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 CO₂ capture (Fig. 2). In addition to its highest EPR, hydropower causes extremely low carbon emissions. According to WEC (2004), the CO₂ 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 CO₂ 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 CO₂ 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).
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 m³ while Israel (HDI=0.888) and Switzerland (HDI=0.903) with per capita storage capacities of 27 m³ and 440 m³, 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.
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.
References


Joint Efforts for Better Development of Dams and Reservoirs

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Kyoto, Japan
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Investment in dams & reservoirs is investment in the green economy
A quick developing world

1. Population growth & socio-economic development
2. Water security
3. Food and energy security
4. Ecological security
Freshwater availability per capita 1950-2050

1950: 12,050 m³
2000: 7,310 m³
2025: 5,120 m³
2050: 4,580 m³
In 2025, water-stressed countries will increase to 48 countries with combined population of 3 billion
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
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.

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

Rachel Kyte, Vice President of WBG for sustainable development

Investment in hydropower development (WBG, 2009)
Water storage for sustainable development

World Declaration on water storage for sustainable development

issued jointly by:

ICOLD
ICID
IHA
IWRA
% of hydropower generation to its economical potential by continents

- World: Developed 40%
- Europe: Developed 71%
- N America: Developed 65%
- Australia: Developed 45%
- Asia: Developed 25%
- Africa: Developed 11%
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
- \( E_{opL} \) = total energy invested in operating the plant over its 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 reservoir
- Run-of-river hydropower
- Wind power
- Nuclear
- Plantation Biomass
- Solar photovoltaic
- Coal conventional boiler
- Coal Conventional boiler with CO2 capture and sequestration

Energy Payback Ratio

High estimation
Low estimation
Hydropower with extremely low carbon emissions

- Hydropower with reservoir: 33 tons per GWh
- Run-of-river hydropower: 4 tons per GWh
- Wind power: 20 tons per GWh
- Nuclear: 16 tons per GWh
- Plantation Biomass: 90 tons per GWh
- Solar photovoltaic: 121 tons per GWh
- Coal conventional boiler: 300 tons per GWh
- Coal Conventional boiler with CO2 capture and sequestration: 220 tons per GWh
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
Concerns in future development of dams & reservoirs

--- Dam safety
## The construction of 300m-high dams

### Highest Dams in the World (Top 10)

<table>
<thead>
<tr>
<th>Dam</th>
<th>Country</th>
<th>Height (m)</th>
<th>Type</th>
<th>Storage Capacity (km³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jingpin I Dam</td>
<td>China</td>
<td>305</td>
<td>VA</td>
<td>15.0</td>
</tr>
<tr>
<td>Nurek Dam</td>
<td>Tajikistan</td>
<td>300</td>
<td>ER</td>
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<td>Xiaowan Dam</td>
<td>China</td>
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<td>ER</td>
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<td>VA</td>
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Concrete experiment on hydraulic fracturing
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

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Time</th>
<th>Location</th>
<th>Magnitude</th>
<th>Death toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wenchuan</td>
<td>May 12, 2008</td>
<td>Sichuan, China</td>
<td>8.0</td>
<td>&gt; 68,000</td>
</tr>
<tr>
<td>Haiti</td>
<td>Jan. 12, 2010</td>
<td>Haiti</td>
<td>7.0</td>
<td>217,000-230,000</td>
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<td>Chile</td>
<td>Feb. 27, 2010</td>
<td>Concepcion, Chile</td>
<td>8.8</td>
<td>500-1,000</td>
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<td>Indonesia</td>
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<td>Unknown</td>
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<tr>
<td>Japan</td>
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<td>Northeastern Japan</td>
<td>9.0</td>
<td>15,500-16,500</td>
</tr>
</tbody>
</table>
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
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

<table>
<thead>
<tr>
<th>Dam</th>
<th>Location</th>
<th>Height (m)</th>
<th>Completed year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cindere</td>
<td>Turkey</td>
<td>107</td>
<td>2008</td>
</tr>
<tr>
<td>Beydag</td>
<td>Turkey</td>
<td>100</td>
<td>2007</td>
</tr>
<tr>
<td>Gongguoqiao</td>
<td>China</td>
<td>56</td>
<td>2009</td>
</tr>
<tr>
<td>Tobetsu</td>
<td>Japan</td>
<td>52</td>
<td>2010</td>
</tr>
<tr>
<td>Can-Asujan</td>
<td>Philippine</td>
<td>44</td>
<td>2004</td>
</tr>
<tr>
<td>Hongkou cofferdam</td>
<td>China</td>
<td>35.5</td>
<td>2006</td>
</tr>
<tr>
<td>Nagashima</td>
<td>Japan</td>
<td>34</td>
<td>2000</td>
</tr>
<tr>
<td>Ano Mera</td>
<td>Greek</td>
<td>32</td>
<td>1997</td>
</tr>
<tr>
<td>Moncion</td>
<td>Dominica</td>
<td>28</td>
<td>2001</td>
</tr>
<tr>
<td>Marathia</td>
<td>Greek</td>
<td>28</td>
<td>1993</td>
</tr>
<tr>
<td>St Martin de Londress</td>
<td>France</td>
<td>25</td>
<td>1992</td>
</tr>
<tr>
<td>Jiemian cofferdam</td>
<td>China</td>
<td>16.3</td>
<td>2004</td>
</tr>
</tbody>
</table>
Hongkou CSG cofferdam (H=35.5m) survived against overtopping (ΔH=8m)
Concerns in future development of dams & reservoirs

New concepts
Better development of dams & reservoirs

4 Shifts

1. **Cognition**
   - Utilize and change nature
   - As well as Protect and adapt to nature

2. **Decision making**
   - Technologically feasible and economically reasonable
   - As well as Eco-friendly and social acceptable

3. **Operation & Management**
   - Project safety and function realization
   - As well as Ecological compensation, safety and regulation

4. **Benefit Sharing**
   - National and collective interests
   - As well as Stakeholders’ benefits
Concerns in future development of dams & reservoirs

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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
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

Datengxia Dam
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**

  **The Hydropower Sustainability Assessment Protocol**
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 IHA President Mr. Abdel-Malek

With IWRA President Mr. Xia
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
ICOLD technical materials downloaded by National Members freely

Welcome to ICOLD website's new homepage. The website has been updated, in order to be more efficient in disseminating ICOLD's experience and knowledge.

- A new design for the homepage with spaces for promoting our events and diffusing our publications;
- A new design for our publications online store, with the possibility of free...
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

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
International Milestone Projects

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

24th ICOLD Congress, Kyoto, Japan, June 2012

IWF&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 earthquakes. Earthquakes have always been a significant aspect of the design and safety of dams. A large storage dam consists of a concrete or soil fill dam with a height exceeding 15 m, a great concern for cities or towns to minimize leakage of water through the dam foundations, 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 nature of the reservoir, there are other components such as power plants, pumped storage, reservoirs, and control of environmental flow, fish hatchery areas, etc.

During the Ritsumeikan University School of Engineering, 141 earthquakes and 400 landfills failed due to various causes rather than these two large earthquakes.

What earthquake action does a dam face in Winito?

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 strong ground shaking. Even an extreme earthquake, which is referred to as the safety factor of a dam (SF) 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-in-100 chance of being exceeded in 100 years. It is very difficult to predict what can happen during such a rare event as a very few earthquakes of this size here and there have occurred. Therefore, it is important to note the following observations on the safety factor of the dam. The main lessons learned from the large Winito and Chūetsu earthquakes will have an impact on the assessment and improvement of existing dams and the design of new dams in the future.

There is a basic difference between the load-bearing behavior of buildings and bridges on the one side, and dams. Under normal conditions buildings and bridges are subject mainly to vertical loads due to the dead load of the structure and some secondary loads. In the case of dams the main load is the water load, which in the case of concrete dams exerts a horizontal pressure on the dam’s structural face in horizontal action. In the case of embankment dams the water loads act normal to the upstream face 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 it has a 1% chance of being exceeded in 100 years. Depending on the risk category of buildings and bridges, important factors are specified in earthquake codes, which translate into longer return periods, but they do not apply for large dams.

Moreover, most of the existing buildings and bridges have not been designed against earthquakes using modern codes, whereas dams have been designed to resist against earthquakes since the 1970s. Although the design criteria and analysis concepts used in the design of dams built from 1990 to today are as strict as in the 1970s, the consequences of the earthquake safety of conservatively designed dams is shown that even 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: (1) the presence of more than one type of hazard; (2) ground shaking causes vibrations and structural deformations in dams, reservoir structures, and reservoirs, and their foundations; (3) failures in the dam foundation or downstream structures in dams may affect the safety or stability of downstream structures; and (4) the occurrence of debris flow is also possible in unstable cases.

Left: Midland County dam built in 1872 in Switzerland. After a serious rehabilita-
tion its service life has been extended by another 50 years. (Photo shows the main elements of a storage dam that is probably not relevant to the case study given below.)

Earthquakes are a type of natural hazard that can affect the structural integrity of dams. There are several ways in which earthquakes can cause damage to dams, including:

- seismic waves can cause vibration and can lead to potential failures in dam foundations or embankments;
- ground liquefaction can cause the dam to move or deform, potentially leading to failure;
- landslides can cause the dam to slope or collapse;
- floods can cause the dam to fail due to overtopping.

These risks are particularly relevant to dams in areas prone to earthquakes. However, effective methods have been developed to mitigate the effects of earthquakes on dams. These methods include:

- improving dam foundations to reduce the risk of liquefaction;
- strengthening dam structures to increase their resistance to earthquakes;
- designing emergency plans to quickly respond to potential failures.

Conclusions

The technology and resilience of modern dams and their components to withstand earthquakes have significantly improved over time. Despite this progress, however, there is always a risk that an earthquake could cause damage to a dam. Therefore, it is crucial to have an emergency plan in place to quickly respond to any potential issues.

For more information, contact: Martin Wieland, Chairman, ICOLD Committee on Seismic Aspects of Dam Design, Purley Energy Ltd., Hardtumuhe 161, CH-6027 Zurich, Switzerland, martin.wieland@purleyenergy.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!