Summary Report as ICOLD President

Joint efforts for better development of dams and reservoirs

Dr. JIA Jinsheng, ICOLD President

May 31st, 2012

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In 2009 at the 23rd Congress in Brazil, with the support of all sides, I was elected as President of ICOLD (2009-2012) and received the responsibility from Prof. Luis Berga. After three busy years, the time has come for me to transfer the responsibility to our new president. I feel privileged to have had the opportunity to serve this organization with brilliant history as well as the 95 national members. Over 80-year endeavor, ICOLD has become a leading organization with world reputation in the water sector. After entering the 21st century, promoting sustainable development of dams and reservoirs in a changing world is the key in the development of ICOLD. In its continuing efforts to achieve a better future in all aspects of planning, designing, constructing, maintaining and operating dams and reservoirs, and to contribute in a sustainable way to the socio-economic development, ICOLD had specific actions implemented in the past three years. The internal actions include revising Constitution and By-Laws, preparing technical bulletins and position papers, realizing free download of technical materials on the website, setting up new technical committees and youth club, promoting communication and cooperation among member countries, especially between developed and developing countries, etc. The external actions include building close relationships with sister organizations, actively joining sorts of international activities in the water sector such as organizing one-week exhibition at the World Water Pavilion stand in Shanghai World Expo in September 2010 and Special Session on Water Storage for Sustainable Development during the 6th World Water Forum (WWF) in Marseille in March 2012, issuing declarations jointly with other international organizations, organizing round table meetings for special topics, etc. As a result, ICOLD has become more dynamic, adaptive, and networked with a growing influence and a louder voice in international community. I would like to express my sincere gratitude to all of you for your great support and friendly collaboration during these years, including the National Committees, the Technical Committees, the Board, the Central Office, and all the members of ICOLD. Without your efforts, ICOLD could not go forward and make distinct achievements. Respecting the history, facing reality and looking towards future is the key to guide ICOLD forward every moment. I am full of strong confidence that under the leadership of new President (2012-2015), ICOLD will continue with its great mission to promote better development of dams and reservoirs for sustainable use of water and energy resources. Looking back on the past and looking forward to the future, it is true that there are too many aspects to be improved; and I would like to address the following main points for your reference.

1. Investment in dams and reservoirs is investment in the green economy

Dams and reservoirs with multi-functions on flood control, drought mitigation, water supply, irrigation, power generation, etc., are vital for human development. The global increase in population and the socio-economic development will continuously raise the requirement for water, food and energy consumption. It is estimated in 2050 that food and energy demands are projected to be double (Tilman et al. 2011; WEC 2007). Meanwhile, due to climate change, water distribution may become more irregular, and disasters related to floods and droughts will worsen. Confronting this exceptional situation, international communities have re-examined and attached growing importance to the development of dams and reservoirs. During the recent international authoritative conferences or forums, it has been repeatedly stressed of the essential of dams and reservoirs to water and food security and energy security and the embraced sustainable development of dams and reservoirs. A new prevailing consensus has emerged in the world that investment in dams and reservoirs is investment in the green economy. It has been constantly addressed at the 6th WWF in Marseille in March 2012. The World Bank Group (WBG) has explicitly indicated that the era of the World Commission on Dams (WCD) has gone and the guidelines for sustainable development of dams and hydropower are used in practice. The WBG's recent lending reflects this re-engagement in hydropower project investments (See Fig. 1). The World

Declaration on water storage for sustainable development prepared jointly by ICOLD, International Commission on Irrigation and Drainage (ICID), International Hydropower Association (IHA), International Water Resources Association (IWRA), etc. will be issued at the 24th Congress in Japan. It is emphasized that sustainable development of dams and reservoirs and other water storage facilities are effective solutions not only for meeting the continuously growing demands on water, food and energy that are closely interlinked, but also for adapting to climate change and reducing risk of disasters related to floods and droughts.

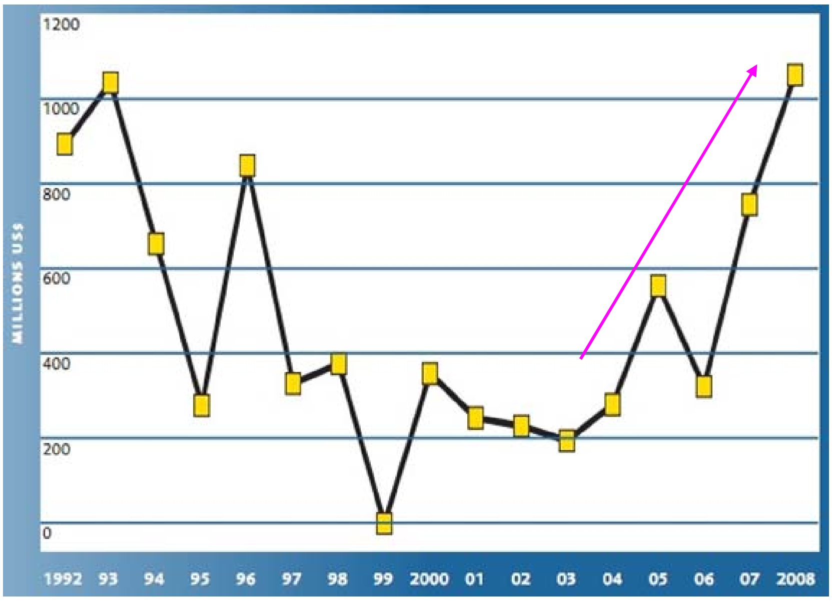


Fig. 1 Value of WBG's contribution to multipurpose hydropower components per financial year (WBG, 2009)

The transition has caused a new era on dams and reservoirs. Many countries have put dams and hydropower as a priority in national infrastructure construction and strengthened relevant investment. More than 165 countries have clear plans for further developing dams and hydropower, of which 110 countries have planned a total construction scale of 338 GW. Developed countries in North America and Europe are shifting their priority to upgrading existing dams and hydropower stations, expanding flood discharge facilities, strengthening flood control capability, adjusting operation of stations for ecological protection and rehabilitation, etc., since they have already exploited almost their hydropower potential. Most developing countries such as in Asia and South America have formulated plans to complete the task of hydropower development by 2025 or so. Some countries and regions, especially in Africa, though with rich water resources and strong intention of developing dams and hydropower, mostly still face great difficulties for the lack of capital, technology, etc. Countries suffering from political turmoil, though urgent for developing dams and hydropower, advance the construction very slowly due to the weak national strength and other unfavorable conditions. In general, it is an obvious trend to accelerate dam construction and hydropower development for better use of water resources in the world, especially in developing countries.

2. Hydropower is with the highest energy payback ratio, extremely low carbon emissions compared with other sources

Among various types of energies, hydropower has the highest energy payback ratio (EPR). The use of EPR emerged with the oil crisis occurred in the early 1970s. After the oil crisis, the energy agenda began to change significantly, resulting in issues like energy independence, air quality, and later, climate change (Gagnon 2008). Many countries started to explore oil substitutes. One of the key problems that became apparent was the selection of efficient energy options for growing demand. To identify appropriate solutions, the concept of EPR was used to evaluate energy options on a life-cycle basis. The EPR of a power plant is defined as the total energy produced over the lifetime of the plant divided by the energy needed to build, operate, fuel, and decommission it.

According to Gagnon (2005), the EPRs of different modes of energy sources are listed as follows: over 170 for hydropower, 18-34 for wind power, 14-16 for nuclear power, 3-5 for biological energy, 3-6 for solar power, 2.5-5.1 for traditional thermal power, and only 1.6-3.3 for thermal power with CO_2 capture (Fig. 2). In addition to its highest EPR, hydropower causes extremely low carbon emissions. According to WEC (2004), the CO_2 emissions per GWh for different modes of energy sources are listed as follows: 941-1022 t for traditional thermal power, 220-300 t for thermal power with CO_2 capture, 38-121 t for solar power, 51-90 t for biological energy, 10-33 t for hydropower with reservoir, 9-20 t for wind power, 6-16 t for nuclear power, and 3-4 t for hydropower run of river.

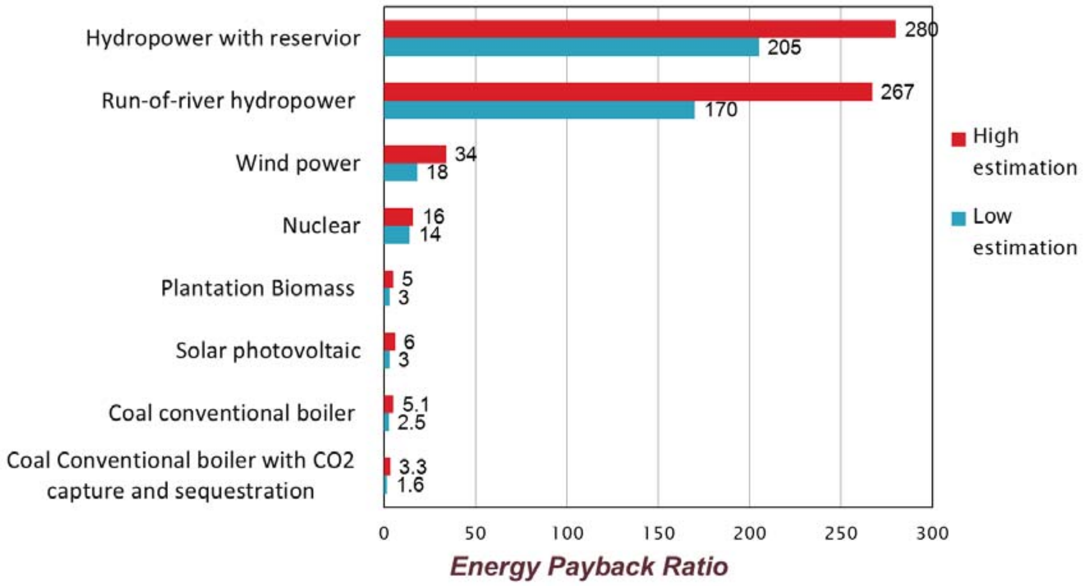


Fig. 2 EPRs of different modes of energy sources

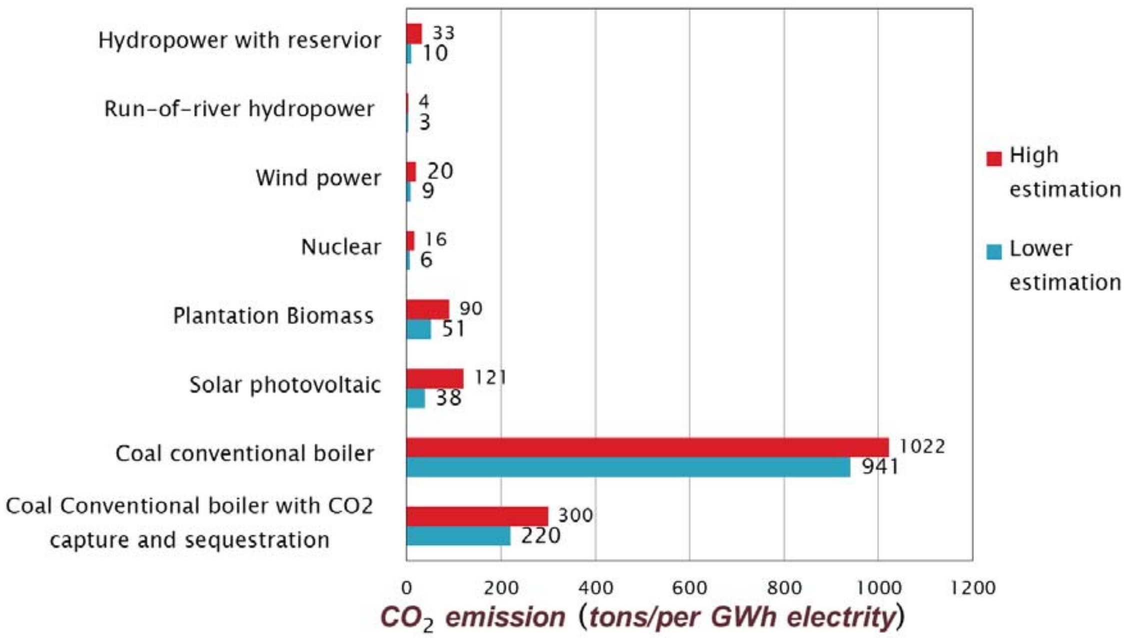


Fig. 3 CO_2 emissions per GWh for different modes of energy sources

In general, hydropower is the energy with the highest energy payback ratio and extremely low carbon emissions. Therefore, preferential development of hydropower has obvious advantages unparalleled by developing other energy options in coping with climate change and building a resource-saving and environmental-friendly society. With the advantages in capital, technology, market mechanism etc., developed countries have completed the exploitation of hydropower earlier, for over 30 years in preference to that in developing countries. It also proves the strategic importance of hydropower development from another perspective of view.

3. Relationship between the development of dams and hydropower and the socio-economic development

The development of dams and hydropower is closely related with the socio-economic development. To better demonstrate their coherence, the correlation between the UN Human Development Index (HDI) and the per capita storage capacity or the degree of development of the economic hydropower potential is studied based on the data for about 100 countries (United Nation 2011; Word Atlas & Industry Guide 2011).

The United Nation has set HDI to comprehensively measure the level of socio-economic development in the UN member countries. HDI is the weighted average of the per capita GDP, health and education and hence can reflect the quality of human development. HDI is a value ranging from 0 to 1, the closer it is to 1, the higher the human development level is. The countries with HDI higher than 0.8 are mostly developed countries, e.g., Norway (0.943), United States (0.910); the countries with HDI between 0.7-0.8 are largely advanced developing countries, e.g., Russia (0.755) and Brazil (0.718); the countries with HDI between 0.5-0.7 are mostly developing countries in Asia, Africa and Latin America, e.g., China (0.687), Egypt(0.644); the countries with HDI less than 0.5 are largely less developed countries, e.g., Nigeria (0.459).

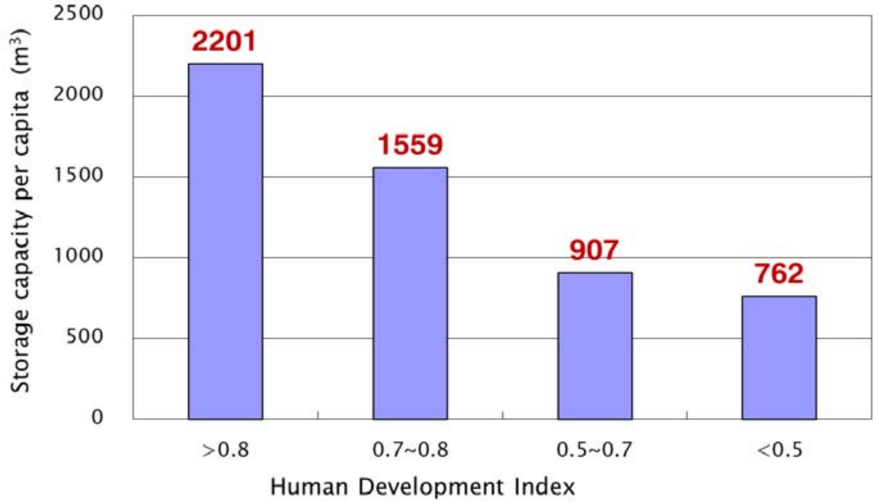


Fig. 4 Correlation between the per capita storage capacity and HDI

Berga (2008) proposed that the development of dams and reservoirs is closely related to the socio-economic development. Figure 4 compares the average values of the per capita storage capacity in different sorts of countries. It is indicated that developed countries have a solid ground for securing water safety, but developing countries still face a challenging task as limited by financial, technical and human resources. In general, the level of dam development in a country is about consistent with the level of human development. It is coincide with the result of United Nation (2006) that the global distribution of water infrastructure is inversely related to the global distribution of water insecurity risks. Note that quite a few exceptions also exist, such as Mozambique (HDI=0.322) with a per capita storage capacity of 2727 m^3 while Israel (HDI=0.888) and Switzerland (HDI=0.903) with per capita storage capacities of 27 m^3 and 440 m^3, respectively. Mozambique has a small population and a relatively large amount of water resources exploited; whereas Israel is dry and rainless with very limited water resources and Switzerland has a large number of natural lakes.

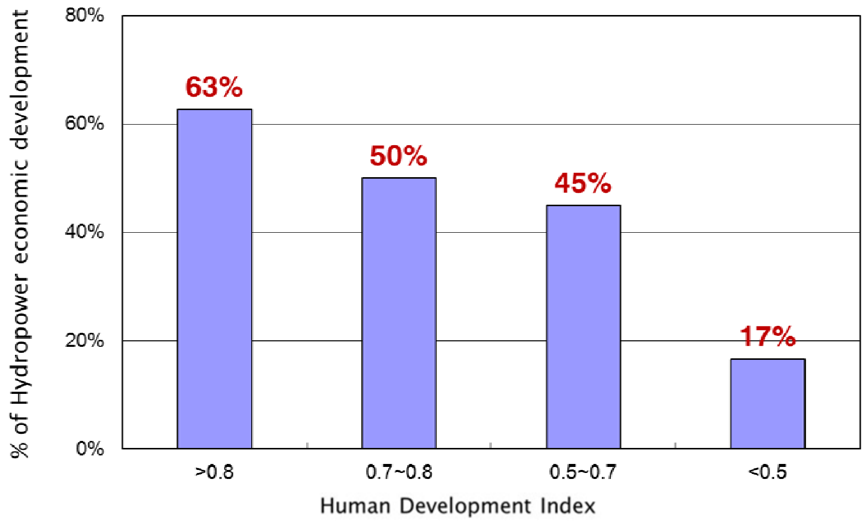


Fig. 5 Correlation between the degree of development of the economic hydropower potential and HDI

In addition to the development of dams and reservoirs, it is found that the development of hydropower has also a tight relation with the socio-economic development. Figure 5 compares the average degrees of development of the economic hydropower potential in different sorts of countries. It is indicated that developed countries have already exploited much of their potential hydropower while developing countries still have a long way to go. For instance, United States (HDI=0.910) has a development degree more than 70%, largely in line with the average situation in developed countries while China (HDI=0.687) has a development degree of 41%, largely in line with the average situation in developing countries. In other words, hydropower development in both United States and China basically matches their socio-economic development, respectively. Note that a few exceptions also exist, such as Burkina Faso (HDI=0.331) with a development degree of 54% while Australia (HDI=0.929) and Norway (HDI=0.943) with development degrees of 38% and 57%, respectively. The total amount of potential hydropower in Burkina Faso is low and hence easy to be exploited; whereas Australia has abundant coal resources and in Norway hydropower has already accounted for 95% of its power supply and satisfied the demand.

4. Main issues of concern in future development of dams and reservoirs

According to historical information, per 1000 existing dams in the world corresponds to 10 dam failures (Jansen 1980). The failure probability of dams in early days was startling. Although a lot of dams and reservoirs were constructed across countries, a very limited number of them survived. In terms of incomplete statistics, tens of thousands of reservoirs were built before 1900; but less than 200 dams were higher than 15m due to technical limitations, most of which ended in failure as a result of poor construction and management while only few survived with long-term maintenance and reinforcement. After 1900, with the rapid advancement of science and technology, dam construction ushered in a period of rapid development, firstly in European and North American regions, then in South American and Asian regions. In 2010, the total number of large dams, in terms of the definition by ICOLD (higher than 15m or between 5-15m with a reservoir capacity of larger than 3 million m^3), constructed and under construction in the world reached more than 50,000, including over 60 dams higher than 200m. The fast development of dam technology in the 20^{th} century has not only advanced the worldwide dam construction, but also greatly improved the reliability and safety of dams.

Although modern dam construction has made great achievements, it is expected in the future to not only improve the maintenance and operation of existing dams, but also further develop new dams in a sustainable way. The main challenging issues of concern are listed as follows:

(1) The construction of 300m-high dams

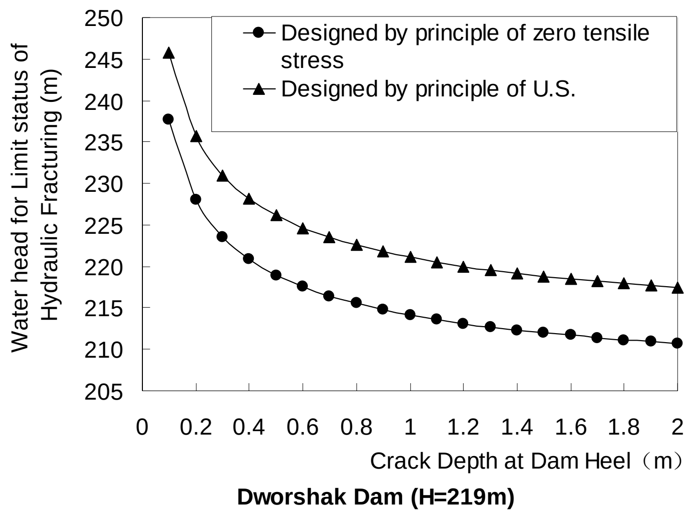
The construction of 300m-high dams is beyond the existing experience and thus technical uncertainties may result in the existence of unbearable hidden dangers. These dam projects have often large scales of construction and some of them are located in areas with very intricate terrains and geological conditions. As a result, the construction and operation of these projects face world-wide technical challenges that cannot be completed addressed by the current knowledge and experience and hence need to be studied vigorously. For instance, it is very difficult to predict the occurrence of cracking at concrete dam heel, especially for super high concrete dams. The cracks may further expand due to hydraulic fracturing of high water pressure. The design of 300m-high concrete dams should consider the influence of hydraulic fracturing. Figure 6 basically compares the capacities of super high gravity dams against hydraulic fracturing with three different design codes based on lab test of concrete structure, FEM analyses and etc.

(2) The safety of dams against extreme natural disasters

The safety of dams against extreme natural disasters has been demonstrated by the recent good performance in the Wenchuan earthquake in China in 2008, and the earthquake and tsunami in Japan in 2011. But it does not mean that the safety of dams against extreme natural disasters like earthquakes and floods will be guaranteed completely. Instead, it is an issue requiring a long-term study for two aspects. First, extreme natural disasters are of great uncertainty. Secondly, good performance of super high dams against extreme natural disasters is strictly required. Figure 7 shows the shear failure of Shigang dam in the Taiwan region due to the earthquake fault zone across the dam foundation.

(3) The operation of cascade reservoirs

Climate change has made reservoir operation more difficult as hydrological patterns change. A chain of dam failures may cause huge losses that are unbearable. On the other hand, reservoir operation must be optimized to store more floodwater to better meet sorts of demands of both upstream and downstream areas. Therefore, the study on integrated operation of cascade reservoirs is needed for achieving the best balance between engineering safety and the wise use of water resources.



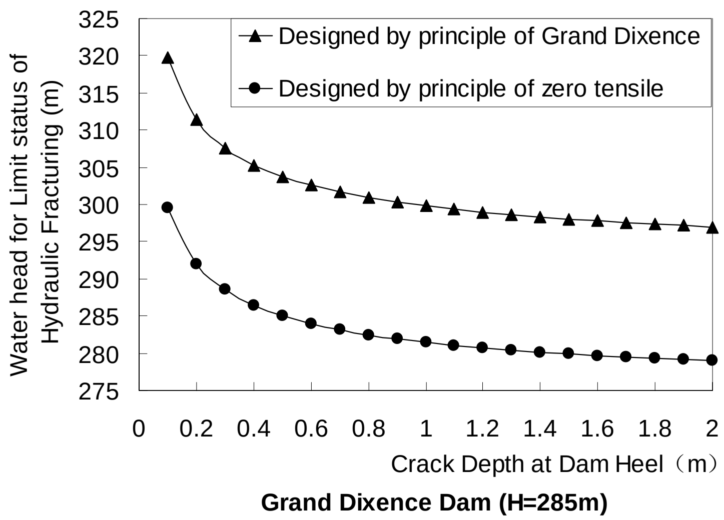


Fig. 6 Comparison of the capacities of super high gravity dams against hydraulic fracturing with three different design codes

Fig. 7 Shear failure of Shigang dam

(4) Cemented Material Dams

In recent years, cemented sand and gravel dams (namely CSG or Hardfill dams) have been widely used in countries including France, Turkey, Japan, Greece, China, etc. Rockfilled concrete dams (namely RFC dams) have been investigated and used for new dam construction and old dam rehabilitation in China. RFC technology is a new progress based on masonry dams with modern dam construction technology. In conclusion, masonry dams, RFC dams, and CSG or Hardfill dams represent a transitional dam type linking RCC dams and embankment dams, which is defined as cemented material dams (namely CMD). CMD uses the materials that are formed by granular materials mixed with cementing materials including cement, mortar, concrete, etc. CMD is between embankment dams and RCC dams. The successful practice of CMD in countries such as Turkey, Japan, and China demonstrates this new type dam is safe, economical, and eco-friendly, which represents the future development trend of dam technology.

5. New concepts for future development of dams and reservoirs

In recent years, especially after entering the 21st century, ecological and social issues related to dams and reservoirs have drawn increasing attention. As a result, new concepts and solutions for dam construction and operation are urgently needed to bridge the gap between the strict requirements from the society and the current technical support levels. It is worth noting that the construction of dams and reservoirs is not just a simple scientific and technical issue; instead, a wide range of issues such as economic, social and environmental aspects are involved. Hence, a more open and transparent process is required. Based on the successful and mature experience in the world, it is feasible to develop water and hydropower resources in the form of being reliable, economically feasible, and environmental-friendly. To further develop dams and reservoirs in a better way, four transitions are required in practice as follows:

(1) Cognition

It is necessary to convert from emphasizing transformation and utilization of the nature to emphasizing not only transformation and utilization of the nature but also protection and adaptation to the nature. We need to learn from the past worldwide experience and, more importantly, to encourage innovation to meet the current and future development requirements.

(2) Decision-making

It is necessary to convert from considering technical feasibility and economic reasonability to considering not only technical feasibility and economic reasonability but also socially acceptable and environmental-friendly requirements. We need to formulate plans and adjust targets to realize scientific decision making and sustainable development.

(3) Operation and management

It is necessary to convert from ensuring engineering safety and traditional functions to ensuring not only engineering safety and traditional functions but also ecological safety and compensation. We need to develop a comprehensive operation and management program for hydropower stations to satisfy different requirements and balance different demands.

(4) Benefit sharing

It is necessary to convert from taking into account national and collective interests to taking account of not only national and collective interests but also interests of affected persons and requirements of ecological compensation. We need to make an integrated plan to take all related factors into consideration for achieving social harmony and sustainable development.

6. Ecological function of dams and reservoirs

With sufficient and high-quality dams constructed, more attention should be paid to the operation by considering different requirements of both upstream and downstream areas, both left and right banks, both main and tributary streams, especially for fulfilling ecological function of dams and reservoirs. Dams and reservoirs can keep the healthy life of rivers through ecological operation and serve wider environmental services. They can allow upkeep of minimum flows during dry seasons which enable the preservation of many aquatic animals and plants during droughts. Moreover, dams and reservoirs contribute to stabilizing ground water levels in adjacent land areas. Reservoirs can also be used to create new and biologically desirable habitats and to irrigate wetland biotopes or wetland forests.

A good example can be seen at the Xiaolangdi Dam (H=157m) constructed in 2001 on the Yellow River in China. From 1980s to 1990s, due to excessive development and utilization of water resources, the lower reaches of the Yellow River appeared dry-up river problems. The longest cutoff period took place in 1997 with as long as 226 cutoff days in the year, and the cutoff length more than 600 km, which has led to a series of eco-environmental disaster, such as river bed uplift, serious river atrophy etc. Upon Xiaolangdi dam’s construction, the eco-environment restoration in the lower reaches of the Yellow River was taken as an important goal of the reservoir operation. First, through the joint operation of the reservoirs in the upper reaches, we ensured the basic ecological river flows. Since 1999, dry river problems have not happened. Second, to address the serious sand silting problems in the lower reaches of the Yellow River and to recreate the flood discharge capacity of the river course, since 2002, water and sediment regulating operation of the Xiaolangdi Dam has been conducted for 13 times up to now to realize effective downstream river erosion. Nowadays the Yellow River flows all year long and the estuary ecosystem has been improved a lot.

To reduce the negative impacts of dams and hydropower on river ecology and realize ecological restoration, a few countries or international communities have established relevant technical standards and certification systems, of which representatives include Green Hydropower Certification of Switzerland, Low Impact Hydropower Certification of US and Sustainable Hydropower Certification of IHA. All these are crucial in achieving a balance between ecological protection and the use of water resources. Therefore, studies on technical standards and certification systems for green dams and hydropower should be paid more attention in the near future.

7. Role of ICOLD

Since it was founded in 1928, ICOLD has gradually absorbed all the countries of the world interested in the benefits of dam construction. Up to now it has included 95 national members. ICOLD has been always committed to promote initiatives in all related fields of sustainable development of dams and reservoirs based on the changing requirements of the world. This is being done through joint efforts to promote communication and cooperation among nations, capacity building programs for engineers of developing countries and young engineers, International Milestone Dam Project Awards, preparation of technical materials such as bulletins and position papers, etc.

In the past three years, ICOLD organized or co-organized numerous congresses, symposia, workshops, and meetings. All these events have attracted an increasing number of participants. ICOLD has also helped and enthusiastically supported numerous regional and national conferences initiated by the National Committees and the Technical Committees, which can provide a possibility for capacity building among the members. During its 80th Anniversary in 2008 in Paris, ICOLD initiated the World Declaration on Dams and Hydropower for African Sustainable Development, jointly with other relevant international organizations. The World Declaration intends to call on the international community to help African countries promote dam construction and hydropower development. As a follow-up, four special round table meetings were organized for implementing the World Declaration, including 1st meeting in Hanoi, Vietnam in May 2010, 2nd meeting in Lisbon, Portugal in September 2010, 3rd meeting in Beijing, China in November 2010, and 4th meeting in Zhengzhou, China in September 2011, respectively. Besides, training programs have been organized for African delegates in countries such as Turkey, Sweden and

China. Those meetings and training programs have enhanced the mutual understanding and cooperation between African countries and other countries of the world.

To recognize major achievements of dam technology and define milestone projects in this field, with the support of ICOLD, International Milestone Awards for RCC dams, CFRDs, and concrete dams have been set up respectively. These milestone dam projects represent the main achievements and can be used as valuable reference for future development of dams. Recognizing International Milestone Dam Projects is an effective way to focus on, and raise awareness about, achievements in dam technology and promote best practice in the world.

With the rapid development of dam engineering, ICOLD pays great efforts in preparing technical materials at the request of not only the professionals but also the public. The ICOLD Congress proceedings include technical papers on discussing new dam technologies, latest challenges and possible solutions, etc. The ICOLD Bulletins prepared by different technical committees discuss specific topics on sustainable dam development and provide important references for worldwide dam professionals. These ICOLD technical materials can be downloaded freely for the national members. In addition to the regular and normal materials, ICOLD is more and more active to prepare urgent materials in response to sudden events. A good example is the quick response of ICOLD and its relevant national members to the worldwide tension regarding dam and reservoir safety after the three disasters, including the earthquake and tsunami in Japan in 2011, the accident at the Sayano-Shushenskaya hydropower station in Russia in 2009, and the Wenchuan earthquake in China in 2008. Within a very short time after those disasters, ICOLD and the National Committees of Japan, Russia, and China provided comprehensive information and shared their views, lessons learned, and experiences, which were of particular value to the international dam engineering community. Besides, the ICOLD Committee on Seismic Aspects of Dam Design issued a position paper on dam safety and earthquake in 2010. All the

ICOLD technical materials provide a solid basis for worldwide engineers to develop dams in a sustainable way.

ICOLD has continued to build closer relationships with sister organizations such as WWC, ICID, IHA, IWRA, and WEC. ICOLD has also continued to strengthen the relationships with international organizations such as WBG, UNDP, and EU. In addition, ICOLD has continued to collaborate actively with international media such as Hydropower & Dams and HydroVision. All these efforts have led to a growing influence and a louder voice of ICOLD in the international water affairs.

8. Joint efforts for a better world

The world, especially most of developing countries, has great potential for further develop eco-friendly dams and reservoirs for optimizing the use of water resources. It is now time for us to accelerate sustainable development of dams and reservoirs. For this, the following five aspects are of great concern:

(1) It is expected to issue and promote more Protocols, Bulletins, and Guidelines in the world for satisfying new requirements of sustainable development of water resources. ICOLD will continue to prepare more technical materials jointly with other international communities and promote best practice in the world.

(2) During the construction and operation of dams and reservoirs, many countries in the world will encounter similar problems and difficulties. It is required for us to enhance international cooperation on new technology research and development and application promotion.

(3) Dam and reservoir projects are highly capital intensive. Governments, financial institutions, and private sectors are encouraged to give more investment and speed up water infrastructure construction.

(4) It is expected to advance the development of sharing rivers with win-win cooperation to better serve regional socio-economic development. For instance, the Itaipu Hydropower station at the frontier between Brazil and Paraguay on the Parana River constructed and operated jointly by the governments of two sides has made great contribution to regional and national economies.

(5) International communities need to strengthen the exchange and cooperation to advance sustainable development of water resources in the world, especially for developing countries. More round table meetings, more communication between developed and developing countries, more capacity building programs, and more other relevant activities are expected to be organized and promoted by joint efforts in the future.

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Joint Efforts for Better Development of Dams and Reservoirs

Dr. JIA Jinsheng

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Kyoto, Japan
June 6, 2012

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A quick developing world

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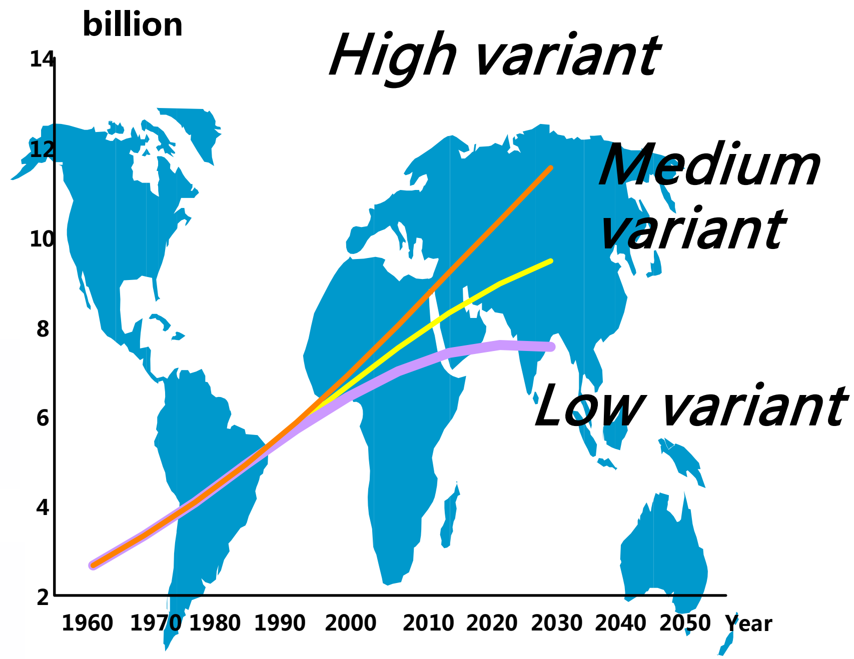
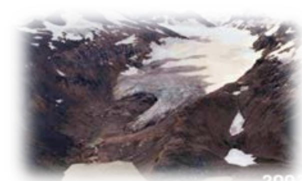
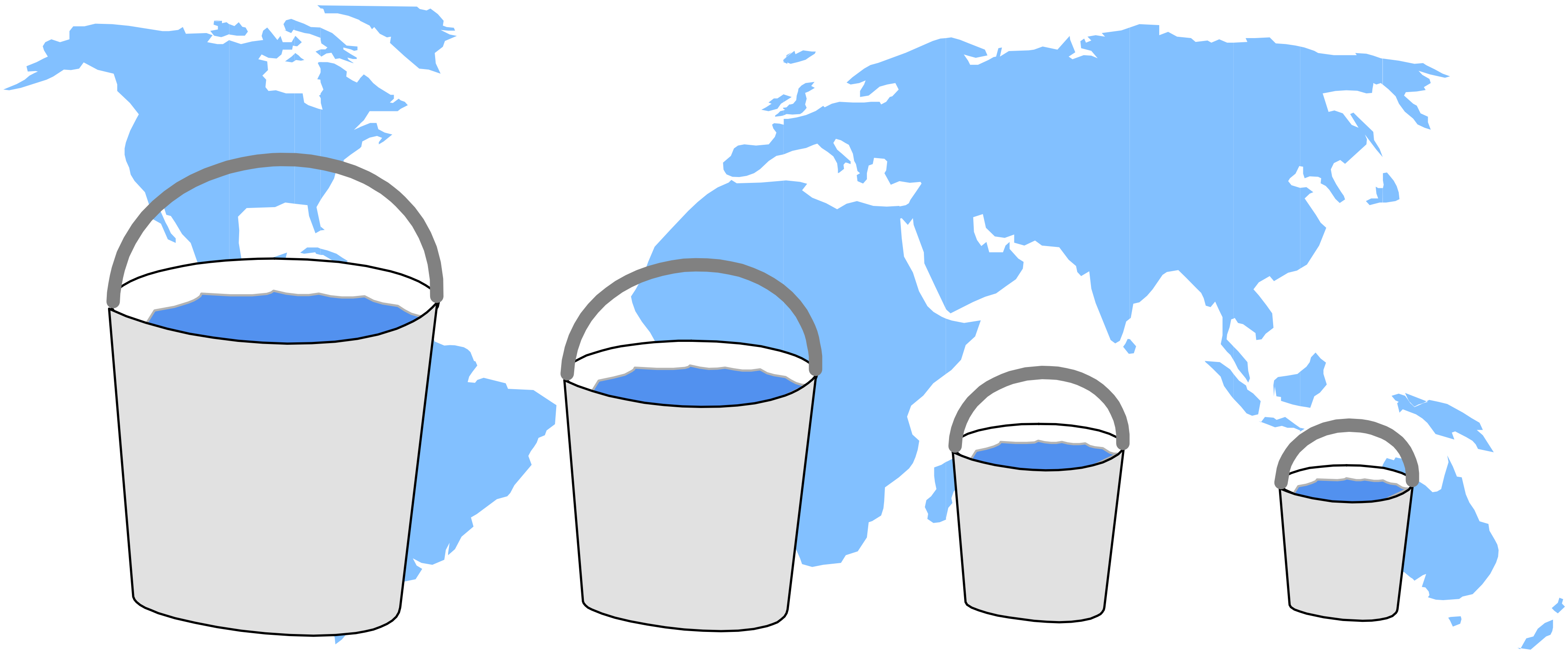


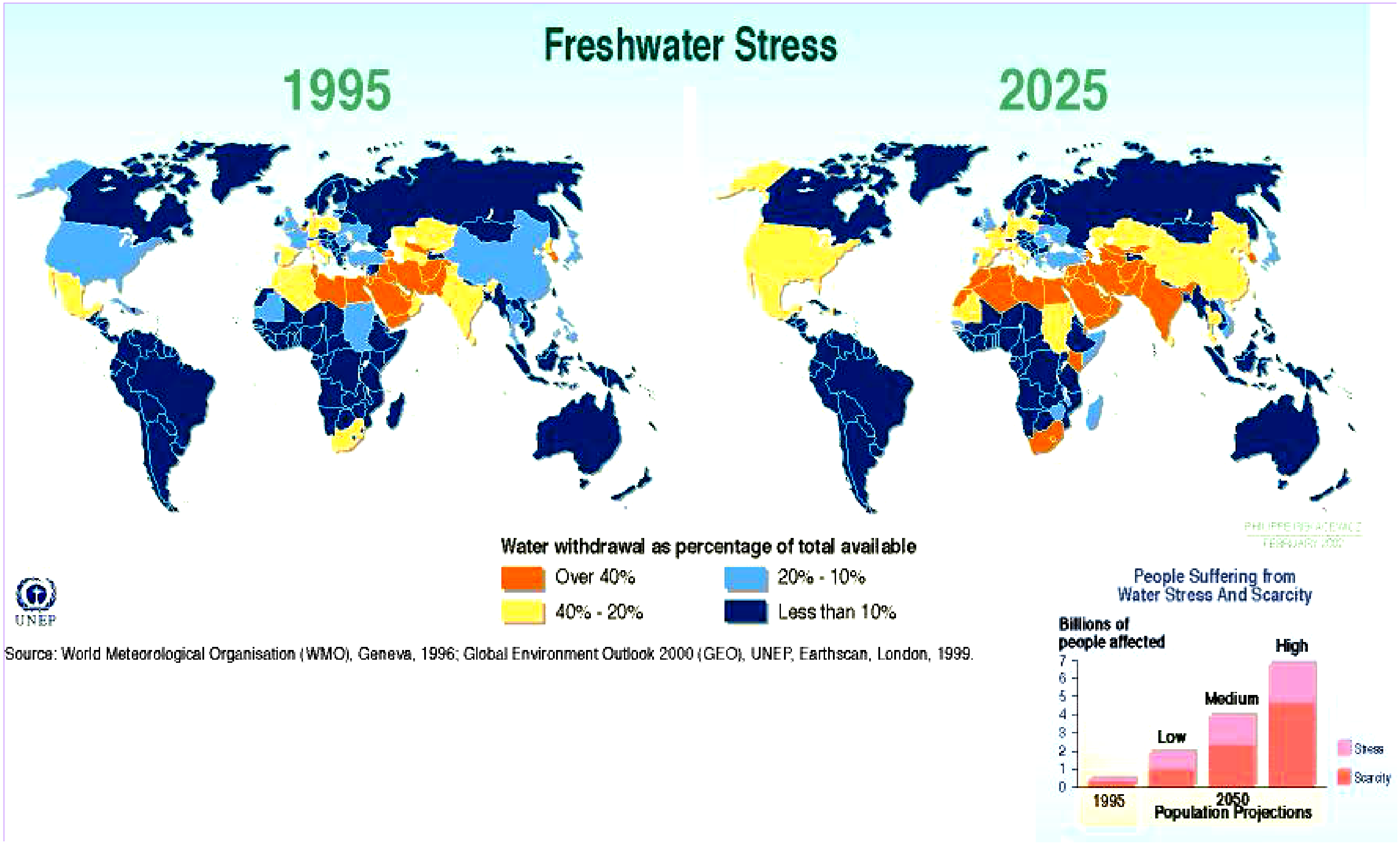


Freshwater availability per capita 1950-2050



1950	2000	2025	2050
12,050 m^3	7,310 m^3	5,120 m^3	4,580 m^3

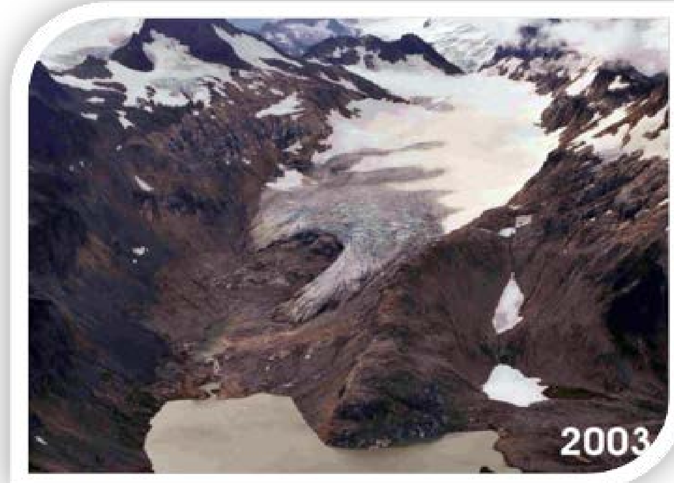
In 2025, water-stressed countries will increase to 48 countries with combined population of 3 billion

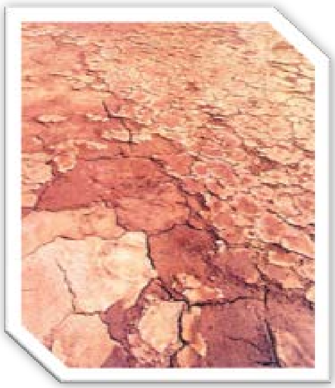


Source: World Meteorological Organisation (WMO), Geneva, 1996; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

Adaptation to the impact of climate change

Glacier smelting





Extreme weather events

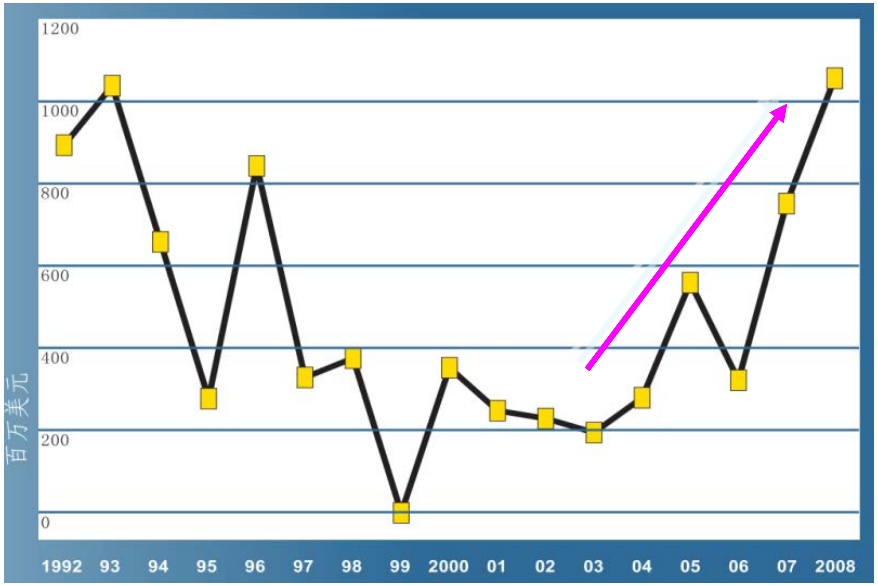
A major focus: Drought and water scarcity

Drought in South West China in 2010

Rachel Kyte, Vice President of WBG for sustainable development

- Large hydropower facilities have become a key milestone for green growth.

- The era of the World Commission on Dams (WCD) has gone and the guidelines for sustainable development of dams and hydropower are used in practice.



Investment in hydropower development (WBG, 2009)

Water storage for sustainable development

World Declaration on water storage for sustainable development

issued jointly by:

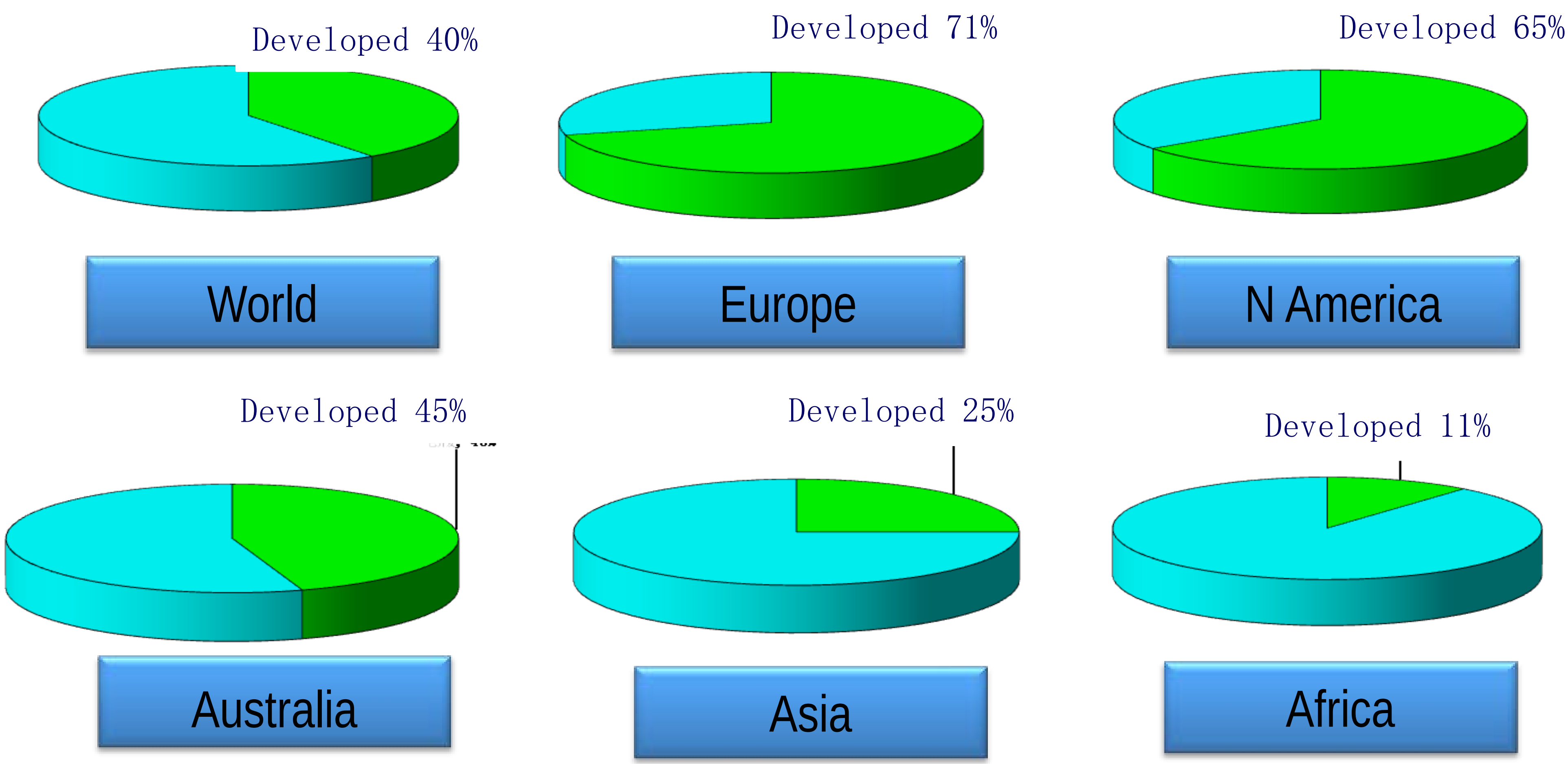
CIGB ICOLD — **ICOLD**

ICID

IHA

IWRA — **IWRA**

% of hydropower generation to its economical potential by continents



Accelerate dam construction and hydropower development for better use of water resources

- Developed countries in North America and Europe are shifting their priority to upgrade and reinforcement of existing dams.
- Most developing countries such as in Asia and South America have formulated plans to complete the task of hydropower development by 2025.
- Some countries and regions, especially in Africa, though with rich water resources and strong intention of developing dams & hydropower, mostly still face great difficulties for the lack of capital, technology, etc.
- Countries suffering from political turmoil, though urgent for developing dams and hydropower, advance the construction very slowly due to the weak national strength and other unfavorable conditions.

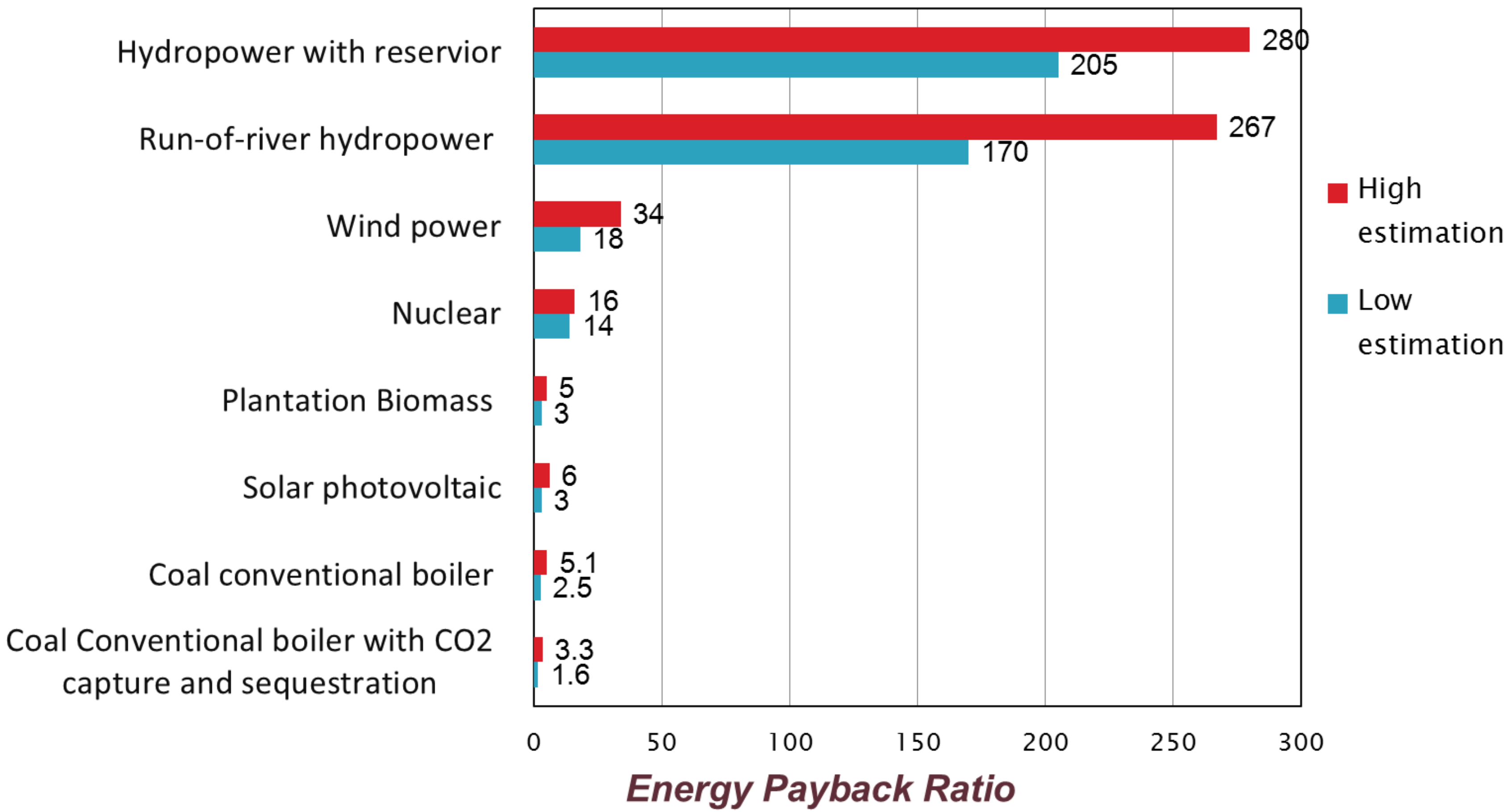
Hydropower with the highest energy payback ratio and extremely low carbon emissions

Energy payback ratio:
a case of thermal power station

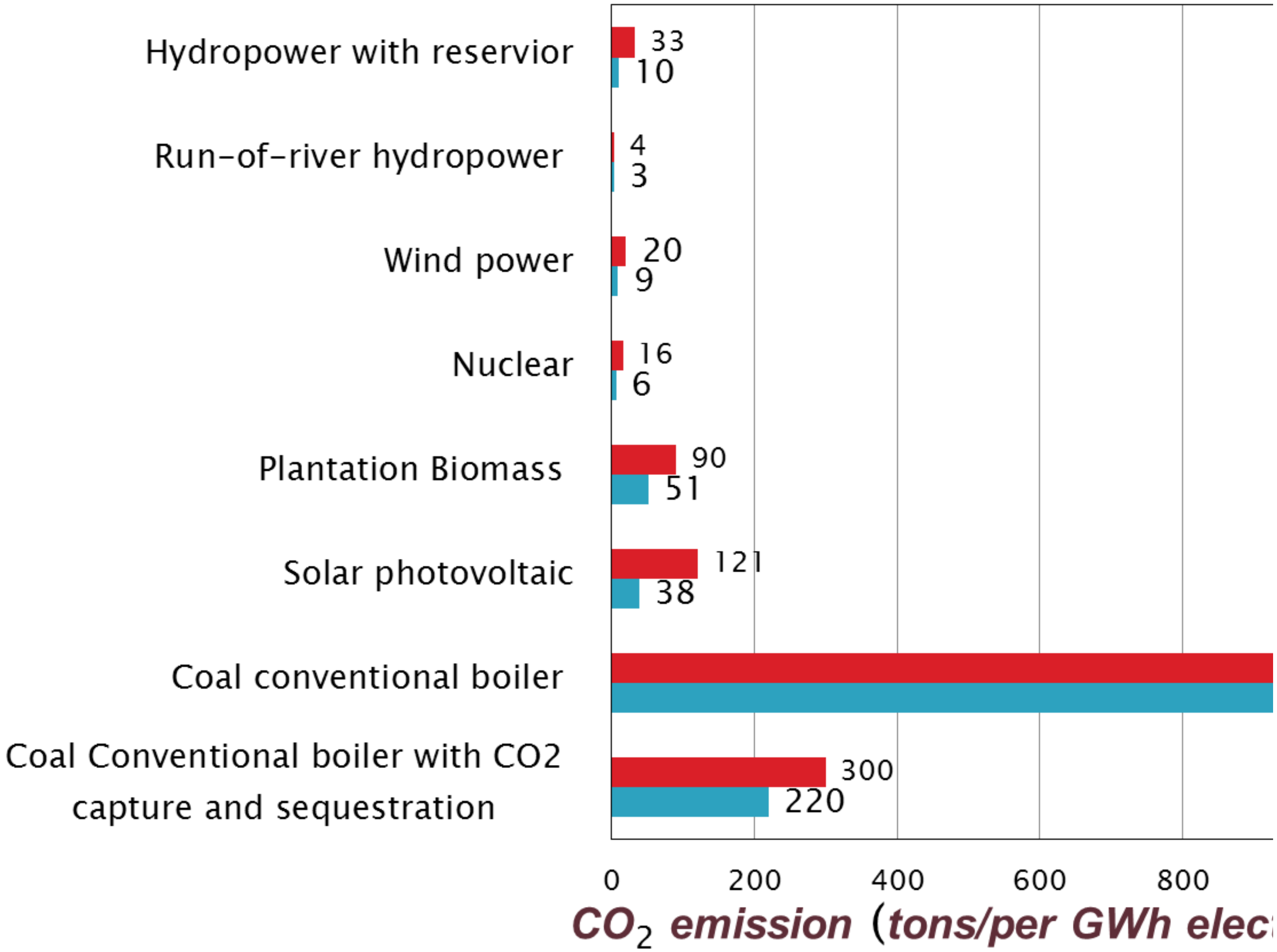
$$EPR = \frac{E_{nL}}{(E_{matL} + E_{conL} + E_{opL} + E_{decL})}$$

- E_{nL} = the net electrical energy produced over a given plant lifetime L
- E_{matL} = total energy invested in materials used over a plant lifetime L
- E_{conL} = total energy invested in construction for a plant with lifetime L
- E_{opL} = otal energy invested in operating the plant over the lifetime L
- E_{decL} = total energy invested in decommissioning a plant after it has operated for a lifetime L

Hydropower with the highest energy payback ratio



Hydropower with extremely low carbon emissions



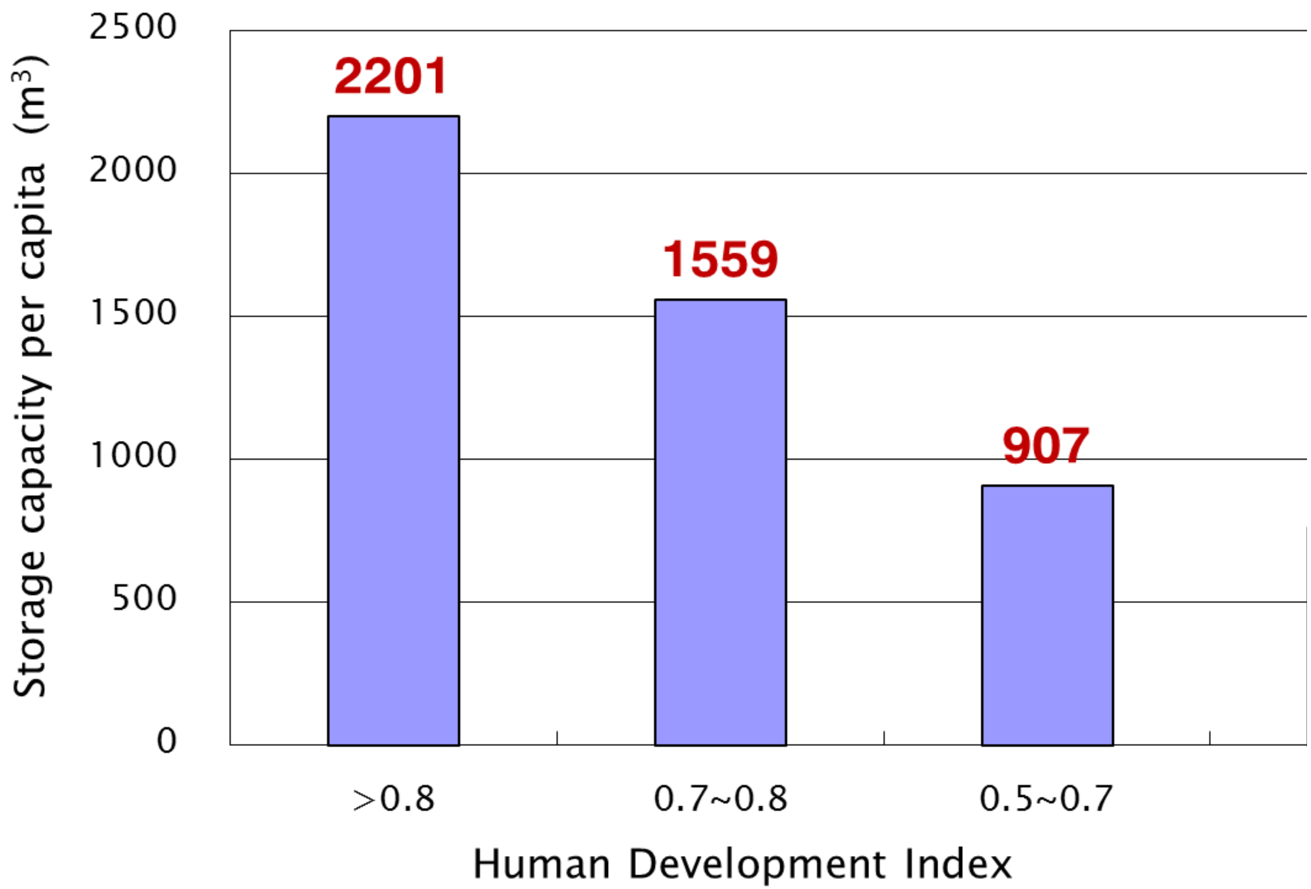
2 Relationship between dams and socio-economic development

The development of dams & hydropower is related with the socio-economic development.

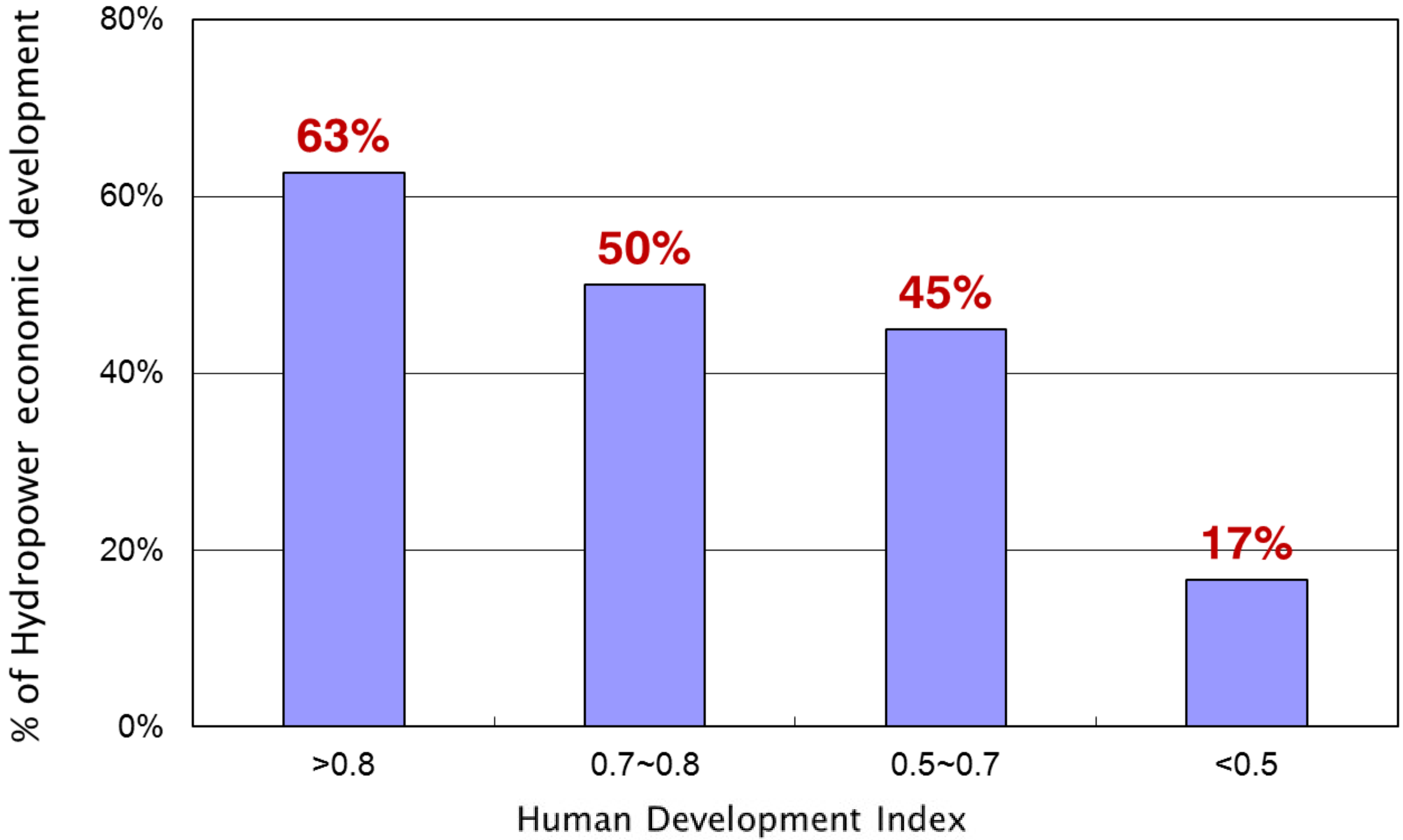
- Indicators of dams & hydropower
  - per capita storage capacity (Berga 2008)
  - the degree of development of the economic hydropower potential (Jia 2012)

- Indicators of socio-economic development
  - the UN Human Development Index (HDI)

    weighted average of the per capita GDP, health and education



Correlation between the per capita storage capacity and HDI



Correlation between % of hydropower economic development and HDI

3 Concerns in future development of dams & reservoirs

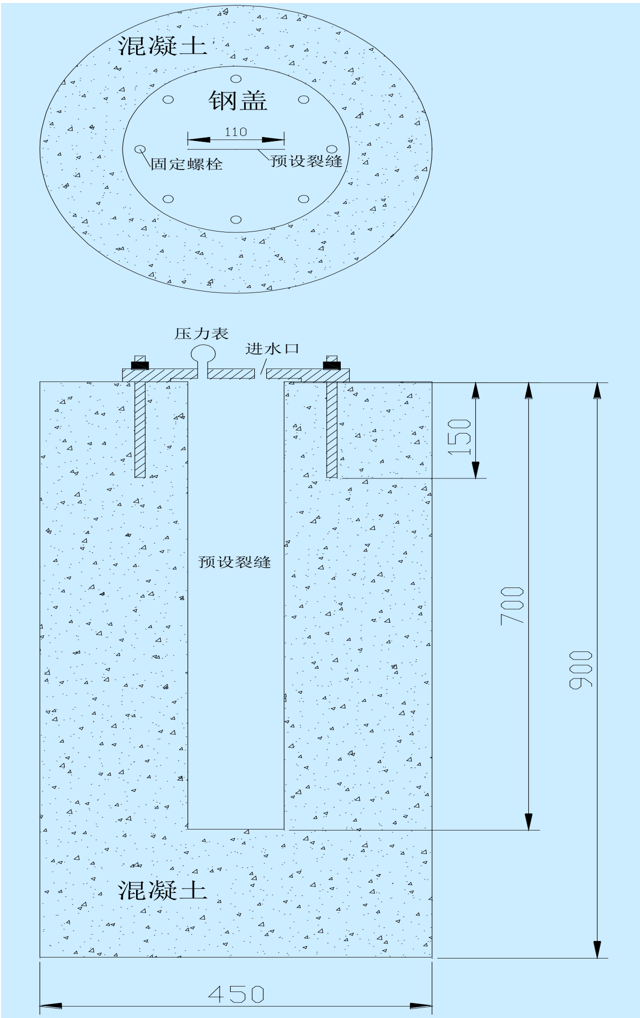
——Dam safety

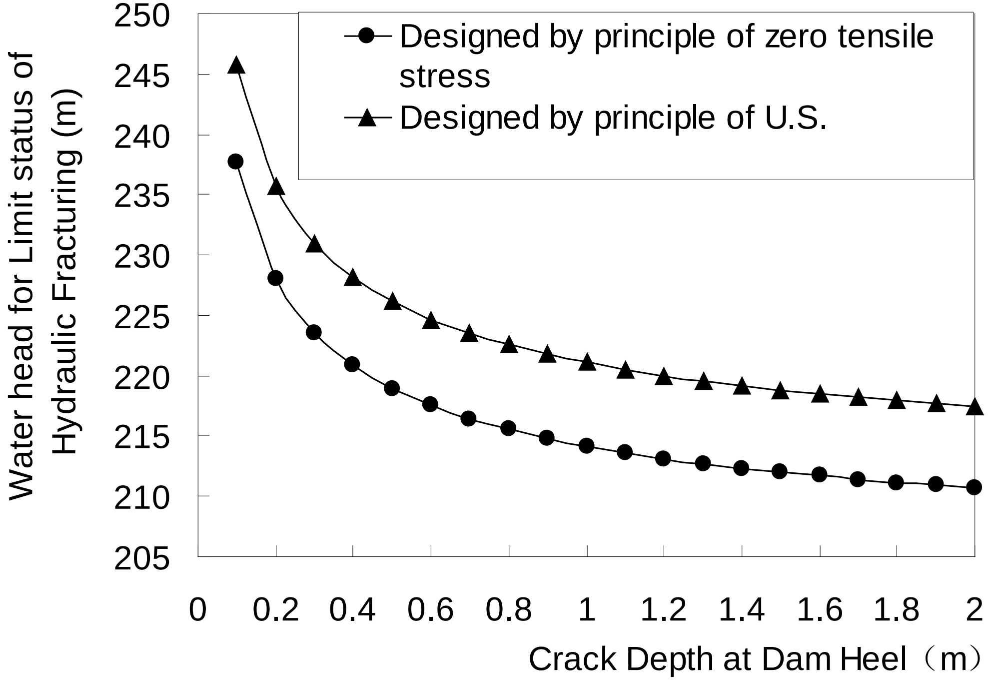
The construction of 300m-high dams

Highest Dams in the World (Top 10)

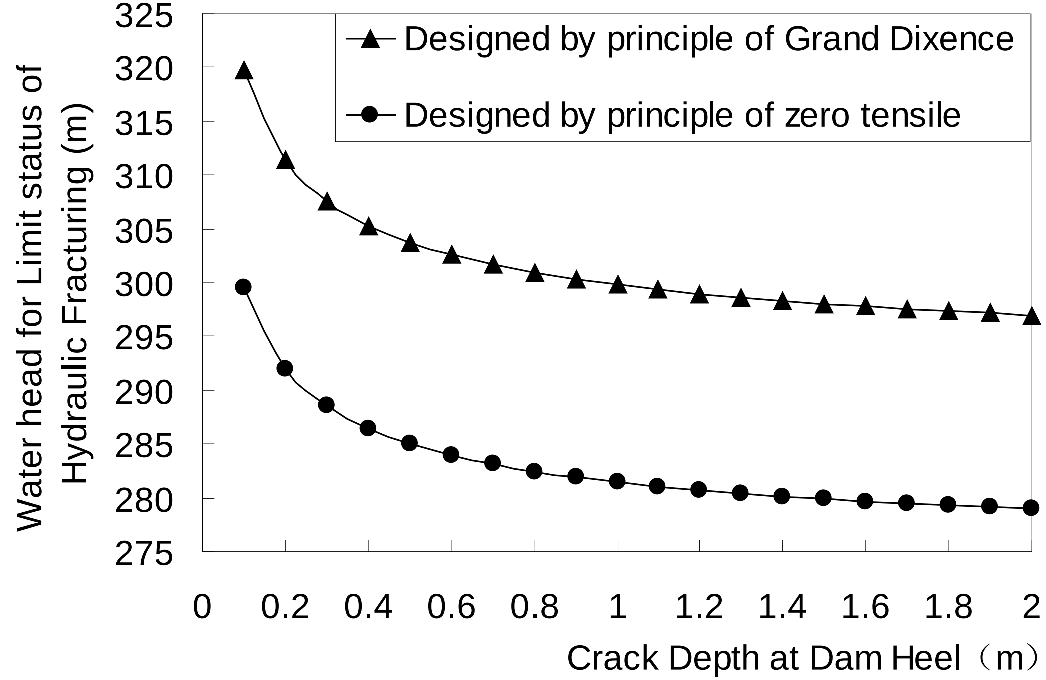
Dam	Country	Height (m)	Type	Storage Capacity (km^3)
Jingpin I Dam	China	305	VA	15.0
Nurek Dam	Tajikistan	300	ER	10.5
Xiaowan Dam	China	294.5	VA	15.1
Grande Dixence Dam	Switzerland	285	PG	0.4
Keban Dam	Turkey	282	ER	31.0
Xiluodu Dam	China	285.5	VA	12.9
Kambarazin I Dam	Kyrgyzstan	275	ER	3.6
Inguri Dam	Georgia	271.5	VA	1.11
Vaiont Dam	Italy	262	VA	0.169

Concrete experiment on hydraulic fracturing





Dworshak Dam (H=219m)



Grand Dixence Dam (H=285m)

Comparison of the capacities of super high gravity dams against hydraulic fracturing with three different design codes

The safety of dams against extreme natural disaster

Recent earthquake events

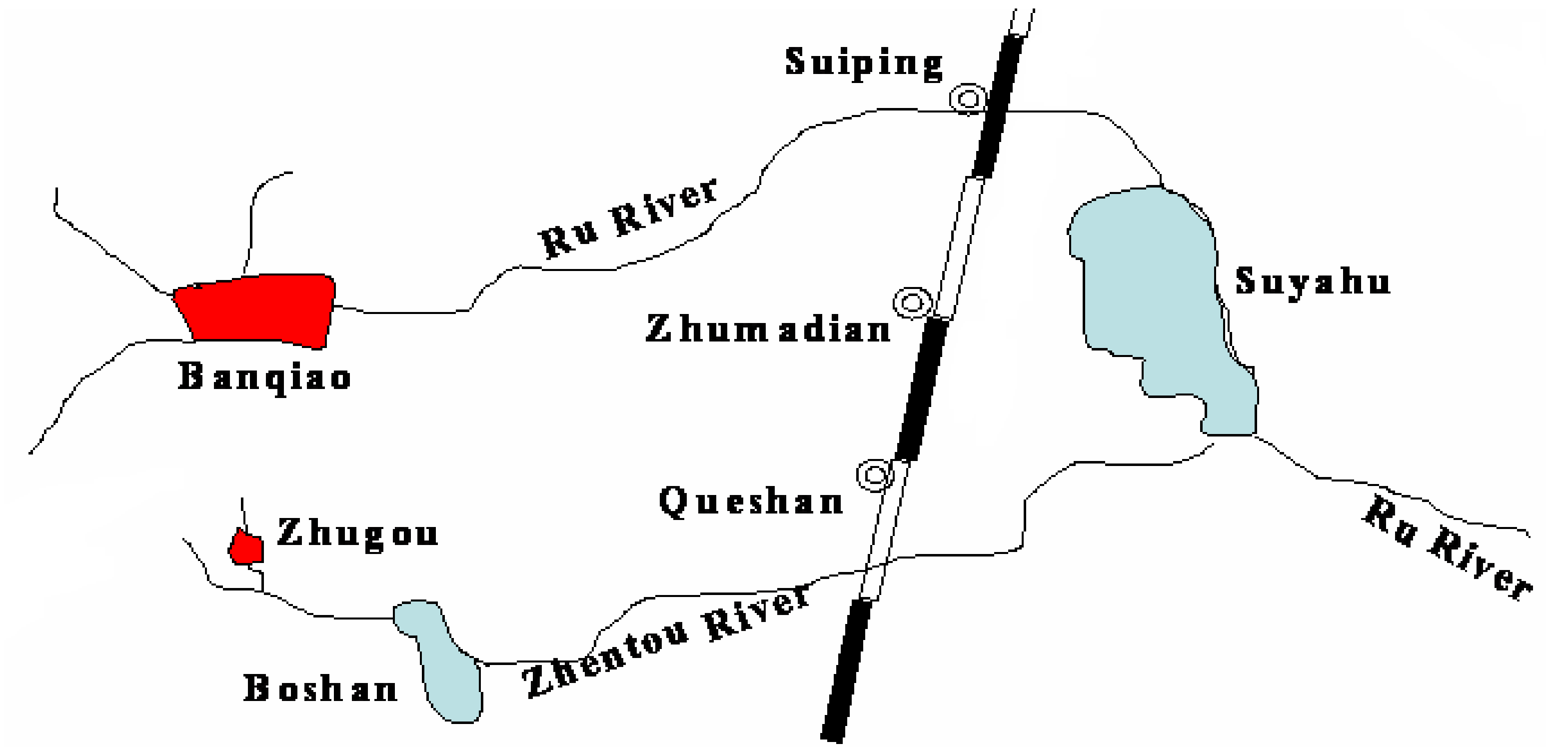
Earthquake	Time	Location	Magnitude	Death toll
Wenchuan	May 12, 2008	Sichuan, China	8.0	> 68,000
Haiti	Jan. 12, 2010	Haiti	7.0	217,000-230,000
Chile	Feb. 27, 2010	Concepcion, Chile	8.8	500-1,000
Indonesia	Apr. 7, 2010	Eastern Indonesia	7.8	Unknown
Japan	Mar. 11, 2012	Northeastern Japan	9.0	15,500-16,500

Zipingpu Dam in good condition after Wenchuan earthquake

Shear failure of Shigang dam

The safety of cascade reservoirs

- A four-dam-system on Ru River, including Banqiao, Zhugou, Boshan, and Suyahu Dams.
- In August 1975, the former two dams failed by overtopping during an extreme storm while the later two dams survived.

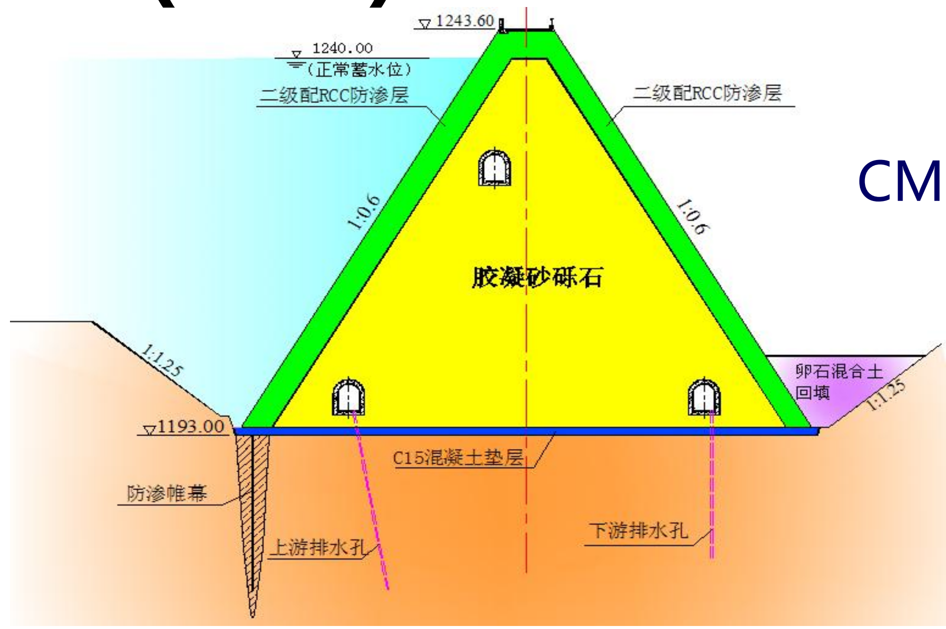


3 Concerns in future development of dams & reservoirs

——New technology

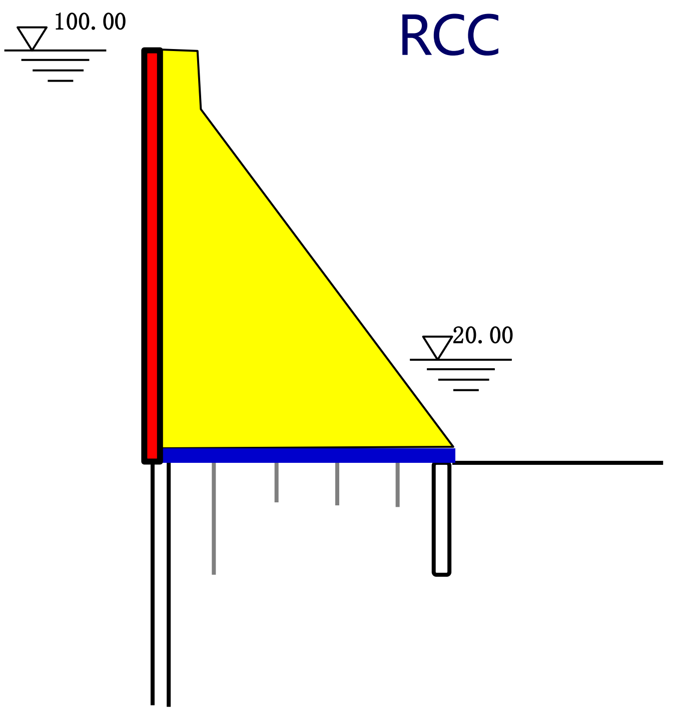
Cemented Material Dams (CMD)

between RCC dams & embankment dams

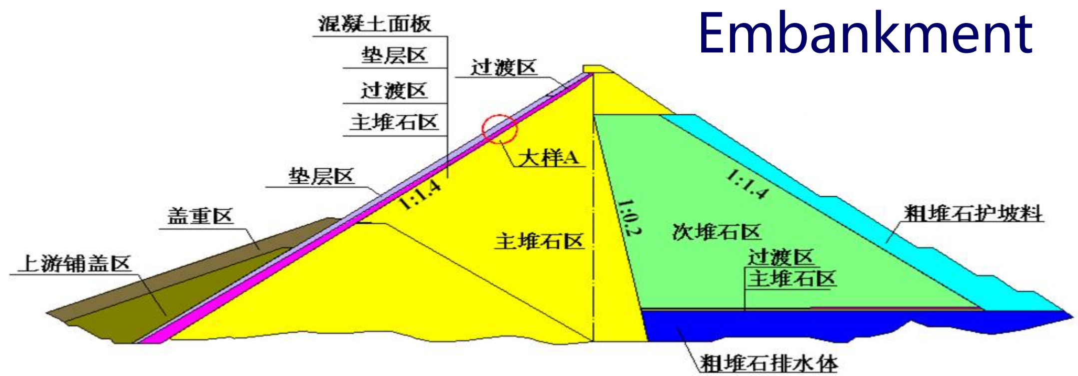


CMD

RCC



Embankment



Cemented Material Dams (CMD) include:

- Hardfill dams and CSG dams (Cemented sand and gravel dams)
- Rock filled concrete dams (RFC dams)
- Masonry dams in a modern way
- …

Cindere dam (H=107 m) in Turkey, the highest hardfill dam in the world

Changken RFC dam (H=26.5 m) in China

Characteristics of CSG dam

Dam Safety

- High anti-seismic ability
- High ability against overtopping

Economy

- Use local materials
- Cost saving > 15%

Environment

- Few waste materials, and even “zero” waste materials

Tobetsu CSG dam (H=52 m) in Japan

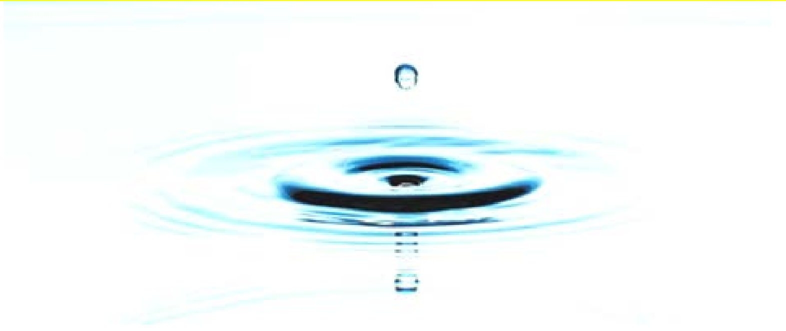
List of the new type of dams in the world

Dam	Location	Height (m)	Completed year
Cindere	Turkey	107	2008
Beydag	Turkey	100	2007
Gongguoqiao	China	56	2009
Tobetsu	Japan	52	2010
Can-Asujan	Philippine	44	2004
Hongkou cofferdam	China	35.5	2006
Nagashima	Japan	34	2000
Ano Mera	Greek	32	1997
Moncion	Dominica	28	2001
Marathia	Greek	28	1993
St Martin de Londress	France	25	1992
Jiemian cofferdam	China	16.3	2004

Hongkou CSG cofferdam (H=35.5m) survived against overtopping (ΔH=8m)

3 Concerns in future development of dams & reservoirs

——New concepts



Better development of dams & reservoirs

4 Shifts

	Shift	
Utilize and change nature	1 Cognition	As well as Protect and adapt to nature
Technologically feasible and economically reasonable	2 Decision making	As well as Eco-friendly and social acceptable
Project safety and function realization	3 Operation & Management	As well as Ecological compensation, safety and regulation
National and collective interests	4 Benefit Sharing	As well as Stakeholders' benefits

3

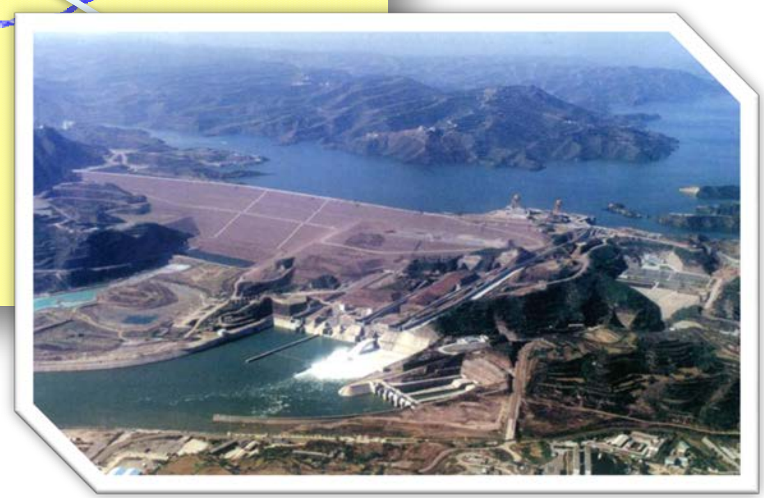
Concerns in future development of dams & reservoirs

——Ecological function

Dams & reservoirs keep healthy life of rivers

- To allow upkeep of minimum flows during dry seasons which enable the preservation of many aquatic animals and plants during droughts.
- To contribute to stabilizing ground water levels in adjacent land areas.
- To create new and biologically desirable habitats and to irrigate wetland biotopes or wetland forests.
- ...

Yellow River:
Ecological Function of Xiaolangdi Dam



H=157m

P=1,800MW

Achievements of Water & Sediment Regulation of Xiaolangdi Dam

- 13 times since 2002
- scour the whole riverbed of lower reach
- mill. tons of sediments into sea
- riverbed 1.5 m (average) lower

Water & sediment regulation by Xiaolangdi Dam

Improved Ecosystem

- **River flows all year long**
- **Estuarial ecosystem improved**
- **Estuarial wetland restored**
- **Biological diversity increased**

-- Bird Species: 187 (1990s) → 283 (present)

Ecological Regulation on Pearl River Delta

- **Salt water intrusion in dry season**
- **Water supply problem in delta areas (e.g. Macau)**

Emergency Water Diversion to Guarantee Water Supply

To Guarantee Water Supply in Pearl River Delta

To Unify Water Resources Regulation

To Build Datengxia Ecological Reservoir

To Achieve Full Ecological Functions of Dams

Technical standard and certification system

- eawag aquatic research

  Green Hydropower Certification

- LOW IMPACT HYDROPOWER INSTITUTE

  Low Impact Hydropower Certification

- IHA International Hydropower Association

  The Hydropower Sustainability Assessment Protocol

4 Joint efforts for a better world

- To issue more protocols, bulletins, and guidelines.
- To enhance international cooperation on new technology and application promotion.
- To encourage governments, financial institutions, and private sectors to give more investment.
- To advance the development of sharing rivers with win-win cooperation.
- To promote more round table meetings, more communication between developed and developing countries, more capacity building programs,etc.

ICOLD and other International Organizations

- Closely with ICID, IHA, IWRA, WWC, …

With ICID Hon. President Mr. Madramootoo

With IWRA President Mr. Xia

With IHA President Mr. Abdel-Malek

New members of ICOLD family

- Since 2009, the total number of ICOLD members has grown from 88 to 95, with 7 new countries.
- The 7 new members are: Armenia, Georgia, Kenya, Mozambique, Niger, Ukraine, Uzbekistan

Update Constitution and By-laws

CIGB
ICOLD

CONSTITUTION

STATUTS

July 2011 / Juillet 2011
Previous edition was dated January 2002
L'édition précédente datait de Janvier 2002

ICOLD / CIGB
61, avenue Kléber 75116 Paris
Tel. (33-1) 47 04 17 80 – E-mail: secretaire.general@icold-cigb.org

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BY-LAWS

RÈGLEMENT INTÉRIEUR

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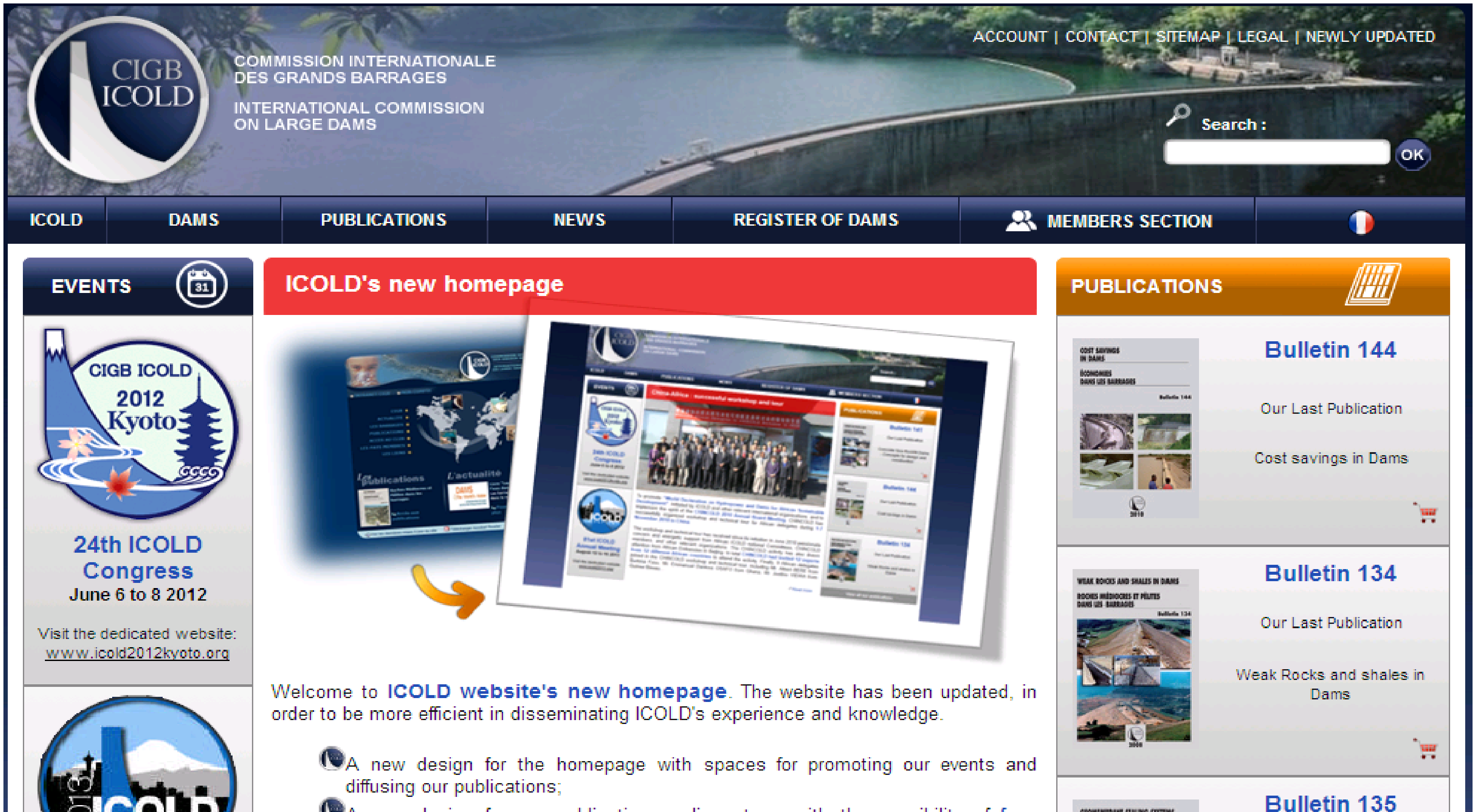
ICOLD technical materials downloaded by National Members freely



Organize or co-organize sorts of activities

Special Session on Water Storage for Sustainable Development during the 6th WWF (Marseille, March 2012)

One-week exhibition at the World Water Pavilion stand in Shanghai World Expo (Shanghai, Sept. 2010)

Dams & Hydropower for African Sustainable Development

World declaration

Dams and Hydropower for African Sustainable Development

Aproved on November 24th 2008 in Paris, by:

The African Union (AU), The Union of Producers, Transporters and Distributors of Electric Power in Africa (UPDEA), The World Energy Council (WEC), The International Commission On Large Dams (ICOLD), The International Commission on Irrigation and Drainage (ICID) and The International Hydropower Association (IHA).

issued jointly by

ICOLD

ICID

IHA

WEC

…… ……

Round Table Meeting on "Dams and Hydropower for African Sustainable Development"

- **The 1st in Hanoi, Vietnam, 2010.5**
- **The 2nd in Lisbon, Portugal, 2010.9**
- **The 3rd in Beijing, China, 2010.11**
- **The 4th in Zhengzhou, China, 2011.9**

Beijing, China, 2010.11

Hanoi, Vietnam, 2010.5

Lisbon, Portugal, 2010.9

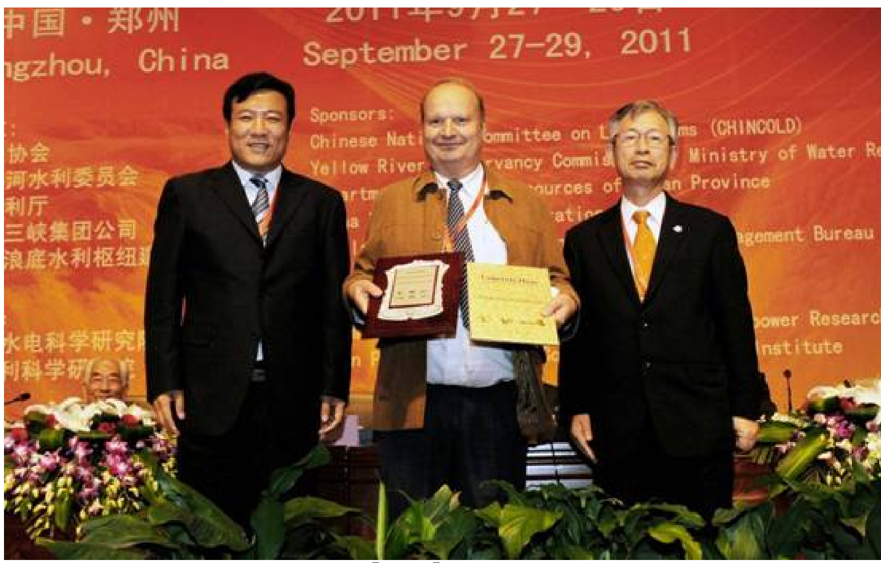
International Milestone Projects

- Achieving innovative progress
- Good performance
- Environmental Friendly
- Realizing the functions designed
- Other

24th ICOLD Congress, Kyoto, Japan, June 2012

Hoover Dam

Three Gorges Dam



Grand Dixence Dam

Itaipu Dam

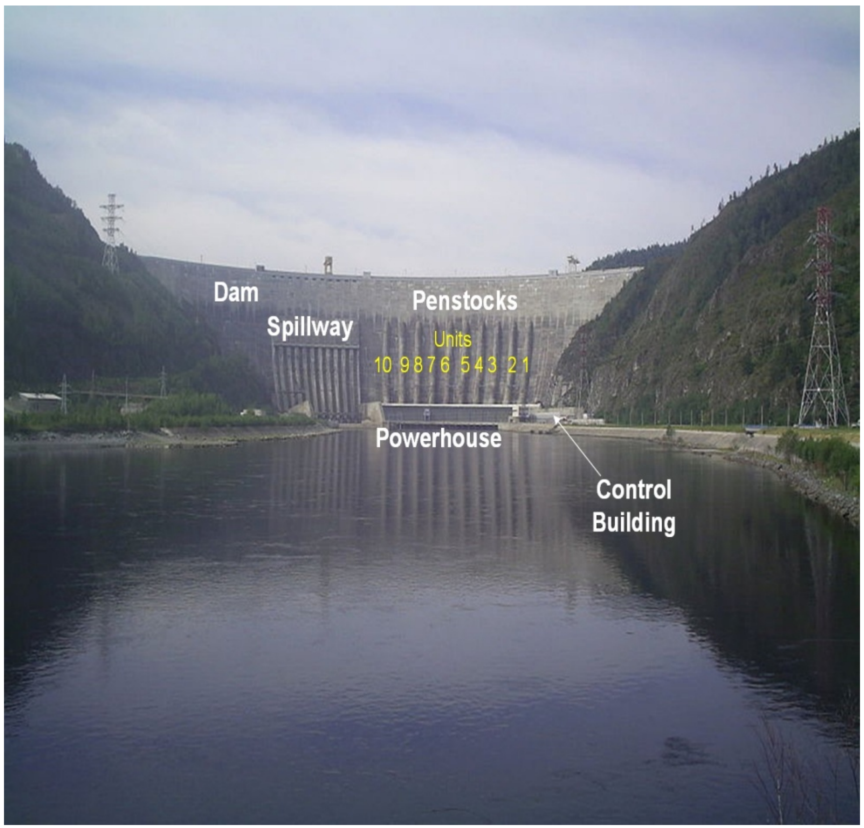
Capacity building programs for engineers of developing countries and young engineers

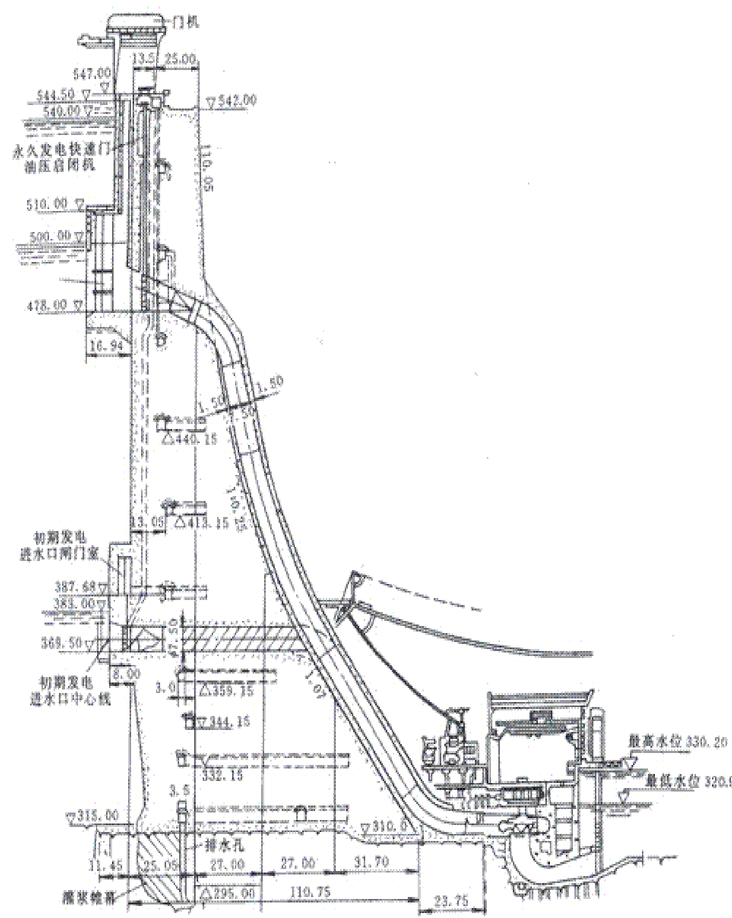
Youth Forum during 79th Annual Meeting in Switzerland 2011

Training Program for African experts in China in 2010

Quick response to sudden events

Accident of Sayano-Shushenskaya HHP





Presentation on the accident of Sayano-sushensike hydropower station by Russian Committee on Large Dams during the 78th Annual Meeting of ICOLD in Hanoi, Vietnam

Dam safety and earthquakes

IWP&DC presents a position paper of the International Commission on Large Dams (ICOLD), prepared by the Committee on Seismic Aspects of Dam Design

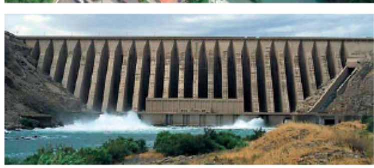
UNTIL now no people have died from the failure or damage of a large water storage dam due to earthquake. Earthquakes have always been a significant aspect of the design and safety of dams.

A large storage dam consists of a concrete or fill dam with a height exceeding 15m, a grout curtain or cut-off to minimise leakage of water through the dam foundation, a spillway for the safe release of floods, a bottom outlet for lowering the reservoir in emergencies, and a water intake structure to take the water from the reservoir for commercial use. Depending on the use of the reservoir there are other components such as a power intake, penstock, powerhouse, device for control of environmental flow, fish ladder, etc.

During the Richter magnitude 8 Wenchuan earthquake of 12 May 2008, 1803 concrete and embankment dams and reservoirs and 403 hydropower plants were damaged. Likewise, during the 27 February 2010 Maule earthquake in Chile of Richter magnitude 8.8, several dams were damaged. However, no large dams failed due to either of these two very large earthquakes.

What earthquake action does a dam have to withstand?

In order to prevent the uncontrolled rapid release of water from the reservoir of a storage dam during a strong earthquake, the dam must be able to withstand the strong ground shaking from even an extreme earthquake, which is referred to as the Safety Evaluation Earthquake (SEE) or the Maximum Credible Earthquake (MCE). Large storage dams are generally considered safe if they can survive an event with a return period of 10,000 years, i.e. having a one percent chance of being exceeded in 100 years. It is very difficult to predict what can happen during such a rare event as very few earthquakes of this size have actually affected dams. Therefore it is important to refer to the few such observations that are available. The main lessons learnt from the large Wenchuan and Chile earthquakes will have an impact on the seismic safety assessment of existing dams and the design of new dams in the future.



There is a basic difference between the load bearing behaviour of buildings and bridges on the one side, and dams. Under normal conditions buildings and bridges have to carry mainly vertical loads due to the dead load of the structures and some secondary live loads. In the case of dams the main load is the water load, which in the case of concrete dams with a vertical upstream face acts in the horizontal direction. In the case of embankment dams the water load acts normal to the impervious core or the upstream facing. Earthquake damage of buildings and bridges is mainly due to the horizontal earthquake component. Concrete and embankment dams are much better suited to carry horizontal loads than buildings and bridges. Large dams are required to be able to withstand an earthquake with a return period of about 10,000 years, whereas buildings and bridges are usually designed for an earthquake with a return period of 475 years. This is the typical building code requirement, which means the event has a 10% chance of being exceeded in 50 years. Depending on the risk category of buildings and bridges, importance factors are specified in earthquake codes, which translate into longer return periods, but they do not reach those used for large dams.

Moreover, most of the existing buildings and bridges have not been designed against earthquakes using modern concepts, whereas dams have been designed to resist against earthquakes since the 1930s. Although the design criteria and analyses concepts used in the design of dams built before the 1990s are considered as obsolete today, the reassessment of the earthquake safety of conservatively designed dams shows that in general these dams comply with today's design and performance criteria and are safe. In many parts of the world the earthquake safety of existing dams is reassessed based on recommendations and guidelines documented in bulletins of the International Commission on Large Dams (ICOLD).

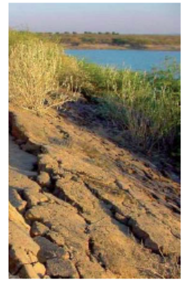
Seismic hazard is a multi-hazard

Earthquakes represent multiple hazards with the following features in the case of a storage dam:

Ground shaking causes vibrations and structural distortions in dams, appurtenant structures and equipment, and their foundations;

Fault movements in the dam foundation or discontinuities in dam foundation near major faults can be activated, causing structural distortions;

Left: Malgrauge gravity dam built in 1872 in Switzerland. After a recent rehabilitation its service life has been extended by another 50 years. Photo shows the main elements of a storage dam for power production: spillway, reservoir, concrete dam body, power intake and powerhouse (left); Below from left to right: Downstream view of the 106 m high Sefid Rud buttress dam in Iran damaged by the magnitude 7.5 Manjil earthquake of June 21, 1990. Bottom irrigation outlets were opened after the earthquake to lower the reservoir (left). Rockfall damage near left abutment (middle) and right abutment (right).



ge of embankment dams caused
ujarat province, India, January
and water supply were damaged.
lings on top of intake towers of the
an earthquake

bottom may cause water waves
;
damage to gates, spillway piers
g), surface powerhouses (crack-
, electro-mechanical equipment,
ıes, etc.
ir may cause impulse waves in

nd forming landslide dams and
ertopping of run-of-river power
rhouses with equipment, and

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tortions in dams; and
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voir oscillations (seiches) are of
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ne other hazards, which are nor-
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gn of dams all seismic hazard
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viour of large dams is still lim-
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exceeding 100m were damaged
lsewhere, there are another • ve
, which were damaged due to
lams the damage was mainly in
open up leading to the release of
mbankment dams the damage is
ong the crest that can eventually
rough the dam.
each dam is a prototype located
nd hazards. Therefore, based on
haviour of other dams it is still
he damage that could occur in a
ll in a learning phase as very few
ed to strong earthquakes. In the

case of the Wenchuan earthquake, a large number of rockfalls took place, which caused signi• cant damage to dams and appurtenant structures. Surface powerhouses were particularly vulnerable to rockfalls in the steep valleys in the epicentral region of the Wenchuan earthquake.

Could reservoirs be lowered in case of successful earthquake predictions?

If earthquakes could be predicted, one could attempt to lower the reservoir prior to the occurrence of a large earthquake. There are two problem areas related to this concept. First, despite some 40 years of research on earthquake prediction, it is still not possible to predict the time, location and size of a large earthquake reliably. Small earthquakes may be predicted but not large ones. The prediction is usually given in terms of the probability of occurrence, e.g. there is a 50% probability that a magnitude 7 earthquake occurs in a certain region within a period of 30 years. Such predictions are basically useless for warning purposes and for lowering a reservoir.

Even if a large earthquake could be predicted reliably, there would not be suf• cient time to lower large reservoirs. Lowering of a reservoir would have to happen by low level outlets (bottom outlets) or the power waterways if the intake is at low elevation. Unfortunately, bottom outlets are not available everywhere. Therefore the lowering of a reservoir by say 50% may take weeks or months, and in some cases it may not be possible at all.

As a conclusion, earthquake prediction, which is a slowly developing science, is not a viable option to improve the earthquake safety of dams. The only real option is to have a dam which can withstand the strongest earthquake effects to be expected at the dam site. This is the current practice in dam design.

The greatest hazard of a dam is the water in the reservoir. Therefore, in the seismic design of dams, we have to ensure the safety of the dam under full reservoir condition. Although an arch dam may be more vulnerable to the effect of ground shaking when the reservoir

12, 2008 Wenchuan earthquake; Above right: Sheared off pier of Futan weir earthquake

The role of ICOLD

Hoover Dam in the US built in the 1930s was the • rst concrete dam designed against earthquake where both the inertial effects of the dam and the hydrodynamic pressure of the reservoir were taken into account. Embankment dams were designed against earthquakes as early as in the 1920s in Japan where the seismic action was taken into account in the stability analyses.

ICOLD has discussed the effects of earthquakes on dams at several Congresses and Annual Meetings. At the 5th ICOLD Congress in Paris, France in 1955 the following subject was discussed: 'Settlement of earth dams due to compressibility of the dam materials or of the foundation, effect of earthquakes on the design of dams'.

In June 1968 the ICOLD Committee on Earthquakes was established. This committee now exists under the name: Committee on Seismic Aspects of Dam Design. Thirty-one countries from all continents are represented in this important committee. In recent years the following Bulletins have been published by the committee:

- Bulletin 62 (1988 revised 2008): Inspection of dams following earthquakes – guidelines;
- Bulletin 72 (1989 revised 2010): Selecting seismic parameters for large dams - guidelines;
- Bulletin 112 (1998): Neotectonics and dams - guidelines;
- Bulletin 113 (1999): Seismic observation of dams - guidelines;
- Bulletin 120 (2001): Design features of dams to effectively resist seismic ground motion - guidelines;
- Bulletin 123 (2002): Earthquake design and evaluation of structures appurtenant to dams - guidelines; and
- Bulletin 137 (2010): Reservoirs and seismicity – state of knowledge.

Conclusions

The technology is available for building dams and appurtenant structures that can safely resist the effects of strong ground shaking.

Storage dams that have been designed properly to resist static loads prove to also have signi• cant inherent resistance to earthquake action. Many small storage dams have suffered damage during strong earthquakes. However, no large dams have failed due to earthquake shaking.

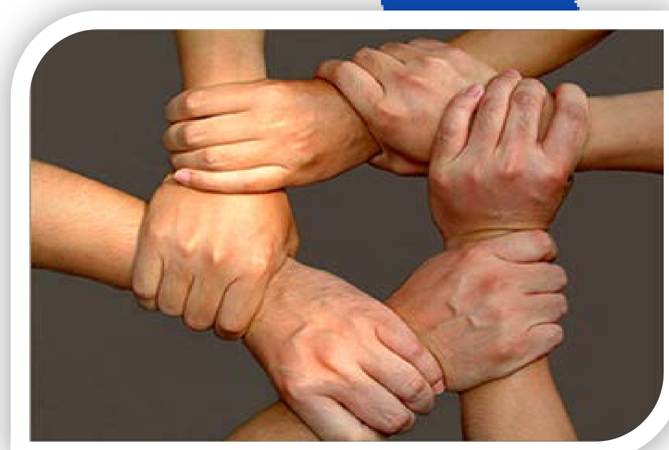
Earthquakes create multiple hazards at a dam that all need to be accounted for. There are still uncertainties about the behaviour of dams under very strong ground shaking, and every effort should be made to collect, analyze and interpret • eld observations of dam performance during earthquakes. IWP&DC

For further information, contact: Martin Wieland, Chairman, ICOLD Committee on Seismic Aspects of Dam Design, Poyry Energy Ltd., Hardturmstrasse 161, CH-8037 Zurich, Switzerland. martin.wieland@poyry.com

International Seminar on Earthquake & Dam Safety (China, March 30 - April 3, 2009)

World Hand in Hand

- **Promoting** Exchange & Cooperation
- **Sharing** Experience & Lessons
- **Meeting** Challenges Jointly



Thank You !