

“Dams in Japan”

Memorial lecture at 24<sup>th</sup> ICOLD Congress in Kyoto  
June 6<sup>th</sup>, 2012

Norihisa Matsumoto  
Japan Commission on Large Dams

1. Distinguished guests, ladies and gentlemen. It is my great pleasure to have this opportunity to talk on “Dams in Japan” at this opening ceremony of 24th ICOLD Kyoto Congress<sup>1</sup>.

**24th ICOLD Congress**  
**2 to 8 June 2012 ~ Kyoto, Japan**

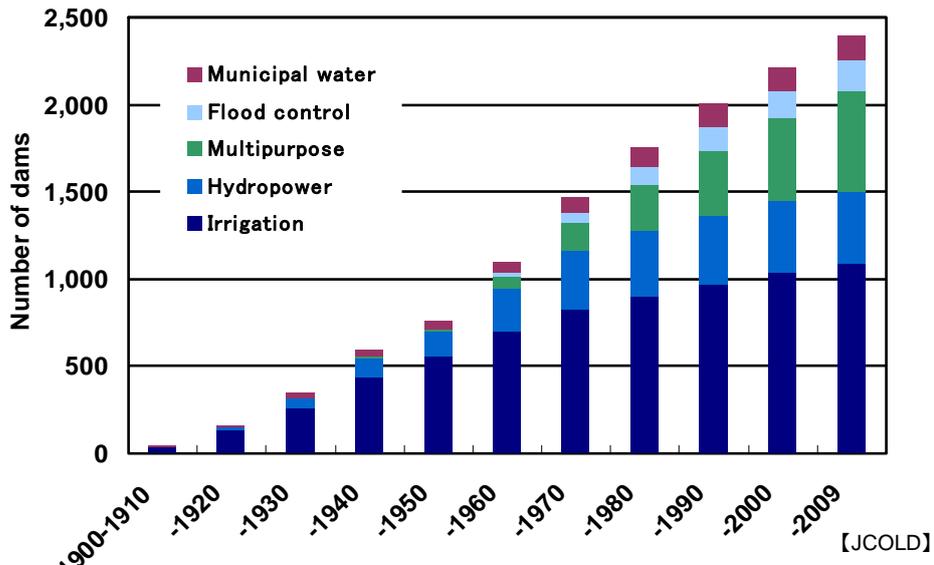


**[JWA]**

**Norihisa Matsumoto**  
**Japan Commission on Large Dams**

2. This diagram shows the increase in the number of dams which are higher than 15 m. Before 1900, we had about seven hundred irrigation dams. We started our modern dam construction in the end of the 19<sup>th</sup> century. The first masonry concrete gravity dam was completed in the year 1900. In those early days, the irrigation dams dominated in numbers, and hydropower and multipurpose dams increased later on<sup>2</sup>.

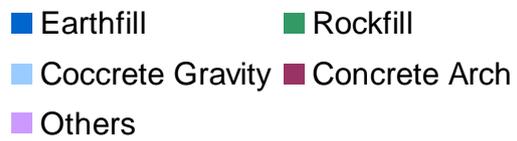
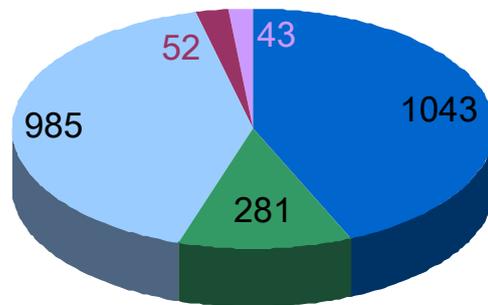
The increase of dams higher than 15 m after 1900 



Excluding 672 dams constructed before 1900, mainly irrigation use.

3. This chart shows which dam types are adopted in Japan<sup>3</sup>. Earthfill, concrete gravity and rockfill are major dam types. The earthfill type is usually used for small irrigation dams.

## Type of dams in Japan



4. Now we are looking at Sayama-ike Dam<sup>4</sup>. It was built in the early 7th century to supply irrigation water for rice crops, a Japanese staple food. It is one of the oldest dams in Japan. In 2001, the reservoir bottom was excavated by as much as three meters and the dam crest was raised by 1.1 meter. Increased storage capacity is used for flood control and irrigation.

## Sayama-ike Dam 2003

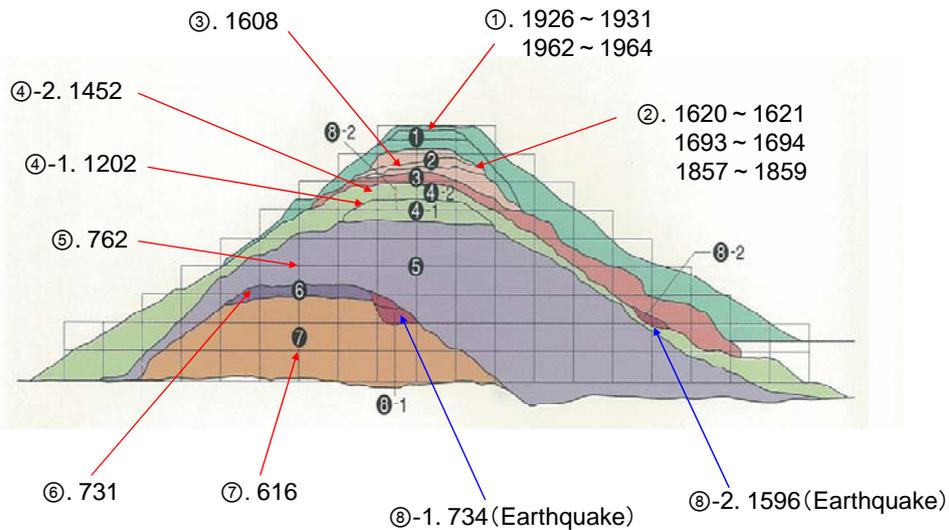


【Osaka Pref.】

5. During its modification work, the embankment was trenched, as shown in this slide<sup>5</sup>. This shows how Sayama-ike was raised and rehabilitated in the past. Major rehabilitations were made six times in 1,400 years. The foliage of broadleaf trees was found spread in layers at depths of every 10–15 cm. This was presumably used to ensure trafficability and good compaction. Traces of sand boiling and sliding caused by earthquakes were also found in the embankment. Still, the Sayama-ike Dam is commissioned for irrigation and flood control.

**History of Modification of Sayamaike Dam** 

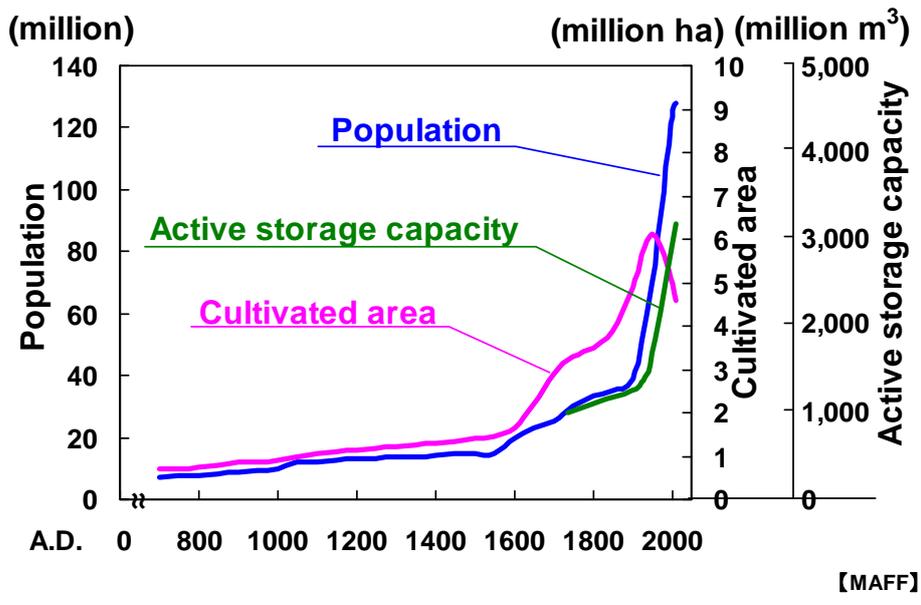
**2001 Rehabilitation**



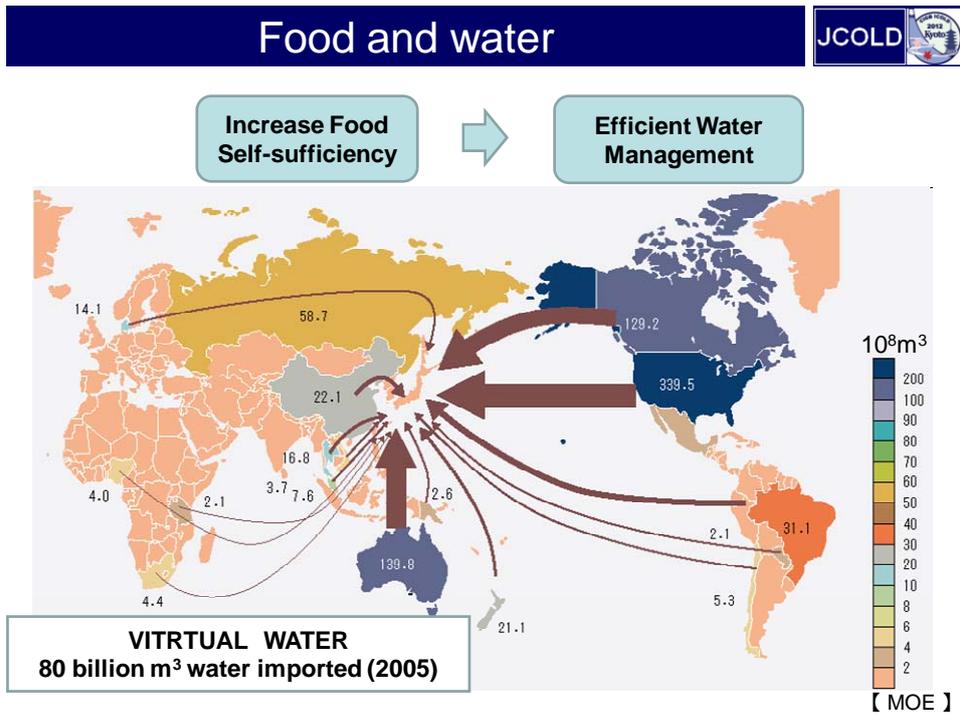
【Osaka Pref.】

6. Today, we have a population of 125 million people. The population increase started from the 17th century, and it has been supported by the increase of cultivated areas and irrigation water supply<sup>6</sup>. Numerous small dams stored irrigation water and sustained the food supply.

**Water has sustained population**



7. At present, our food self-sufficiency rate is not enough. We are aiming to increase it. Our annual water demand is 87 billion m<sup>3</sup> and 73 per cent of this volume is used for irrigation. We are importing significant amounts of food which is equivalent to about 80 billion m<sup>3</sup> in virtual water<sup>7</sup>. The snowfall is projected to decrease due to global climate change. We may suffer from serious shortage of irrigation water during and after the spring season because of decreased snow cover and earlier snowmelt. Efficient water management is needed.



8. We are now convening at Kyoto International Conference Center. If we travel 10 km south from here, we can see the first hydroelectric power station for public use in Japan. It is the Keage Hydropower station<sup>8</sup>. The power station started supplying electricity in November 1891 with two 80kW generators using water from Lake Biwa Canal. And the power station is still supplying power for Kyoto City. Electricity generated in the power station was utilized for spinning, textile, lighting, and street tram cars at that time. Most of the generators were imported from the USA and Germany<sup>9</sup>.

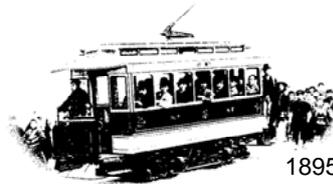
## The first hydropower station in Japan

### Keage Hydroelectric Power Station



1<sup>st</sup> Stage  
60kW - 200kW  
19 units  
Total 1760kW  
Commissioned since  
1891 by Kyoto City

Utilized for  
- Spinning  
- Lighting  
- Textile  
- Street cars

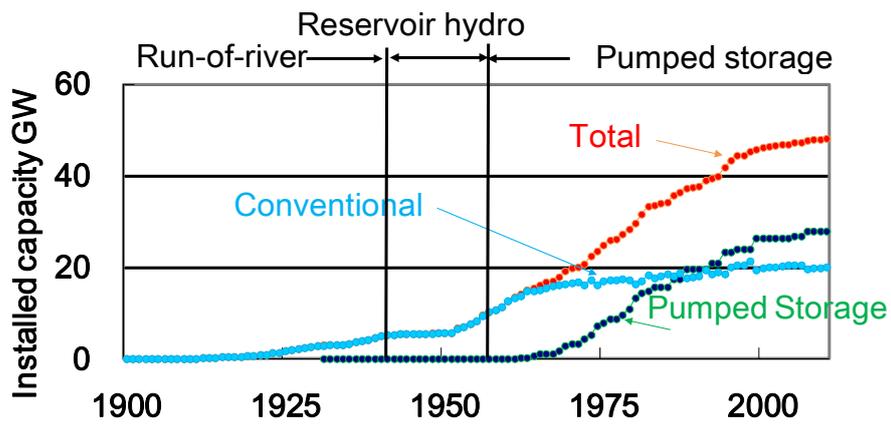


An Element of Lake Biwa Canal Project

【<http://www.suiryoku.com/> Kyoto City & KEPCO】

9. From 1900 to 1960's, hydropower constituted more than one half of the total electricity energy in Japan. In the first stage of hydro history up to 1940's we developed the run-of-river hydro and dam hydro, in the second stage up to early 1960's we built large capacity hydro, and after that we developed pumped storage power stations<sup>10</sup>.

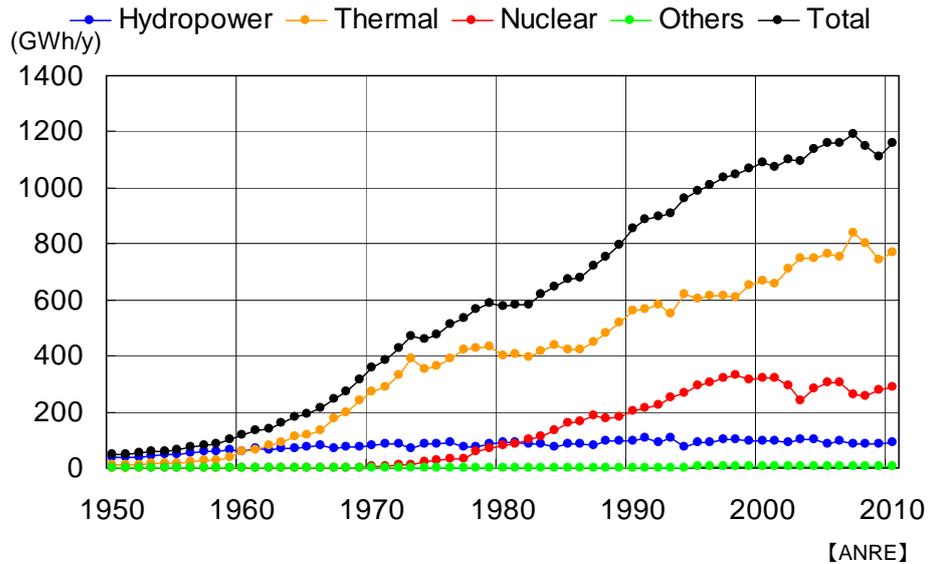
## Development of hydropower in Japan



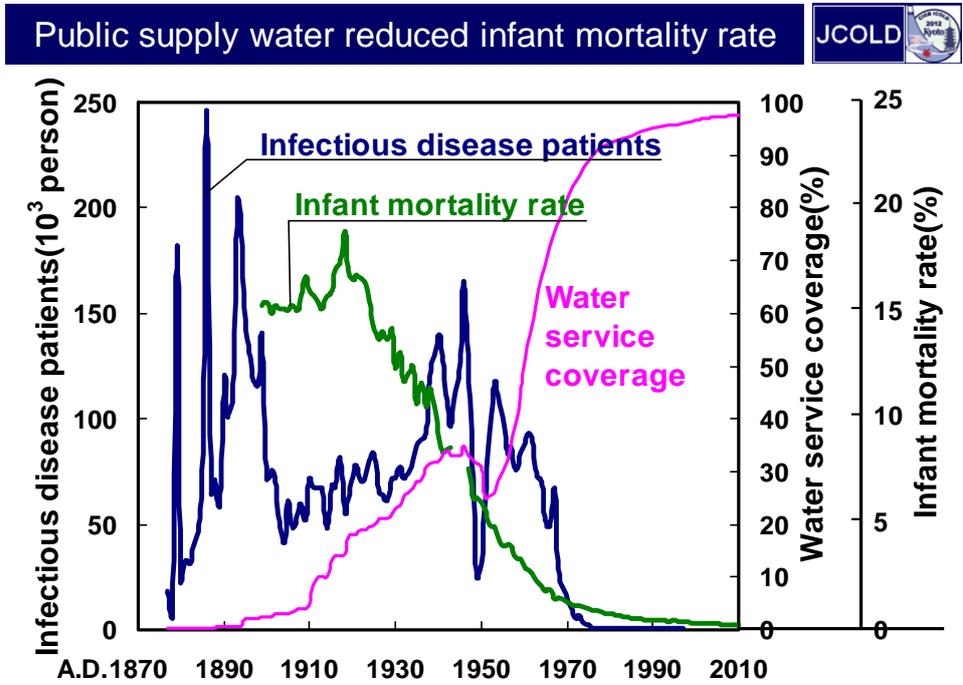
[ANRE]

10. Because of the rapid increase in electricity demand, many large scale thermal power plants have been built since the 1960's and also nuclear power plants since the 1970's. Only 1 per cent of total electricity demand in Japan comes from geothermal power, wind power and photovoltaic. Now the hydro decreased to 20 percent of total installed capacity and 8 percent of produced electricity<sup>11</sup>.

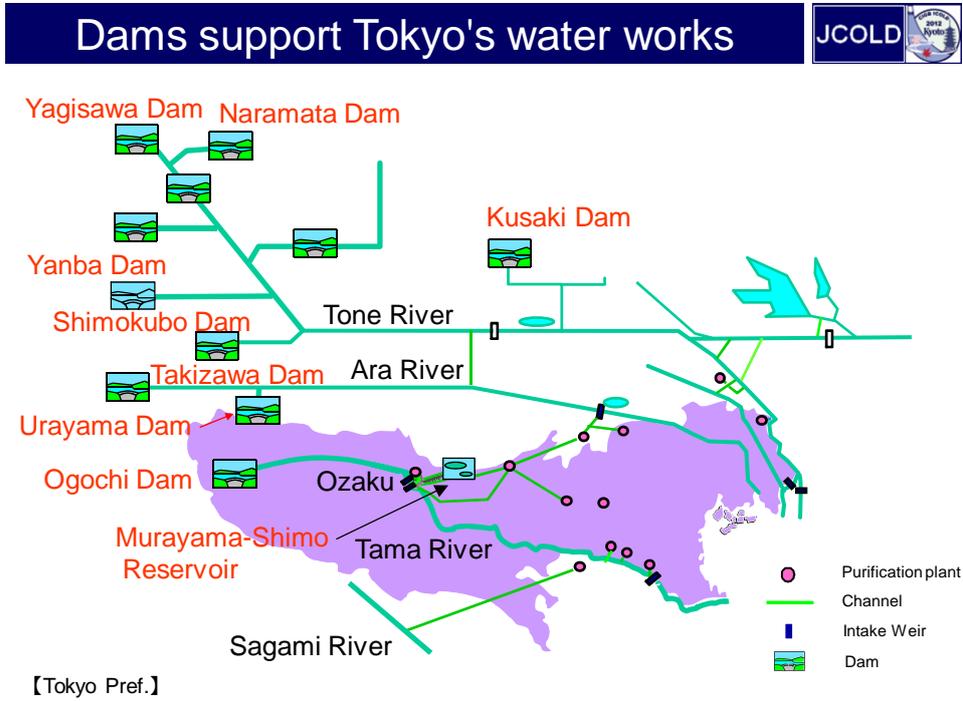
## Source of electricity energy in Japan



11. Nationally isolated Japan opened its door to overseas countries in mid 1800's. The very early modern dams in Japan were built for the water supply for ships and ports. In those days we frequently had outbreaks of epidemics. Chlorinated public water dramatically reduced infant mortality rate and the transmission of water-related diseases<sup>12</sup>.

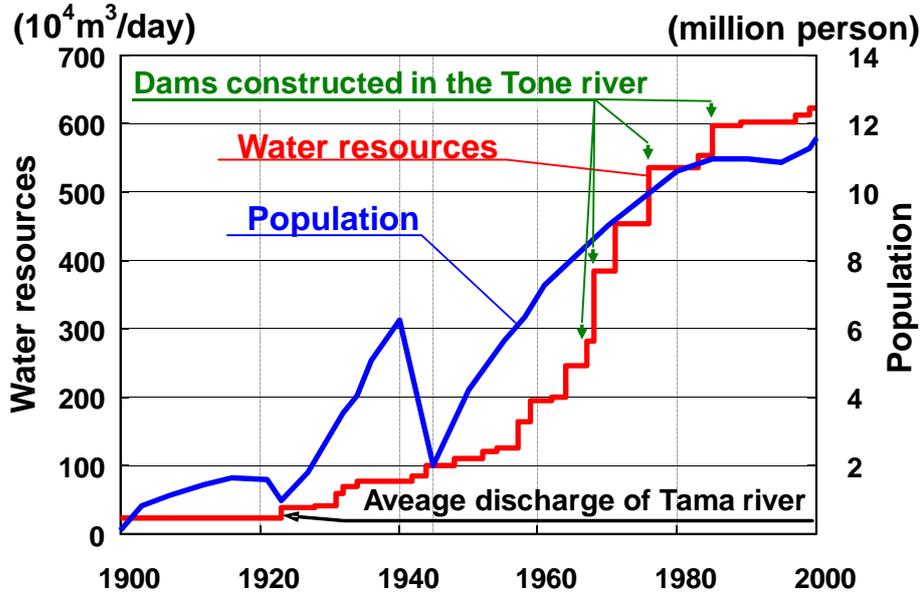


12. This is an outline of Tokyo waterworks that has a service area of 1,200km<sup>2</sup>, and serves a population of 12 million people. And total production capacity is 7 million m<sup>3</sup> per day. Water is provided by 11 dams outside of Tokyo and 1 dam inside of Tokyo<sup>13</sup>.



13. After World War Two, the population of Tokyo increased rapidly. In 1950's, we overused underground aquifers, and the ground subsided. Since then we switched the source from aquifers to surface water stored with dams built in other watersheds<sup>14</sup>.

## Dams support Tokyo's population



14. In August 2009, the ruling party was changed in the general election. Our country is facing an anxious period in the future, with a declining population, a rapidly aging population with fewer children, and a large long-term debt. Considering these factors, “The Future Flood Management Advisory Board” was established at the Ministry of Land, Infrastructure, Transport and Tourism in December 2009 to propel change in flood control policy which has the following statement: “depends on dams as little as possible”. The Board released an interim report in September 2010 to develop flood control plans with a wide-range of measures and concepts for overall assessment. The interim report included new re-evaluation criteria for ongoing dam projects. Individual dam construction plans have been reviewed based on the principles of this report. Cost, environment and feasibility are most important indicators for evaluation of the on-going projects<sup>15</sup>.

## The change of ruling party in 2009



The ruling party was changed in the 2009 general election. The new policy for flood control is that “depends as little as possible on dams”.

The Ministry established “The future flood management advisory board” in December, 2009.

It released the interim report in September, 2010.  
Evaluate ongoing projects based on “cost, environment, feasibility and others.”

15. A total of 83 projects are to be re-examined. As of 31st May, 24 projects were re-examined. The decision was made for 17 examinations to be continued and for 7 to be discontinued.

## Evaluation of on going dam projects



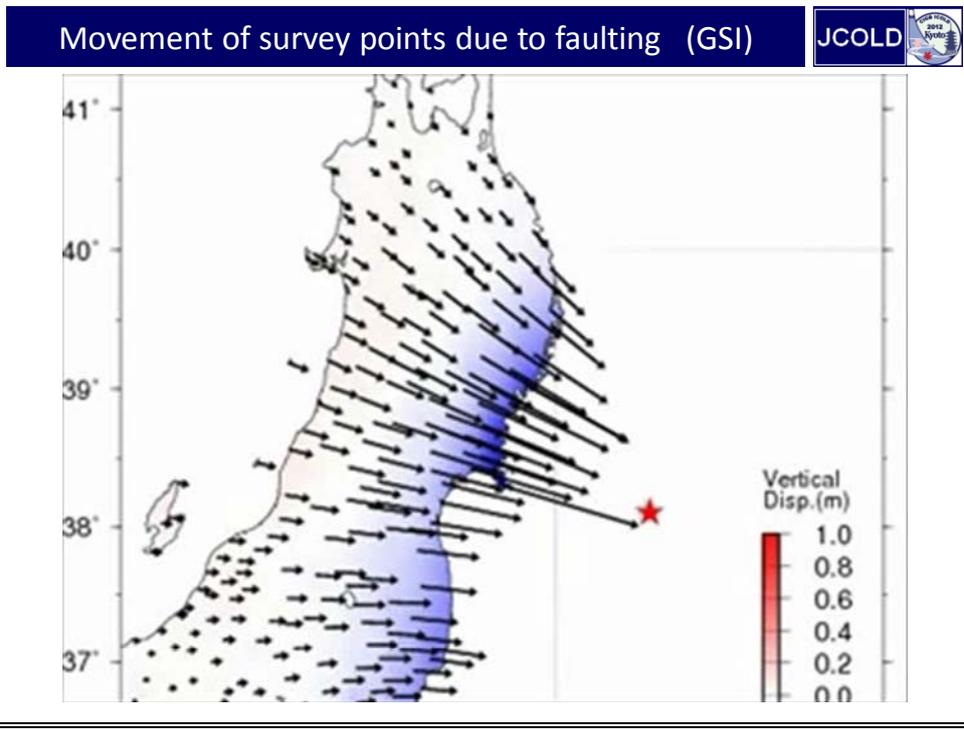
As of May 31, 2012

Jurisdiction	Total	examined	continue	discontinue
Central government	25	3	1	2
Japan Water Agency	5	0	0	0
Local governments	53	21	16	5
<b>Total</b>	<b>83</b>	<b>24</b>	<b>17</b>	<b>7</b>

【MLIT】

16. The 2011 Tohoku Earthquake of magnitude 9.0 shook eastern Japan and caused catastrophic effects including tsunami and nuclear accidents. At 14:46 on March 11th, the rupture started from the off-shore of east Japan and the eastern tip of the Japanese islands stretched as much as 5.1 meters to the east<sup>16</sup>. After the main shock, numerous after-shocks occurred including several events with a magnitude greater than 7.0. The Jogon earthquake of magnitude 8.4 which is now considered to be the predecessor of the Tohoku earthquake occurred on 13 July, 869 in this region. The Sendai area was devastated by a large tsunami. It was a great regret that we forgot this event of eleven hundreds years ago.

We at JCOLD received mails with a strong sense of solidarity. We are deeply grateful to the kindnesses shown by the friends of ICOLD.



17. About 400 dams were inspected immediately after the Tohoku earthquake. Generally dams performed well with minor or moderate damage<sup>17</sup>. Investigations suggest that the very long duration of the ground motions and the number of subsequent strong aftershocks rendered more adverse effects on embankment dams than on concrete dams.

## Inspection of dams after the main shock



Jurisdiction	Owner	Number of dams	
		inspected	suffered unusual behavior* or damage (failure)
Ministry of Land, Infrastructure, Transport and Tourism	Central Gov.	46	11
	Local Gov.	104	8
Ministry of Agriculture, Forestry and Fisheries	Central Gov.	51	4
	Local Gov.	121	23(1**)
Ministry of Economy, Trade and Industry	Utilities	69	2
<b>Total</b>		<b>391</b>	<b>48(1)</b>

\*unusual behavior: small increase of leakage & uplift, nominal settlement and others

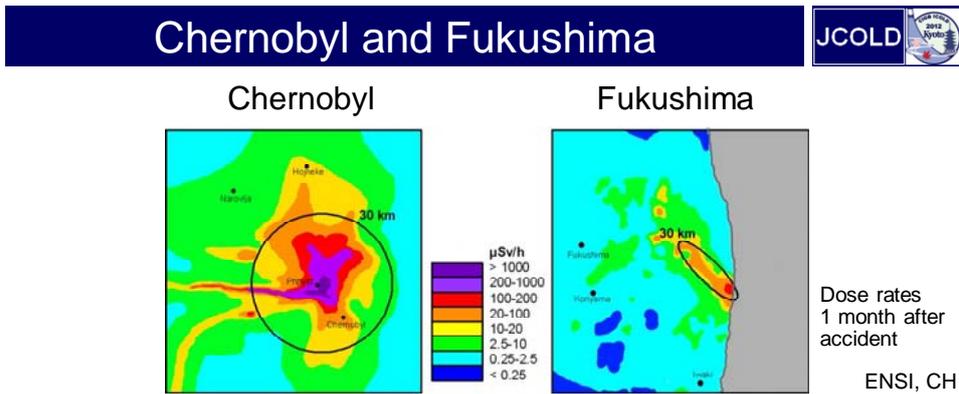
\*\* a failed dam was on a non-regulated river

18. While most dams sustained no damage, one homogeneous earthfill dam for irrigation completely failed. Fujinuma-ike was breached shortly after the earthquake with the loss of eight lives. It is an 18.5 m high earthfill structure on a non-regulated river. The review panel that reviewed the cause of Fujinuma-ike failure concluded that the primary cause of the failure was the composition of its upper embankment of sand rich materials triggered by the strong earthquake motion and its long duration<sup>18</sup>. The compaction of the embankment had been a lower standard than would be acceptable for modern construction practice and the strength of the embankment is small in undrained condition during earthquakes. The upper zone was constructed during the period immediately after the war when the construction environment was poor.

Breached reservoir photoed 14 March, 2011



19. The failure of backup power at Fukushima Dai-Ichi nuclear power station on March 11 caused the worst atomic accident since Chernobyl in 1986, and radiation fallout forced the evacuation of about 160,000 people. Prof. Prasser at the Swiss Federal Institute of Technology presented this slide at Hydro 2011 in Prague, Czech Republic<sup>19</sup>. He allowed me to show this here. Early evacuation was made and there will be no acute radiation diseases and latent health consequences in Fukushima.



- No acute radiation diseases in Fukushima
- Latent health consequences limited due to timely evacuation
- Partial durable land loss in evacuation zones and beyond (partial resettlement possible and planned)
- Contaminated food has to be withdrawn from circulation

Main specifics of severe nuclear accidents

Prof. Prasser,

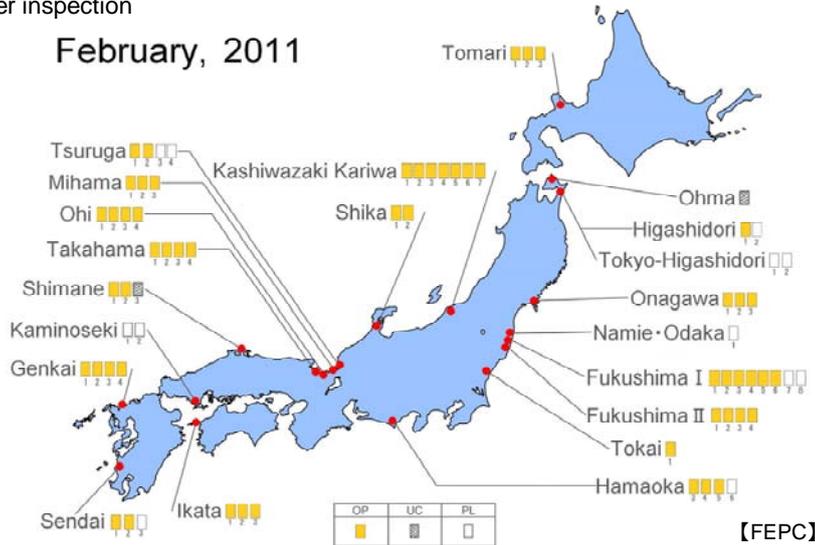
20. Before the March 11 earthquake, we had 54 nuclear reactors<sup>20</sup>. Four reactors of Fukushima-Daiich were decommissioned after the earthquake. Tomari nuclear power station unit 3, the last nuclear reactor remained operational in Japan, was shut down for periodic inspection on May 5. All 50 nuclear power stations in Japan are now shut down for maintenance. This is the first time in 42 years since 1970. They must withstand tests against earthquakes and tsunamis, and local authorities must give their consent in order for plants to restart.

The governors and mayors from western Japan had earlier indicated that they would agree to restart Ohi nuclear power station units 3 and 4 of Kansai Electric Power Co. According to the papers, the Prime Minister will make a final decision to restart those two reactors to avoid a summer power crunch very soon.

**Locations of nuclear power stations in Japan** 

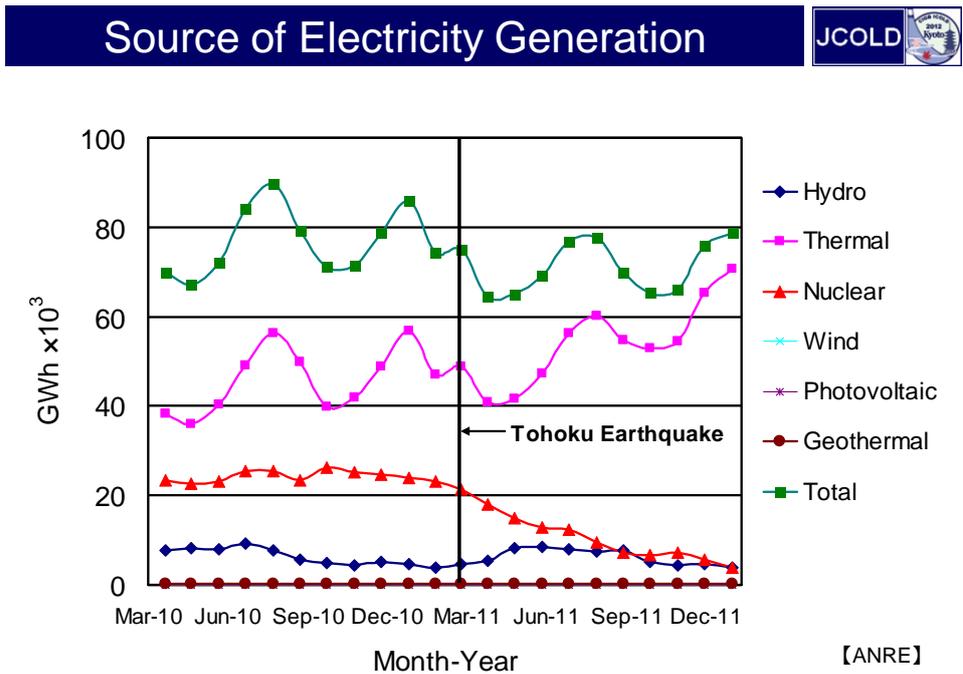
In February 2011, 54 units were operating.

In June 2012, 4 units were decommissioned and the rest of all 50 are not operating under inspection



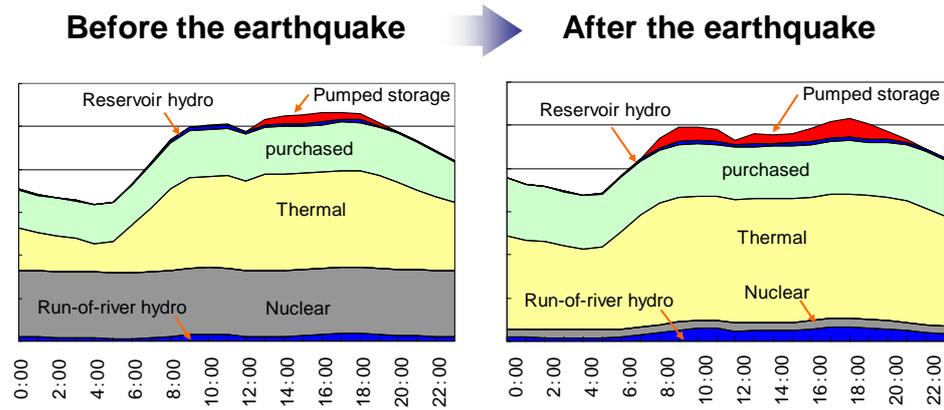
21. The utilities have been forced to turn to coal, oil and gas-fired plants to keep factories, offices and households supplied with electricity<sup>21</sup>. Buying and importing those fuels is driving up costs and may lead to higher electric bills and a further drag on an economy that's contracted in three of the past four years.

In the summer of 2011 stringent energy conservation measures were applied leading to a 12% reduction in power consumption in August, and more significantly, a reduction in peak demand reaching 18%, exceeding the government target of 15%.



22. We are looking at the load curves of power before and after the earthquake. To compensate for the shutdown of nuclear power for electricity generation, the utilities are generating energy from combustion power plants. Since the earthquake, there is more reliance on run-of-river hydro power, reservoir hydro and pumped storage power stations.

## Load curves for one sample day



23. Now the majority of people see hydropower in a new light. We recognized again hydro is domestic, renewable, clean and reliable electricity. Although hydropower development is relatively mature in our country, we have various ways to increase hydropower such as small hydro, installing turbine in existing dams, improving efficiencies at generating dams, and raising the dam. Government policy and promotional measures play a vital role in sustainable hydropower development. We should work with institutions involved.

## Hydropower after the earthquake



People have begun to see hydropower in a new light.

It is domestic, renewable, clean and reliable electricity.

Adding new hydropower capability to existing dams,  
improving efficiencies at generating dams.

Building small scale hydropower.

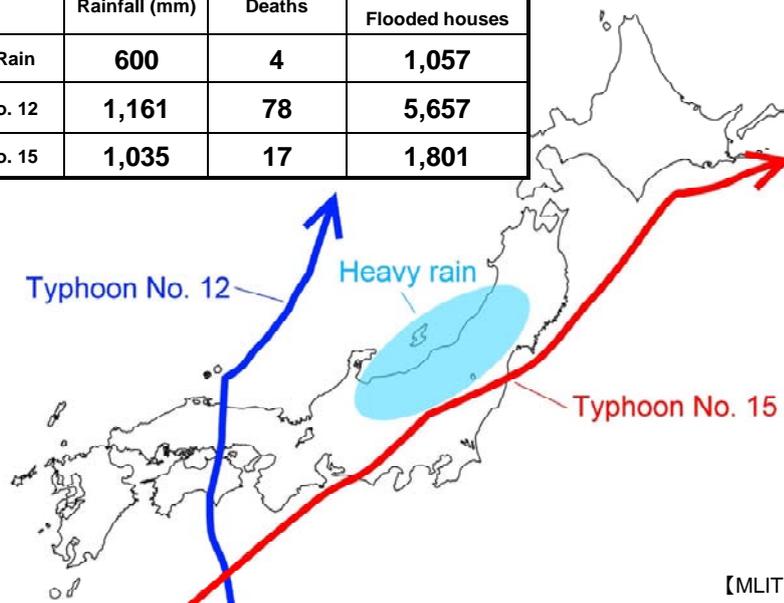
Government policy and promotional measures play a key  
role in sustainable hydropower development.

24. We not only had the Tohoku earthquake but we had floods in 2011. In July, Northern Japan was battered by torrential rain<sup>22</sup>. Niigata and Fukushima prefectures were the areas worst hit. Four hundred thousand people were advised to evacuate their homes as authorities fear potential flooding damage. We also had two powerful typhoons in September. Landslides caused "natural dams" that blocked the flow of rivers. Emergency measures were implemented such as river course digging.

## Flood disaster in 2011 in Japan

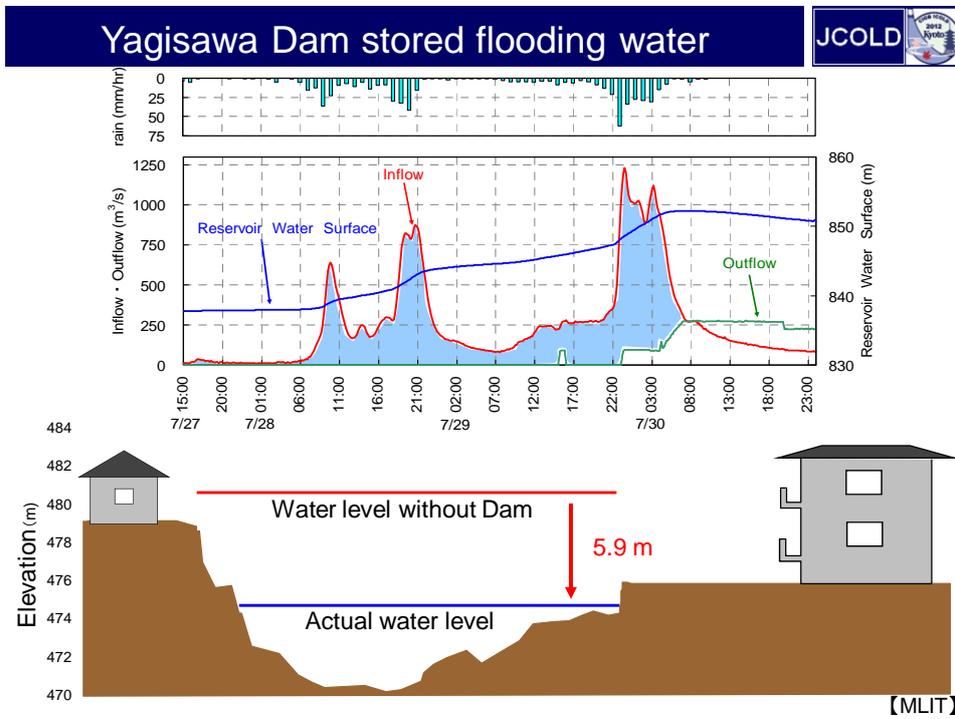


	Rainfall (mm)	Deaths	Number of Flooded houses
July Heavy Rain	<b>600</b>	<b>4</b>	<b>1,057</b>
Typhoon No. 12	<b>1,161</b>	<b>78</b>	<b>5,657</b>
Typhoon No. 15	<b>1,035</b>	<b>17</b>	<b>1,801</b>



【MLIT】

25. During the July torrential rain, we had 600 mm of rain for three days. Three dams upstream of Tone River stored flooding water and it reduced the downstream water level as much as six meters and successfully mitigated the flooding damage<sup>23</sup>.



26. Our other challenges are to use existing reservoirs effectively. We have been tackling rehabilitation, environmental upgrading and strengthening.

## Our challenges

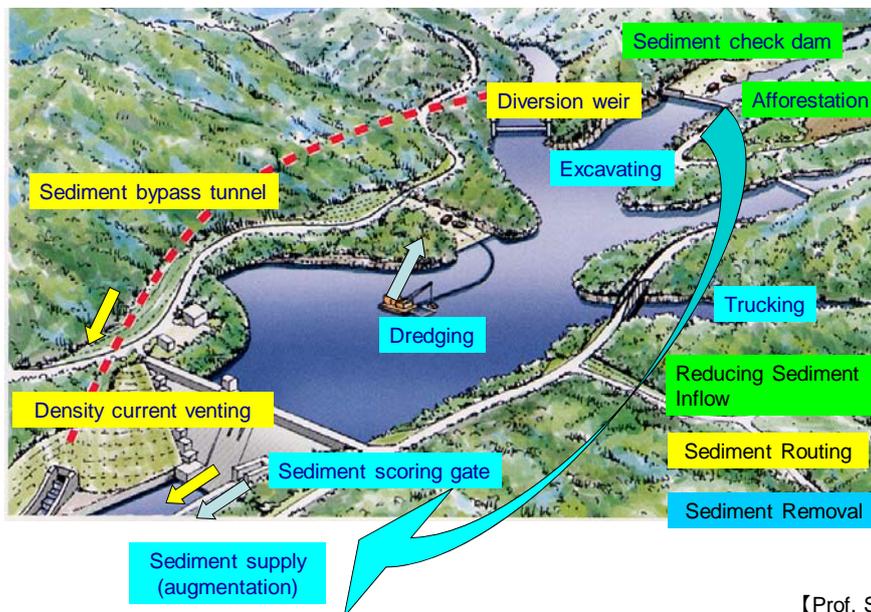


- Effective use of existing reservoirs
- rehabilitation (aging, earthquake, flood)
- water quality
- sedimentation
- fishway
- climate change
- flood security

27. When we discuss the sustainability of water resources, one of the critical issues is the sedimentation of the reservoirs. The negative aspects of reservoir sedimentation are progressive loss of storage capacity, and increased erosion in the downstream river channels. Sedimentation rates vary with regions. We find highest yields in the geologically active regions where earthquakes often occur. In these regions, some of dams aged over 50 years old have lost 60 to 80 percent of the reservoir volume due to sedimentation. Therefore we need some countermeasures against sedimentation. Various sediment-handling measures are available to mitigate the negative impacts of reservoir sedimentation. These are erosion control by fostering and safeguarding the natural vegetation cover, bypassing, sluicing, flushing and dredging<sup>24</sup>.

Rivers not only transport water but also transport sediments. For the prevention of degradation of the downstream rivers and coastal erosion, we have to develop comprehensive management schemes for sediment routing.

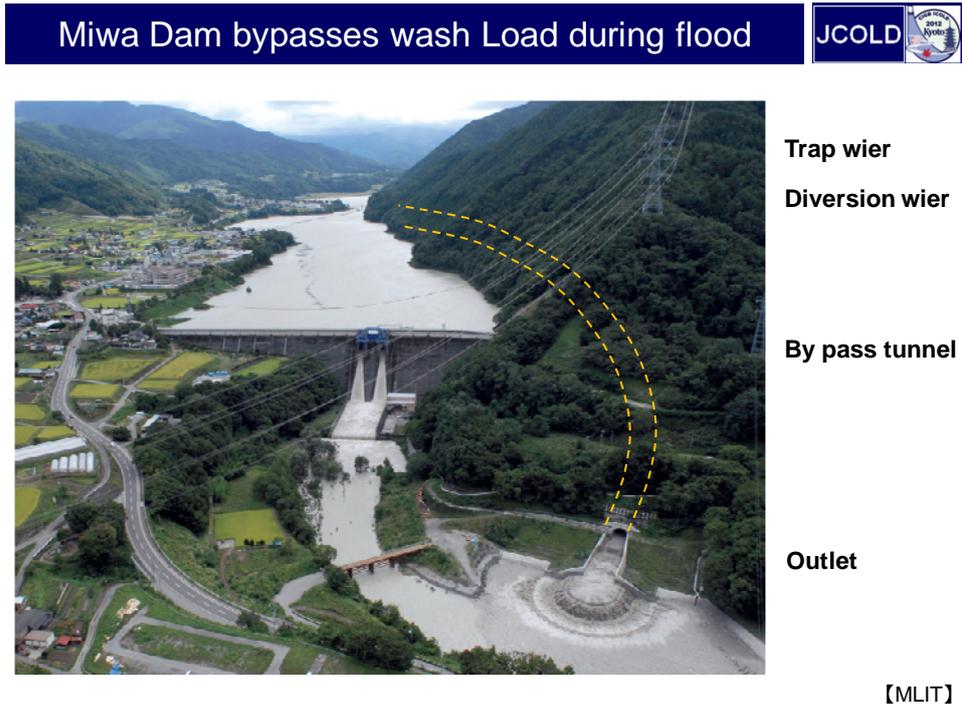
Reservoir sediment management measures in Japan 



【Prof. Sumi】

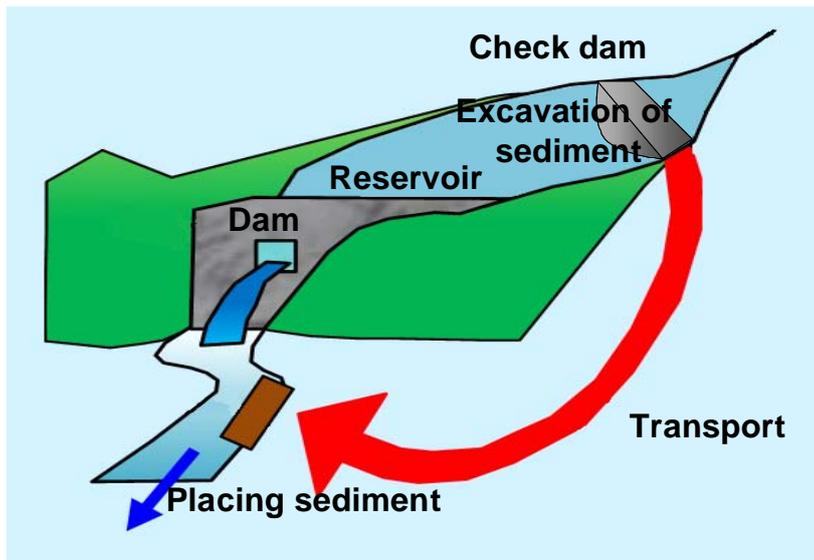
28. Now I am showing you the sediment bypassing at Miwa Dam<sup>25</sup>. The bypass tunnel with the length of 2.4 km was installed in 2005, 46 years after the dam completion. The sediments are bypassed from the upstream weir to downstream of the dam without being trapped in the reservoir. In three years from 2006 to 2008, 70% of inflow sediments were bypassed and the bypass operation prevents the loss of storage capacity.

After the bypass operation started, sand and gravels accumulated in the riverbed and it has been good for river fauna.



29. Another measure for sedimentation control is placing excavated sedimentation downstream from dams. During flooding, placed sediments are carried away and the downstream area is supplied with sand and gravel. This procedure is adopted at about 30 dams in our country.

### Placing excavated sediments downstream



30. This is the photo of Tobetsu Dam during the first filling of the reservoir this March<sup>26</sup>. Its dam type is a trapezoidal Cemented Sand & Gravel dam or hardfill dam. This type of dam minimizes the quantity of disposal materials, enables rapid construction and is cost effective.

Tobetsu Dam during the first filling March 2012



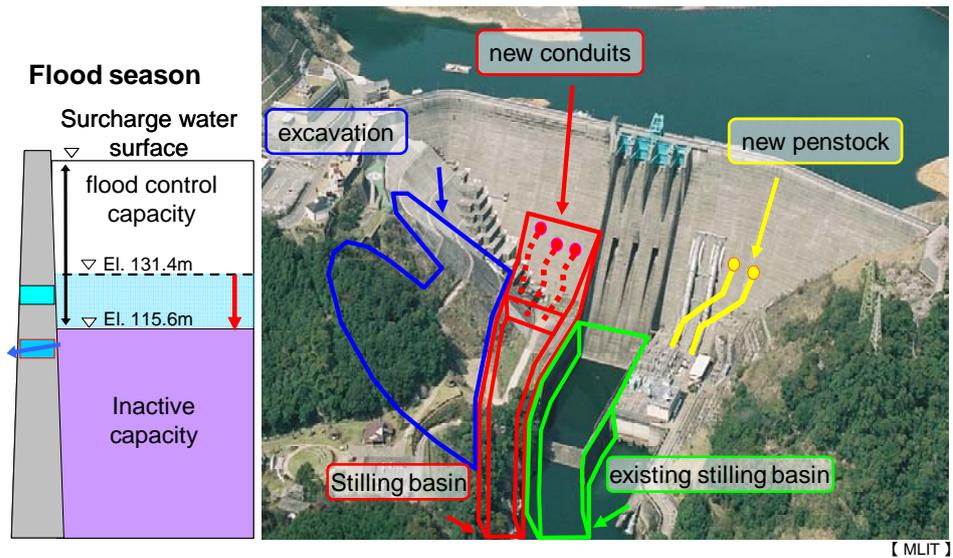
【Hokkaido Pref.】

31. Tsuruta Dam was completed in 1965. In July, 2006, we had heavy rains of 1,000 mm in a week. About 2,000 houses downstream were flooded. So the ministry started modification of the dam. The new conduits with larger capacity will be installed at lower elevation and they will make more effective flood control. During the flood season, the water level will be lowered to increase the flood control capacity<sup>27</sup>.

**Increasing flood control capacity at Tsuruta Dam** 

increase capacity for flood control

$75 \times 10^6 \text{m}^3$   $\rightarrow$   $98 \times 10^6 \text{m}^3$



32. Murayama Dam was built in 1927 to supply water to Tokyo. When it was built, the population downstream from the dam was scarce. But now you can see there are many houses downstream. This reservoir can also supply raw water downstream to several purification plants in gravity flow at any time<sup>28</sup>.

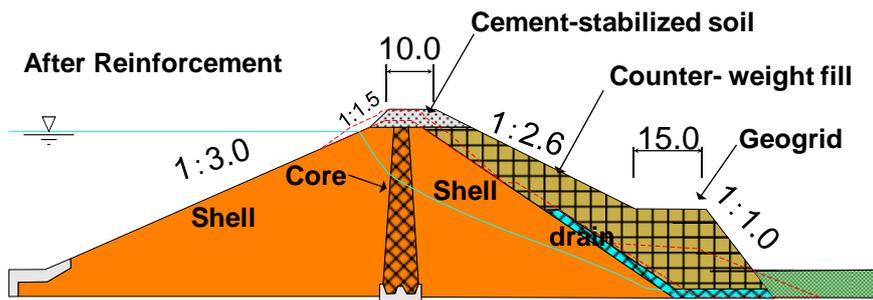
The downstream area is densely populated



【Tokyo Pref.】

33. The local government decided to strengthen the dam against earthquakes. We added buttress on downstream face. Further, drainage was installed to lower the seepage surface and cement-stabilized soil was built on the crest. People wanted downstream park to be preserved. Therefore, geosynthetics was adopted to steepen the slope to not extend into the park<sup>29</sup>.

## Strengthening to resist earthquakes



- Install drainage layers
- Construct a counter-weight fill
- Reinforce the steep slope with polymer geogrid
- Cover the crest with a cement-stabilized soil layer

【Tokyo Pref.】

34. Now I would like to talk about new technologies of hydropower.

This is the Sea Water Storage Power Station in Okinawa. The upper reservoir is an octahedral pond and the lower pond is large enough, the Pacific Ocean. The dam is 25 meter tall and it impounds six hundreds thousand cubic meter sea water. The capacity is 30 MW.

The technical features are first, corrosion of metal due to saline water, second, adhesion of oceanic creatures, and third, tidal wave barrier for a typhoon. We have to protect environment from saline water.

The pumped storage station was completed in 1999. The upper reservoir was completely drained for inspection after 9 years of operation. It was proved to be in good condition<sup>30</sup>.

Sea water Pumped Storage Power Station J-Power 



35. This map shows the dam projects Japanese engineers have participated in. We would be glad to participate and help in any overseas projects<sup>31</sup>.

Oversea projects Japanese engineers participated in 

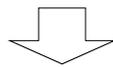


36. The population in Japan switched to a declining trend in 2005, two years earlier than projected, due to the effects of an aging society with fewer children. The future population may decline. To achieve safe and secure society, self-sufficiency of food, clean domestic energy and environmental preservation issues will become more important. We need water to live. We have used dams and reservoirs. We have rehabilitated, modified and upgraded dams. We just hope to transfer our experience to next generation. Thank you.

## Future of dams and water in Japan



**Decline in population**  
**Self sufficiency of food**  
**Clean domestic energy**  
**Safety**  
**Global climate change**



**Use dams and reservoirs wisely**

---

---

---

## References

- 1 Photo: Tokuyama Dam, Japan Water Agency
- 2 JCOLD, Register of dams, 2010
- 3 JCOLD, Register of dams, 2010
- 4 Osaka Prefectural Government
- 5 Osaka Prefectural Government
- 6 Ministry of Agriculture, Forest and Fisheries  
[http://www.maff.go.jp/j/budget/2010\\_3/pdf/enkatu-haikei1.pdf](http://www.maff.go.jp/j/budget/2010_3/pdf/enkatu-haikei1.pdf)
- 7 Ministry of Environment [http://www.env.go.jp/water/virtual\\_water/img/img\\_big.jpg](http://www.env.go.jp/water/virtual_water/img/img_big.jpg)
- 8 Photo of the power station by H. Akune, <http://www.suiryoku.com/>
- 9 Kansai Electric Power Company
- 10 Federation of electric power companies of Japan, Handbook of Electric Power Industries, pp.16-19、
- 11 Federation of electric power companies of Japan,  
<http://www.fepec.or.jp/library/data/60tokei/index.html>
- 12 Japan Water Works Association, “Outline of Water Works”, 2008
- 13 A. Suzuki, “The project of reinforcement of embankment for measure against earthquake of the Murayama-Shimo Reservoir”, Proceedings of the 6th Taiwan-US-Japan Workshop on Water System Seismic Practices, October 2009
- 14 Bureau of Water Works, Tokyo Metropolitan Government, “100 Years History of Modern Water Works in Tokyo, Data and chronology”, 1999
- 15 Ministry of Land, Infrastructure, Transport and Tourism, “White paper on Land, Infrastructure, Transport and Tourism” , 2009, p.63
- 16 Geospatial Information Authority of Japan,  
<http://www.gsi.go.jp/cais/chikakuhendo40010.html>
- 17 Ministry of Land, Infrastructure, Transport and Tourism, Public Works Research Institute, “The behavior of dams during the 2011 Tohoku Earthquake (Preliminary survey)” May 12, 2011、 JCOLD, N. Matsumoto, N. Sato, T. Sasaki, “2011 Tohoku Earthquake on Dams”, International Symposium on Dams for a Changing World, 24 ICOLD Kyoto Congress, June 5, 2012
- 18 Fukushima Prefectural government :  
[http://www.cms.pref.fukushima.jp/download/1/nosonkeikaku\\_kensyo\\_houkoku1.pdf](http://www.cms.pref.fukushima.jp/download/1/nosonkeikaku_kensyo_houkoku1.pdf)  
JCOLD : <http://www.jcold.or.jp/e/activity/FujinumaSummary-rev.120228.pdf>
- 19 H. M. Prasser, “Can nuclear enhance safety of the energy supply?” Hydro 2011, Practical Solutions for a sustainable future, Prague, October, 2011
- 20 Federation of electric power companies of Japan,  
<http://www.fepec.or.jp/library/publication/pamphlet/nuclear/zumenshu/digital/index.html>
- 21 Ministry of Economics, Trade and Industry  
<http://www.enecho.meti.go.jp/info/statistics/denryoku/result-2.htm>
- 22 Ministry of Land, Infrastructure, Transport and Tourism
- 23 Ministry of Land, Infrastructure, Transport and Tourism
- 24 Prof. T. Sumi of Kyoto University
- 25 Ministry of Land, Infrastructure, Transport and Tourism
- 26 Hokkaido Prefectural Government
- 27 Ministry of Land, Infrastructure, Transport and Tourism
- 28 A. Suzuki, “The project of reinforcement of embankment for measure against earthquake of the Murayama-Shimo Reservoir”, Proceedings of the 6th Taiwan-US-Japan Workshop on Water System Seismic Practices, October 2009
- 29 ditto
- 30 J-Power
- 31 JCOLD, [http://www.jcold.or.jp/j/dam/w\\_dam/dam\\_asia.html](http://www.jcold.or.jp/j/dam/w_dam/dam_asia.html)