirs is recycled as precious resources.

Recycle center on Sho River（"EL FARM"）

KANSAI established a recycling plant and processes driftwood into stationery, fertilizer and other things there without emitting carbon dioxide caused by incineration.

Driftwood

EL FARM（Recycle center on the Sho River）

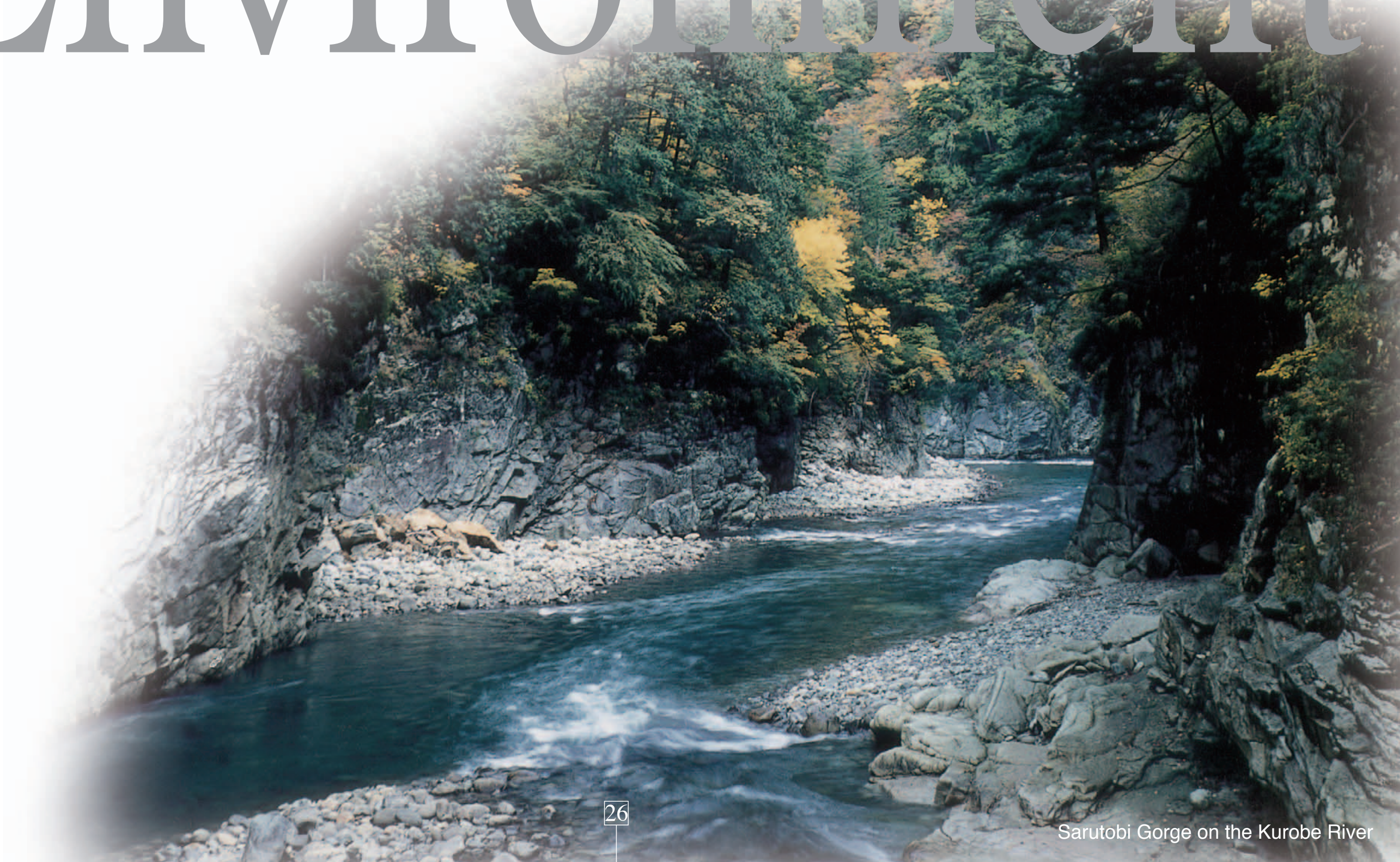
Stationery "KUROBE no KISEKI"

A lot of landslides occur in the Kurobe River basin due to its steep topography and hard climate.
KANSAI is practicing reforestation program in the Kurobe River basin, which is designated as a national park, for landscape preservation and slope protection.

Kurobe Dam downstream reforestation Before

After

Environment



Sarutobi Gorge on the Kurobe River

KANSAI is applying its technology to overseas projects.

KANSAI is participating in the improvement of electric infrastructures abroad mainly in Asian countries, utilizing its technology and know-how on hydropower. KANSAI hopes to assist the development, maintenance and operation of hydropower plants all over the world as a clean energy resource.

Signing ceremony of the contract

Hydropower Training participants

MYANMAR

Consulting services on hydropower development projects in Myanmar

KANSAI has contracted engineering consulting services on hydropower projects with Myanma Electric Power Enterprise (Department of Hydroelectric Power since February, 2002) in August, 2001. KANSAI is transferring hydropower expertise to Myanmar engineers serving as in-house engineers. Furthermore, KANSAI provides Hydropower Training Program for Myanmar engineers in Japan every year.

Seminar at the Department of Electricity

Electric Power Technical Standard Establishment Project in Laos

JICA (Japan International Cooperation Agency) is conducting the "Electric Power Technical Standard Establishment Project" in Laos from May, 2000 and KANSAI is participating in this project. Two hydropower engineers from KANSAI are playing technical instructors in Laos.

LAOS

VIETNAM

TAIWAN

PHILIPPINES

San Roque Multi-purpose Project (Philippines)

The San Roque Multi-purpose Project is a privatized project (BOT basis: Build Operate and Transfer) located on the Agno River in the Philippines. The hydropower plant is dam type with 345 MW rated output and the commercial operation started in May 2003.
This is the first IPP (Independent Power Producer) project for Japanese utility companies.

Overseas

INDONESIA

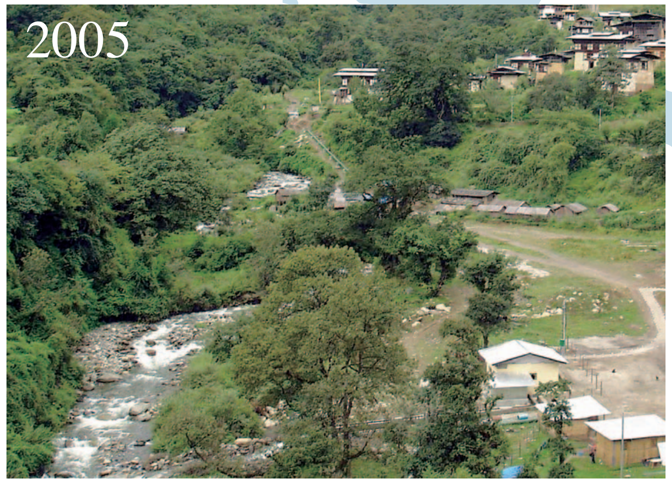
Hydropower Implementing Agreement (IEA)

The Hydropower Implementing Agreement is a working group of International Energy Agency (IEA) member countries and others that have a common interest in advancing hydropower worldwide. The Implementing Agreement's program is carried out by task forces, called Annexes. KANSAI serves as the Operating Agent in Annex XI which provides useful information to facilitate decision-making on the renewal and upgrading of existing hydropower facilities, through the presentation and analysis of relevant case histories covering good practice.

Annex XI Expert Meeting

Bhutan Micro-Hydro Project (CDM)

KANSAI constructed a micro-hydro power plant and distribution lines at a remote village in Bhutan through activities of "E7". This project demonstrated Clean Development Mechanism (CDM) as the worldwide leading case.



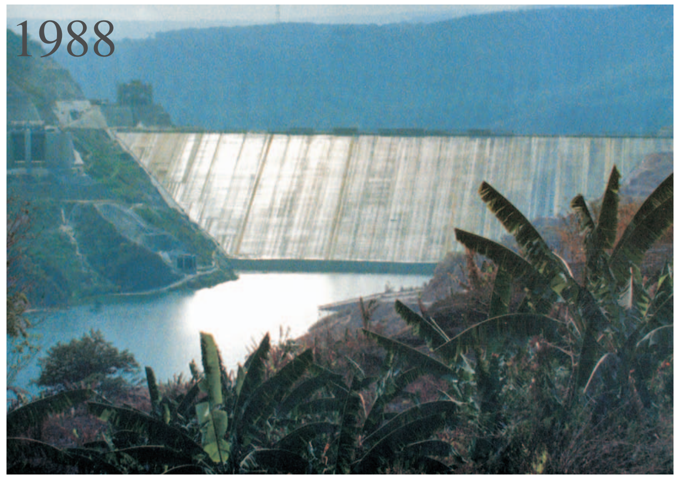
Chendebji Power Plant
Installed capacity: 70kW

Saguling and Cirata Project (Indonesia)

All development stages through the feasibility study to the construction management of these two big hydropower projects in Indonesia were conducted by NEWJEC which is one of the subsidiary companies of KANSAI.
The challenging spirit cultivated by the Kurobe Dam Project was applied to these projects.

Cirata Power Plant (Underground powerhouse excavation)
Installed capacity: 1,008,000kW
Discharge: 1,080m³/s Effective head: 112.5m

Saguling Dam
Dam height: 99m



Cirata Dam
Dam height: 126m

Corporate Data

(As of March 31, 2012)

Overview

Date of establishment	May 1, 1951
Paid-in capital	¥489,300 million
Outstanding shares	938.73 million
Operating revenues	¥2,503,100 million (consolidated: ¥2,811,400 million)
Total assets	¥6,660,400 million (consolidated: ¥7,521,300 million)
Employees	22,376
Energy sales volume	Lighting: 49,991 million kWh Power: 96,036 million kWh Total: 146,028 million kWh
Contracted customers	Lighting: 12,450 thousand Power: 1,070 thousand Total: 13,510 thousand
Gross system input	158,600 million kWh
System peak demand	33,060 MW (August 2, 2001)
Supply area	Entirety of Osaka, Kyoto, Nara, Shiga and Wakayama prefectures, greater part of Hyogo prefecture, and portions of Mie, Gifu and Fukui prefectures (total coverage area: 28,700km²)

Supply facilities

Power plants

Hydropower plants	151	8,199 MW (As of March 31, 2013)
Thermal power plants	12	16,910 MW
Nuclear power plants	3	9,770 MW
Solar power plents	1	10 MW
Total	167	34,889 MW

Transmission lines

Overhead	14,102 km	
Underground	4,413 km	
Substations	1,582	153,230 thousand kVA

Kansai International Airport