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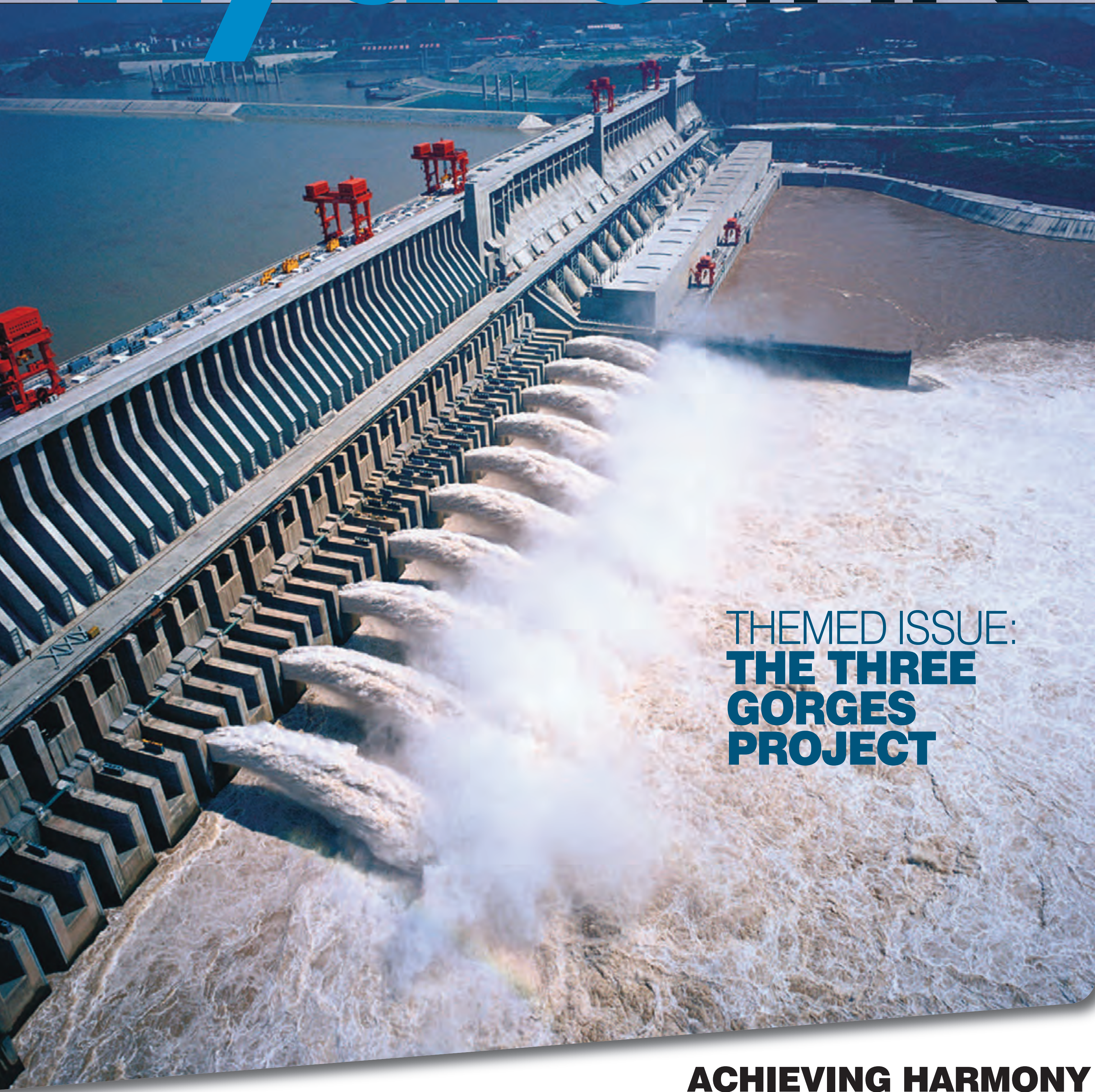

THEMED ISSUE:
THE THREE GORGES PROJECT

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LARGE DAMS: LEARNING FROM THE PAST, LOOKING AT THE FUTURE

EDITORIAL BY MICHELE MOSSA

The history of dams is ancient. As can be read in Pierre-Louis Viollet's book entitled "Water engineering in ancient civilizations – 5,000 years of history" (see IAHR eShop), one of the first codes, which includes edicts that regulate use of irrigation systems, is that of the Babylonian King Hammurabi. It requires that riverside inhabitants maintain the dikes that protect the fertile lands near the river courses, and sets compensatory penalties for those who are remiss in this responsibility: "If a man has been slack in maintaining [the bank of] his [field] and has not maintained [his] bank and when a breach has occurred in his [bank] and so he has let the waters carry away (the soil on) the water-land, the man in whose bank the breach has occurred shall replace the corn which he has (caused to be) lost." Furthermore, "if a man has released the waters and so has let the waters carry away the works on his neighbor's field, he shall pay ten gur of corn for every bur of land."

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In about 60 AD the Emperor Nero built his villa at Subiaco, on the river Anio upstream of Tivoli, in Italy where he created lakes for his personal pleasure by damming the river. The largest of the structures he built for this purpose spans a natural gorge and, at 40 m, is the highest dam of all the Roman Empire. This dam remained standing until 1304, when the monks of a neighboring monastery dismantled it to recover the stones for other uses. Forty years after Nero, Frontinus built the new intake for the Anio Novus aqueduct on one of these lakes to improve the quality of its water, as we have seen earlier.

In the modern era the construction of large dams initiated with the Aswan Low Dam in Egypt in 1902, a gravity masonry buttress dam on the Nile River. Following their 1882 invasion and occupation of Egypt, the British began construction in 1898. The Hoover Dam in the US was a massive concrete arch-gravity dam, constructed in the Black Canyon of the Colorado River, on the border between the US states of Arizona and Nevada between 1931 and 1936 during the Great Depression. Such a large concrete structure had never been built before, and some of the techniques were unproven. The torrid summer weather and the lack of facilities near the site also presented difficulties. Nevertheless, the contractor "Six Companies" turned over the dam to the federal government on March 1, 1936, more than two years ahead of schedule. By 1997, there were an estimated 800,000 dams worldwide, some 40,000 of them over 15 m high.

The present issue of Hydrolink is devoted to the Three Gorges Dam, which is a hydroelectric dam that spans the Yangtze River by the town of Sandouping, located in Yiling District, Yichang, Hubei province, China. The Three Gorges Dam is the world's largest power station in terms of installed capacity (22,500 MW).

The topic of large dams have become the focus of an intense worldwide debate. However, what is the correct definition of large dams? *The International Commission on Large Dams* (ICOLD) defines "large dams" as dams with a height of 15 meters or more. If dams between 10 and 15 meters high have a crest length over 500 meters, a spillway discharge over 2,000 cubic meters, or a reservoir volume of more than 1 million cubic meters, they are also classified as large dams. The International Journal on Hydropower & Dams uses the term "major dam project" for projects that fulfill one or more of the following criteria: dam height of more than 150 meters: dam volume of more than 15 million cubic meters; reservoir volume of more than 25 billion cubic meters; and installed capacity of more than 1000 MW.

After publication of the August 1996 report on the World Bank's experience with large dams, the World Conservation Union (IUCN) and the World Bank organized a joint workshop in April 1997 to move forward the debate in terms of a new set of principles to guide future decision-making about large dams. Founded in 1948, IUCN brings together States, government agencies and a diverse range of non-governmental organizations (NGOs) in a unique membership. As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.
As a contribution to the workshop of 1997, some papers summarize the lessons learned and trends in the planning, design, construction and operation of large dam projects, specifically addressing engineering and economic aspects.
Environmental and social issues were also addressed in the abovementioned papers.
The crucial points reported in these papers refer to the main trends for large dam projects, as for example :

- Increased understanding and awareness of complex technical, environmental and social issues that are inherent to large dam projects, and realization that the development of large dam projects involves a trade-off between the benefits gained against losses.
- Increased awareness that environmental sustainability and high discount rates are in conflict.

As regards the social impacts of large dams, Thayer Scudder, a professor at the Institute of Development Anthropology at the California Institute of Technology, asserts that the adverse social impacts of dam construction, whether short-term or cumulative, have been seriously underestimated in the past. Large-scale water resource development projects have unnecessarily lowered the living standards of millions of local people. According to the World Bank's senior environmental advisor, involuntary resettlement is arguably the most serious issue of hydro projects nowadays. Besides resettlers and hosts, other people affected by dam construction include rural dwellers residing downstream of a dam. They are often neglected in project assessments because it is assumed that they will benefit from the project; however, there are frequently significant negative downstream impacts.

Robert Goodland, an advisor on environmental assessment in the Environment Department at the World Bank, provides an overview of the debate embroiling the hydroelectric industry regarding the environmental sustainability of dam construction. Goodland examines major controversy over dams, including transparency and participation; demand-side management, efficiency and conservation; the balance between hydro and other renewables, large dams vs. small and medium-size dams; storage dams vs. run-of-river dams; involuntary resettlements; project-specific mitigation; and, finally, the damage costs of greenhouse gas emissions.

Fifty years ago, the United States rushed into a water development program with little understanding of the negative impacts it would have on its rivers and all who depend on them. Today, we are beginning to "pay the piper" in depleted fisheries, damaged ecosystems, receding coastlines and many other problems linked to the damming of our rivers.

Now we must manage our dams differently, allocating more flow to the environment in an effort to stop further dam–related destruction of ecosystems and taking other costly steps to save valuable fisheries. We are even preparing to take down some particularly bad dams, at enormous expense. Dams may destroy wild life habitats, drain wetlands, and cause river pollution by reducing the river flow to a level where the river can no longer self-cleanse. Another possible problem is the risk of failure, which can be catastrophic. As recently as 2004 the Big Bay Dam in Mississippi broke destroying nearly fifty homes. It is a major concern in civil engineering to see that dams are safe from hazards such as landslides and earthquakes.

Nevertheless, we must consider that dams can also offer huge benefits in terms of electrical power generation, water supply, navigation and irrigation. Many massive dams worldwide are a tribute to the achievements of civil engineering and electrical engineering. These great feats of civil engineering are not without problems, however, and there are potential disadvantages as well as benefits to take into account.

As always, the problem must be faced considering both pros and cons and our community can be helpful in the solution of the above-mentioned problems. The present issue of Hydrolink deals with some of these aspects. I am pleased to conclude this editorial offering three films to our readers that I have recently inserted in the IAHR Media Library. The first one is entitled "The dam of the glacier" and is an interesting old Italian documentary on the construction of dams. The film is in Italian, but the images are interesting and unequivocal and refers to the construction of the dam of Morasco in Val Formazza (Piedmont, Italy). The other two films are devoted to the three Gorges Dam. I hope that you enjoy them.

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Cover picture: The China Three Gorges Corporation

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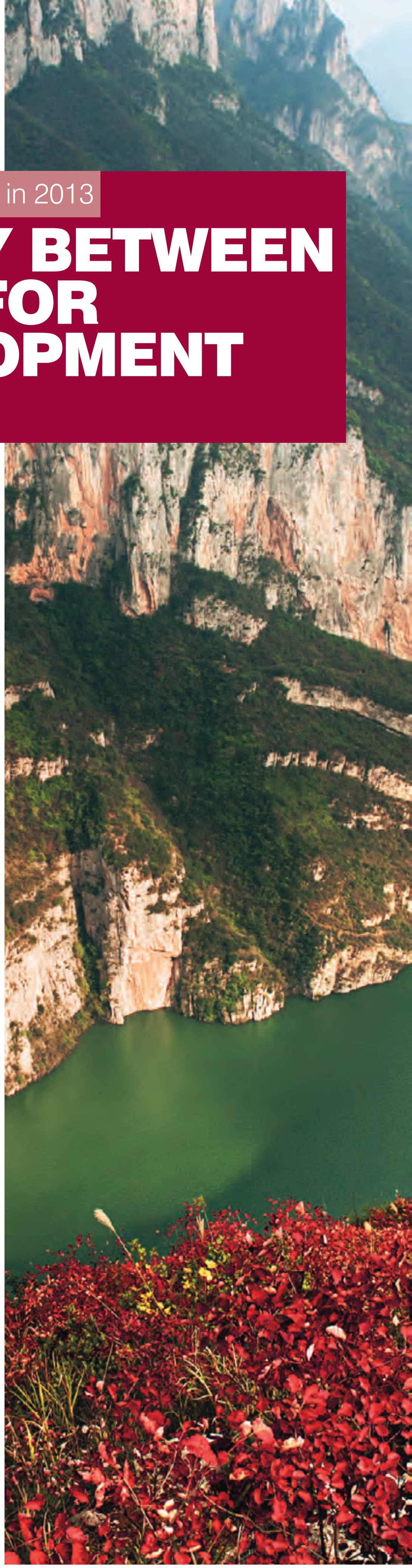
Opening speech at the IAHR World Congress in Chengdu in 2013

ACHIEVING HARMONY BETWEEN PEOPLE AND WATER FOR SUSTAINABLE DEVELOPMENT

BY H.E. DR. JIAO YONG



People-water relation is an essential proposition for the development of modern society

The Chinese sage Confucius said "The wise find pleasure in water and the benevolent in mountains". It means that a person of wisdom seeks a more meaningful life by virtue of love and respect of nature. In a broader sense, it suggests that the love and respect of nature should be universal, and the laws of nature be followed when we exploit natural resources. During our interaction with nature, one of the decisive factors for human survival and development is people-water relation.

Back in the agrarian age, people were ignorant and fearful of nature, helpless in face of floods and droughts, and migrated to escape from water disasters. In the age of industrialization and urbanization, as productivity skyrockets, massive conquest and transformation of nature is staged to satisfy our growing material demand. Along the course dams and reservoirs are built, rivers harnessed and irrigation systems developed to utilize water for higher economic output and better living conditions. However, water in many countries are over exploited and seriously polluted. This plight is unfortunately being repeated in many developing countries now, with local and regional development straining the capacity of water resources, leading to degraded ecological environment.

We now begin to realize that any endeavors to promote socio-economic development must abide by laws of nature, and must be done in a sustainable manner. As scientists and engineers directly dealing with water, we should know it better than anyone else that the spirit of loving and respecting nature should be extensively embodied in water engineering activities throughout the process of research, planning, design and construction.

The evolution of people-water relation in China's modernization process and the achievements

Conflicts induced by people-water relation are no stranger to many countries, but in China the issues are particularly complicated.

The complexity stems first from China's national conditions. China is the most populous country and the second largest economy in the world. Agriculture and industry, the two water-intensive sectors, make up for the lion's share of national economy. As the economy begins to run on the fast track since the reform and opening-up, water related conflicts also emerged acute.

The complexity stems also from China's water conditions. Water ownership per capita in China is 2,100 m3, only 28% of the world average. Water is temporally and geographically unevenly distributed: 60% to 80% of precipitations occur in the flood season; less than 20% of water resources are in north China, which accounts for 64% of national land area, 46% of the population and 60% of the arable land. China therefore has to walk a fine line between utilizing water for socio-economic development and protecting the aquatic eco-environment.

Practices tailored to China's water picture yield many successes: a water-related legal system is put in place, combining both basin management and regional administrative management. A flood control mechanism for major rivers has been developed, raising the flood defense standard for large cities to 100-200 year flood. To enhance food security and poverty alleviation, massive efforts are put to developing irrigation agriculture, with irrigated area producing 75% of food and over 90% of cash crops. China has fed 21% of world population using 6% of world fresh water and 9% of arable land. Last but not least, aquatic eco-environment protection is being reinforced. Ecological restoration projects have been carried out on key river basins and ecologically fragile regions. Successful examples include the ones on Tai Lake, Tarim River and Shiyang River.

Challenges ahead

Despite the achievements, China still faces an

uphill journey of eliminating and mitigating water induced conflicts.

Tense supply of water. As China's industrial economy will remain un-proportionally large for quite a period ahead, the industrial demand for water will continue to rise. Urban population will only grower larger in the next two decade, hence more water is needed. Despite the hard-work to produce more food with no bigger agricultural water consumption, developing a more water-efficient agriculture is challenging.

Low water use efficiency. In terms of industrial water, GDP output per m^3 of water fall short of the world average by two thirds, and water usage per 10 thousand RMB of industrial added value is three to five times that of the international advanced level. In terms of agricultural water, irrigation water coefficient is much lower than the international advanced level.

Rampant water pollution. The pollutants discharged into water bodies are almost twice their pollution-carrying capacity.

Degraded aquatic eco-environment. Water overexploitation in various places has led to dried-up river channels, shrinking lakes, reduced aquatic biodiversity, depleted ground-water and seawater flowing into estuaries.

Policies and measures to achieve human-water harmony

The philosophy of people-water harmony. Since China strives to become a resource-efficient and environment-friendly economy, more focus is laid on water demand management and the capacity of local water and environment during economic planning. Special policies are formulated to optimize, restrain or prohibit water exploration in areas where serious water shortage or fragile ecology exists.

Water for supporting socio-economic development. The existing water engineering systems are better utilized to more precisely regulate floods of major rivers. Flood control of medium and small sized rivers should be enhanced as well as they are usually densely populated. More efforts are put to improving accuracy of the flood warning system, raising public awareness and strengthening community management against flood casualties.

In the aspect of water supply, rural access to safe drinking water is increased and urban water security is strengthened. In the aspect of

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food security, water-efficient irrigation systems should be further developed to heighten grain productivity and water use efficiency.

The three red lines of water management. In 2012 the Chinese government introduced the strictest water management system, the essence being three red lines for total water usage, water efficiency and water pollution discharge respectively. That is, the total water consumption shall not exceed 700 billion m^3 by 2030; water consumption per unit of industrial added value shall be reduced to 65 m^3 or below, efficient usage coefficient of water shall be increased to 0.55 or higher; and the percentage of major function areas of large rivers and lakes that meet designated water quality shall reach 60% by 2015 and 80% by 2020.

Aquatic ecological restoration. Successful pilot restoration projects include those on Tarim River, Heihe River and Shiyang River, with total investment of 20 billion RMB. Many water engineering projects also put more efforts on restoring the ecological function of rivers. For example, the Xiaolangdi multi-purpose dam project on the Yellow River has restored the natural river course with its flood discharge capacity. The Three Gorges Project on the Yangtze River has managed to provide suitable water flow for the reproduction of rare fish species downstream through accurate discharge regulation. Legal formulation concerning aquatic ecological compensation is underway.

China has both successes and setbacks in its long history of water management. In accordance with our commitment to sustainable development, the harmony between people and water will be actively pursued.

THE WORLD'S BIGGEST HYDR
CHINA THREE GORGES

BY INTERNATIONAL DEPARTMENT, THE CHINA THREE GORGES CORPORATION - CTG

Yangtze River Basin and the Three Gorges Project

Yangtze River Basin

Measuring 6300 kilometers from its source in the Tanggula Mountain Range on the Qinghai-Tibetan Plateau, the Yangtze is China's longest river and the world's third longest. The main stream of the Yangtze River runs from west to east through 11 provinces, autonomous regions and municipalities directly under the central government including: Qinghai, Sichuan, Tibet, Yunnan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu and Shanghai. Its basin area measures 1800000 km^2, covering about one-fifth of China's landmass. The population, farmland area, grain yield, total regional output value of industry and agriculture, and other important socioeconomic indicators in the Yangtze River basin are of correspondingly great importance and account for a large portion of China's totals. The population of the basin accounts for more than one-third of China's total population. The production in the basin accounts for nearly 40% of national GDP.

The Yangtze River is a huge water system with abundant water. Its annual water discharge is about 956 billion m^3. The Yangtze River basin is rich in hydropower resources.

The whole basin has a theoretical annual generating capacity of 243.36 TWh, a technically feasible generating capacity of 118.79 TWh, and economically feasible generating capacity estimated at 104.98 TWh, accounting for 40%, 48% and 59.9% of the total national hydropower resources, respectively. The hydropower resources of the Yangtze River basin are mainly concentrated in the mountainous areas of the middle and upper reaches of the river. The Three Gorges section of the river is particularly rich in water resources and the consecutive elevation drops make it suitable for the construction of large hydropower complexes.

Navigation along the Yangtze River is quite developed, especially on the middle and lower reaches of the main stream, a channel known

Map of the location of the Three Gorges Dam, Sandouping, Yichang, w:en:Hubei Hubei Province, China and major cities along the Yangtze River. Source: Wikimedia Commons

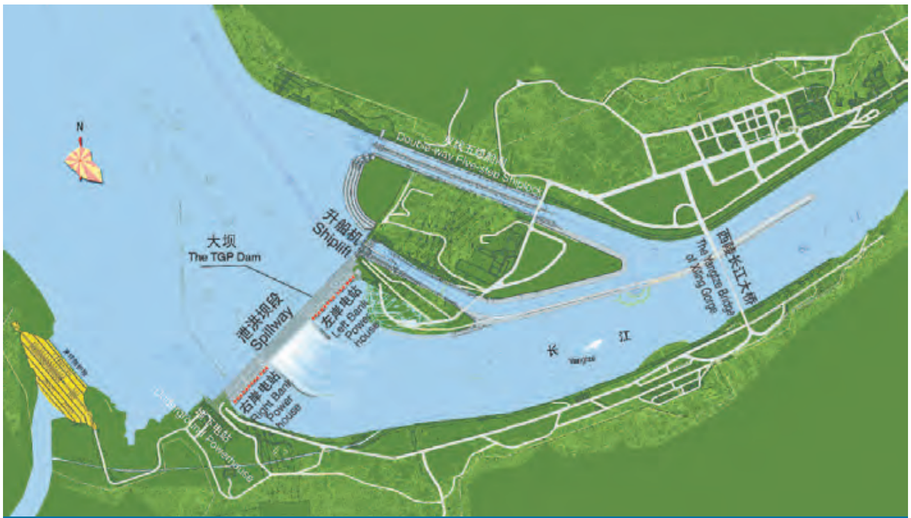
as the "golden waterway". However, before the construction of the Gezhouba and Three Gorges hydro complexes, the main stream above Yichang City featured a lower navigation level and some portions of the river that were not navigable at all times. This was not conducive to exchange between the southwest hinterlands and the more developed eastern areas of the country, unfavorably impacting the economic development along the upper reaches of the Yangtze River.

Although the Yangtze River basin boasts rich natural resources and strong economic foundations, there were many environment problems and living conditions could be difficult. For example, the frequent massive floods that have plagued the plains of the middle and lower reaches of the Yangtze River had been a scourge of the Yangtze River basin. According to historical statistics, over two thousand years, 214 catastrophic floods occurred along the Yangtze River, almost once every ten years. Death tolls for the 1931 and 1935 floods both reached more than 140000 people; while the 1998 flood destroyed 239067 ha of farmland and 2128500 houses and killed 3004 people, for total direct economic losses of 166 billion RMB.

The Project

The Chinese government launched the construction of the Three Gorges Project (TGP)

O COMPLEX PROJECT



General layout of TGP Hydropower Complex

in 1993 as a key backbone project to harness and develop the Yangtze after decades of scientific feasibility studies and democratic decision making. The project has put in place effective measures to manage and develop the Yangtze River, to avoid devastating flood disasters, and to ensure the sustainable economic development and social prosperity of the river basin.
The Three Gorges Project is located at the Three Gorges section of the mainstream of the Yangtze River. It is currently the world's largest hydro complex and most comprehensive water conservancy and hydropower project.
The Three Gorges complex can be divided into three parts: the dam, the hydropower station, and the navigation structures. The dam crest is EL.185 m and the maximum dam height is 181 m, and its axis is 2,309.47 m long. The Three Gorges hydropower station is made up of the left-bank powerhouse, the right-bank powerhouse, the right-bank underground powerhouse and the power source station. Its total installed capacity reaches 22500 MW with an average annual power output of 88.2 to 100 TWh, which makes it the world's biggest hydropower station. The normal impoundment level of the Three Gorges reservoir is EL.175 meters. The total storage capacity of the reservoir is 39.3 billion meters^3 with a total length of 663 km and a surface area of 1084 km^2.

The construction of the Three Gorges Project began in 1993 and lasted 17 years. Apart from the delays approved by the Chinese government on the vertical ship lift and the added right-bank underground powerhouse, the construction work was wholly completed in 2009. Currently, the designed capabilities of the Three Gorges Project have all reached their design parameters. The complex has begun operating and brought forth its full comprehensive benefits.
In accordance with the concept of sustainable hydropower development: "build a hydropower station to stimulate the local economy, improve the local environment and benefit the resettled residents", the Three Gorges Project has begun operations, bringing forth its full comprehensive benefits in flood control, drought relief, power generation, navigation improvement, ecological water supply, tourism development, etc. The construction of the Three Gorges Project has also led to the development of construction enterprises, equipment material supply enterprises, service enterprises, and resource development enterprises; promoting a more reasonable structure for agriculture, industry and the tertiary sector of the reservoir area. It boosted the development of the local economy, delivering benefits to the large number of people living in the reservoir area and the middle and lower reaches of the Yangtze River.

Starting in the 1950s, tens of thousands of scientists and engineers participated in the feasibility study and design of the Three Gorges Project (TGP). After the 1980s, the Central Government mobilized 412 distinguished experts to conduct an exhaustive study into the feasibility of the project on 14 subjects.
On April 3, 1992, the 5th Plenary Session of the 7th National People's Congress of the People's Republic of China adopted a resolution to launch the project.

The Construction

In accordance with the design, construction of the TGP was divided into three phases, with a total duration of 17 years:
Phase I (1993 -1997) had a construction period of five years and was marked by the closure of the Yangtze River.
Phase II (1998 - 2003) had a construction period of six years and was symbolized by the impoundment of the reservoir to the level of 135 m, the commencement of power generation of the first group of generating units and the operation of the double-way five-step ship locks.
Phase III (2004-2009) has a construction period of six years and is characterized by the commissioning of all generating units in the left and right-bank powerhouses and the final completion of the hydropower complex.

On October 26th 2010, TGP trial impoundment achieved 175 m designed water level.

Operation of the Three Gorges Project

Flood Control

Flood control is the most important function of the Three Gorges Project.
The plain along the middle and lower reaches of the Yangtze River is densely populated and economically developed. However, severe floods have frequently occurred in history, as the ground elevation in this region is generally several meters, sometimes even over 10 meters, lower than the Yangtze River's flood

level. Along the thousand-kilometer long Yangtze River, the most flood-prone section is the Jingjiang section. Before the construction of the Three Gorges Project, the Chinese government had taken several measures to manage the river. It heightened dikes, built the Jingjiang flood diversion project and established a hydrological forecasting station network, etc. But the battle between high flood peaks and insufficient flood discharging abilities along the middle and lower reaches of the Yangtze River remained. The Jingjiang plain, with a population of 15 million and 1.54 million ha of farmland, still faced harsh flood threats.

The Three Gorges Project has significantly enhanced the flood control capability of the middle and lower reaches of the Yangtze River. It has a flood control capacity of 22.15 billion meters3 and its flood control benefits and the associated environmental benefits have been significant. In the case of a one-hundred-year frequency flood (83,700 m^3 /s), a one-thousand year frequency flood (98,800 m^3 /s), or a ten-thousand-year frequency flood (124,300 m^3 /s), the Three Gorges Project can prevent the flood through proper regulation and eliminate the flood danger along the middle and lower reaches of the river.

From 2003 to 2012, the Three Gorges Project had blocked and stored a total of 75.4 billion cubic meters of floodwater. On July 20, 2010, the Three Gorges Project faced its first big flood since the project completion, with a 70,000 m3/s peak inflow. By controlling the discharge, the maximum flood cut-off reached 30,000 m3/s and 7.3 billion $meters^3$ of water were blocked. In 2010, the Three Gorges reservoir had stored 26.43 billion $meters^3$ of flood water in total. The effective regulation of the flood peaks by the Three Gorges Project has played a key role in maintaining the safety of the Jingjiang section, which is at the middle and lower reaches of the Yangtze River. In July 24, 2012, the Three Gorges Project experienced a 71,200 m^3/s flood, which was the biggest flood peak since the reservoir has been built. The Project reduced flood peaks by a maximum of 28,200 m^3 /s. A total of 22.8 billion cubic meters of flood was blocked during the flood season. This maintained the safety and serenity of the dikes along the main stream and tributaries, ensuring the peacefulness of the Yangtze River.

Power Generation

As the world's largest water conservancy and hydropower project, the Three Gorges Project is the world's largest renewable energy site. The safe and efficient operation of the Three Gorges hydropower station provides abundant green energy for China's socioeconomic development of China. It increases the share of hydropower in the national power supply and plays an important role in providing energy to eastern, southern, and central China where there are severe power shortages.

The Three Gorges hydropower station is installed with twenty six 700 MW hydro-turbine generating units. Adding 2 hydro-turbine generating units with 50 MW installed capacity each in the power source station, and the later expanded six 700 MW generating units in the right-bank underground power station, the Three Gorges hydropower station's total installed capacity reaches 22,500 MW. Its daily power output accounts for 1/30 of China's daily power output. By the end of 2012, the cumulative power production of the Three Gorges hydropower station had reached 630 TWh. The total power production for 2012 reached 98.1 TWh, accounting for around 14% of China's annual hydropower production.

The construction and operation of the Three Gorges hydropower station and the Three Gorges transmission and transformation project have been very important to realize the Chinese government's West-to-East Electricity Transmission Project, the mutual transmission of power between the north, as well as the connection of the national grids, which made the Three Gorges electrical system the core of the national power grids, turning the Three Gorges hydropower plant into a backbone energy source for the Chinese power grids.

Seen from its geographic position, the Three Gorges hydropower station is exactly at the center of the West-to-East Electricity Transmission Project, as well as for the mutual transmission of power between the North and the South. It can connect to Shanghai in the East, to Chongqing and Sichuan in the West, to Tianjin and Beijing in the North, and to Guangdong in the South. It is the nexus of the entire country's power transmission network and the most ideal energy base. The maximum power transmission radius of the Three Gorges hydropower station extends as far as 1000 kilometers. With the Three Gorges hydropower station at its center, the Three Gorges Project is the world's largest power transmission project. It runs through 9 provinces and 2 municipalities and covers an area of about 1.82 million square kilometers. Power passing through the Three Gorges' transmission and transformation network is sent to central, eastern, and southern China as well as Sichuan. The power from the China Three Gorges hydropower station covered almost half China and more than half of China's population directly benefits from the power, providing a great impetus to China's economic development.

Considering the characteristics of its electric power, the power produced by the Three Gorges hydropower station is not only clean

Power output of the Three Gorges Project

and environmentally friendly, but also reliable. Its price is low, and it can be produced during peak times to perform peak load regulation and supplement the power produced by thermal power plants. As such, the station is of great importance in raising the nation's power grid economic efficiency, safety, flexibility and reliability. Since the beginning of winter 2010, for example, there was increasing pressure on the power supply in Hubei and Chongqing. In line with the demands of the State Grid Corporation, the Three Gorges hydropower station added a 500 MW load to support the municipality of Chongqing during the peak electricity demand period from 9 AM to 9 PM every day. On January 10 and 14, 2011, the Three Gorges hydropower station also added a 600 MW load, but sent it to Hubei this time, thus effectively relieving the production and living pressures on power supply in Hubei and Chongqing. This contributed to the safe and stable operations of the power grid.

Hydroelectricity is a clean renewable energy. Its production process does not make pollution, and it does not consume water resources. The operation of the Three Gorges hydropower station has increased the proportion of hydropower capacity in the country's total power generating capacity mix. It has thus improved China's energy structure while saving energy and reducing emissions. After the completion of the Three Gorges Project, the annual power output has been 84.7 TWh (excluding the underground power station). If this power was produced at a thermal power plant, 40 to 50 million tons of coal would have been burnt. As such, the Three Gorges hydropower station could avoid the release of 100 million tons of CO_2 emissions, 1.2 to 2 million tons of sulfur dioxide, 10 thousand tons of carbon monoxide, as well as 370 thousand tons of oxynitride. Further, the station avoids the release of a large amount of waste water and industrial waste, thus reducing environmental pollution. It also limits the creation of acid rain due to harmful gas emission. According to the State Electricity Regulation Commission's (SERC) thermal power emission standards from the time the first generator unit was commissioned in 2003 until the end of 2010, the Three Gorges hydropower station had produced a total of 630 TWh of electricity which was equivalent to the power produced by burning 216 million tons of coal, thus avoiding the emission of 540 million tons of CO_2. This is a great contribution to environmental protection and the development of clean energy in China.

Double-way Five-step Ship locks

Navigation

The Yangtze River is a main artery for inland navigation in China, linking the country's eastern, central and western regions' economies. There are 660 km with a 120 m drop through separating Yichang and Chongqing. Because navigation conditions used to be very bad due to rapid currents and poor navigation channel, the towing capacity of ships was low and the fuel consumption was high. After the completion of the Gezhouba Dam, the 130 km upstream from Yichang were improved, but 109 rapids still hindered navigation along the Chuan Jiang section of the river, with 37 parts that only allowed one-way navigation. As the economy developed, the navigation was far behind the growing demand for the transport of goods.

After water was impounded at EL.175 m, backwaters of the Three Gorges reservoir reached Chongqing, thus improving navigation over 660 km. Annual one-way navigation improved from 10 million tons to 60 million tons. The cost of transporting a ton of goods over a kilometer was reduced by one third. Through the management and provision of water during the dry season, water depth in the lower reaches of the Yangtze River was increased. The Three Gorges ship locks began its formal operation and providing free passage for ships on June 18, 2003. Lifting the water level greatly improved the navigation conditions along the Chuanjiang section, which allowed for the swift development of the navigation industry on the river.

The navigation structures of the Three Gorges Project include the ship locks and ship lift. The double-way five-step ship lock is an inland ship lock which has the highest water head and the most steps in the world. The total length of the ship locks is 6442 m and a fleet made up of 3000 tonnage ships weighing up to 10000 tons

can go through it. In 2011, the cargo volume passing the Three Gorges Dam hit new records reached 100.33 million tons with a year on year increase about 27.3%, which is the first time more than 100 million tons of cargo passed through the ship locks in 8 years since it has begun operating.
The ship locks have brought a huge boost to the navigation of the Yangtze River and the economic development of the middle and west China.

The cost of boat transportation in the reservoir area was lowered and the fuel savings and emission reduction results were remarkable. As the water speed decreased in the reservoir area after impoundment, the flow regime was stabilized and the gradient was lowered. Shipping capacity increased noticeably and fuel consumption dropped. In 2009, for example, Chongqing water transports saved close to 50,000 tons of fuel, reducing CO_2 emissions by 1.5 million tons and hydrocarbons by 14,000 tons. The Three Gorges Project's navigation channel has become a representative of a green channel that saves energy and reduces emissions.
Navigation safety in the reservoir area was also greatly increased. Initial statistics show that navigation conditions improved after impoundment; average annual reduction in accidents was 70%, in collisions was 73%, in human deaths was 82%, in boat sinking was 62%, and in direct economic losses was 45%.

Navigation along the Three Gorges positively impacted the economic development of the municipality of Chongqing and other localities along the river. Currently, the navigation industry in the Chongqing area directly creates 150000 jobs, close to 80000 of who come from the Three Gorges reservoir area. Industries, such as coal, tourism, road transportation, etc., create more than 500000 jobs. Navigation and industries linked to the navigation industry have recruited more than 2 million surplus laborers.

Drought Relief and Water Supply

The natural inflow of the Yangtze River is featured in seasonal change, uneven spatial and temporal distribution, and highly contrasted in wet and dry seasons. According to statistics, from the 16th century to 1949, the 5 provinces downstream the Yangtze River were affected by frequent droughts. Hubei was affected 146 times, Hunan 139 times, Jiangxi 194 times, Anhui 172 times, and Jiangsu 233 times. This is an average of one drought every 2 to 3 years for each province. After the establishment of the People's Republic, the five worst disasters happened in 1978, 1959, 1988, 2000, and 1961.

According to the project design, one important function of the Project is the regulation of the seasonal water distribution. The use of the Yangtze River's water resources can be optimized through storing in wet season and using in dry season. This ensures that production and living needs are met downstream of the Yangtze River.

The Three Gorges reservoir provided 21.5 billion cubic meters of water for ecological benefits and drought relief

The Three Gorges reservoir is filled every year at the end of the flood season. As the dry season begins, by using the projects' capacity for water regulation, the discharged flow is increased so that the amount of water flowing out of the reservoir is noticeably higher than that coming into it. Since the reservoir began impounding water in 2003, in circumstances where the average water flow into the reservoir was below 4000 m^3/s, the amount of water flowing out of the reservoir always remained above 4850 m^3/s. Even in a historically rare dry period, the reservoir is able to discharge water 1000 m^3/s more than the natural rate without regulation. The water flow below the reservoir has also increased by about 1000 m^3/s compared to a corresponding period before the regulation and storage capacities of the project existed. In 2010, the Chinese government added drought relief to the originally designed basic functions of the Three Gorges reservoir. It became a primary function along with flood prevention.

In recent years, the natural inflows into the upper reaches of the Yangtze River have been relatively low. Inflows during the dry season have often had difficulties meeting the production and living needs of residents, as well as the navigation depths needed in the middle and lower reaches. This was especially true in September 2009, when the middle and lower reaches of the Yangtze River experienced historically rare low water levels. A fairly serious drought affected the Dongting Lake and Poyang Lake areas. To ensure unimpeded navigation in the downstream, as well as to relieve the agricultural, industrial and residential water-use pressure downstream from the areas, the Three Gorges reservoir implemented regulated provision of water to ensure the timely increase of water discharge to provide water to the middle and lower reaches. By the flood season of 2012, the reservoir had provided 21.5 billion m^3 of water downstream. This truly brought forth the social benefits of the Three Gorges Project.

Taking 2011 as an example, the Yangtze River basin suffered a 100-year frequency drought. Drops in precipitation for the middle and lower reaches of the Yangtze River were 40 to 60 percent lower than that in the same period of previous years. This was the lowest amount of precipitation since 1961. While still releasing the naturally flowing waters from the upper reaches of the Yangtze, the Three Gorges reservoir also increased the discharge of water flowing out of the reservoir. Relying on its strong water resource regulation capacity, the Three Gorges reservoir provided 21.5 billion cubic meters of water for ecological benefits and drought relief. This water had met the needs for the anti-drought demand, such as the rice cultures in Hubei and Hunan provinces, and also had alleviated pressures on rural and urban water supply, irrigation and navigation along the river. This ensured that the downstream regions have enough water and guaranteed the safety of navigation, turning the reservoir into a "water resource bank" that stores abundant water to supplement droughts.

Environmental Protection

The construction of any hydropower project can impact the environment and the Three Gorges Project is no exception. The construction and operation of the Three Gorges Project inundated arable land and rare plants, weakened the self-purification capacity of certain water areas, and changed the aquatic ecology in the reservoir area, the middle and the lower reaches of the Yangtze River. At the same time, the Three Gorges Project made enormous contributions to the improvement of the environment and should objectively be acknowledged and evaluated as such. After regulation by the Three Gorges reservoir, the

THREE GORGES PROJECT – RECORD BREAKING FACTS

The total storage capacity of the Three Gorges reservoir amounts to **39.3 billion m³**, of which **22.15 billion m³** is for flood control. The flood regulation could cut flood peak amount by 27,000 - 33,000 m³/s, thus efficiently controlling the flood from the Yangtze River's upper stream, protecting **15 million** people and 1.5 million hectares of farmland at the Jingjiang section of the Yangtze River. The Three Gorges Project is the water conservancy project that has the world's most significant flood control ability.

The total installed capacity of the Three Gorges Hydropower Station is **18,200MW**, with annual power production of **84.68 TWh**. It is the world's largest power station.

The axial length of the Three Gorges Dam is **2309.47 m**, the length of spillway section is **483 m**. The power station consists of 26 generating units with a single unit installed capacity of **700 MW**, double-way Five-step Ship Locks and Ship Lift. TGP is the world's largest water conservancy project in terms of individual projects and the whole project.

The rock-and-earth excavation of the main sections of TGP is **134 million m³**, concrete placement **27.94 million m³**, steel fabrication and installation **463 thousand tons**, metal installation **256.5 thousand tons**. TGP is the world's largest water conservancy project with the most construction quantity.

In the year of 2000, TPG's annual concrete placement was **5.4817 million m³**, the record monthly concrete placement was **550 thousand m³** which creates the world record of concrete placement. TGP is the world's most difficult water conservancy project in terms of construction.

The river closure rate of the Three Gorges Project is **9010 m³/s** and the maximum flood peak flow is **79000 m³/s** during river diversion. It is the largest water conservancy project that has the maximum water flow during the construction phase.

The maximum flood discharge capacity of the Three Gorges Project is **102.5 thousand m³/s**. The discharging sluices are of the world largest discharging capacity.

The total water head of TPG Double-way Five-step Ship lock is **113 m**. It boasts the world maximum steps and the highest water head in inland river ship locks.

The effective dimensions of the TGP ship lift are 120 m × 18 m × 3.5 m, the maximum lifting height is **113 m** and total lifting weight is about **11800 tons**, capable of accommodating 3000-tonnage ship. It is of the world largest scale and difficulty.

The number of dynamic resettlement resident of TPG reservoir will have reached **1.13 million**. It features the world's largest number of resettled resident and most difficult resettlement task.

flood control standards of the Jingjiang section of the river were improved from 10 year-frequency floods to 100 year-frequency floods. In the event of a 1000-year frequency flood, large death tolls and huge property losses along the Jingjiang River section can also be avoided. At the same time, environmental degradation, contagious diseases and other social problems brought by flooding and flood diversion can also be avoided. The Three Gorges Project protects 1.5 million ha of farmland and towns on the Jianghan Plain and the Dongting Lake area, providing safety for its 15 million residents. Studies show that through the regulation of inflows, the Three Gorges Project can decrease sediments and floodwaters diverted to the Dongting Lake in the flood season, thus alleviating dangers to the Dongting Lake, slowing down the speed of sedimentation and extending its life. Due to the regulation of the reservoir, downstream discharge during the dry season has increased, helping to dilute dirty water, improve the water quality and alleviate pollution.

After the completion of the Three Gorges reservoir, the local climate around the reservoir area has improved and agricultural production has increased. Water quality along the middle and lower reaches of the Yangtze River has also improved during dry season. The influx of salt water into the river delta has also been reduced. After repeatedly being proved in the design process, coupled with strict observation for several years following the impoundment, which shows that the reservoir conditions on water quality, sedimentation and seismic activities are better than expected, the conclusion has been drawn that the Three Gorges Project is an ecologically friendly project in its essence and that the advantages outweigh the disadvantages. It has fostered the concepts of respect for nature, harmony with nature, and the protection of nature. It has insisted on protection during development, developing to protect. According to ecological theories, a new and better ecological environment has been created to rebalance the ecology and improve the environment of an area.

During the construction of the Three Gorges Project, a system for water and soil conservation featuring engineering measures supplemented by biological measures, provisional measures in combination with permanent measures was developed. Six projects have been carried out, which are: the protection of excavated slopes, waste landfill protection, a drainage and sewage project, the concentrated disposal and reuse of surface soil, a greening project, and an ancient trees conservation project. By implementing the above six projects, the environment of the construction zone has been recovered and improved, beautifying the construction area and preventing water and soil erosion. Efforts were made to ensure soil and water conservation. At the Three Gorges Project management area, six level-one national indicators standards were met and approved by the Ministry of Water Resources of China in November, 2011.

Efforts were made to protect territorial eco-systems. During construction, measures were taken to avoid unnecessary negative impact on territorial animals and plants. Many efforts were made to ensure biodiversity in areas that had already been affected, these included: ecological restoration, the relocation of rare animals and plants, the building of conservation zones and artificial reproduction measures.

Efforts were made to protect aquatic life. Monitoring of the aquatic ecosystem has been carried out, technology and research development in addition with the building of conservation zones for rare animals and plants have been conducted. To contribute to nature, protections in the original location or through being relocated and artificial reproduction have been used. In 2011, the artificial reproduction of Chinese sturgeons achieved two consecutive successes. The Chinese sturgeons were monitored spawning in the downstream of the Gezhouba Hydropower Complex during their reproduction period. In recent years, the Three Gorges Reservoir has conducted ecological

Release Ceremony of Chinese Sturgeon

dispatching which has facilitated the spawning of the four major Chinese carps.

To protect and rescue the relics, the Chinese government has conducted large-scale survey on the relics in the reservoir area to have a clear understanding and has compiled "The Plan for Relics Protection of the Three Gorges Reservoir Area". 1087 cultural relics were set out for protection in the impoundment submerged area and resettlement area. According to the protection form and characteristics of the culture relics of the reservoir area, a specific plan for each site was made clear for better execution.

Resettlement

The success or failure of the Three Gorges Project hinged upon the resettlement. 1.3 million Three Gorges reservoir area residents were resettled. The reservoir submerged 20 counties, 2 cities, 10 county towns, and 114 townships in Hubei and the municipality of Chongqing. The submerged land area totaled 632 km2, 31,333 ha of fertile farmland and

New Town of Resettled Residents (Fengjie)

34.73 million m^2 of housing were inundated by the Yangtze River and its subsidiaries. A large amount of infrastructure such as roads and bridges, docks and wharfs, transmission and telecommunication lines, etc., were all submerged. 1632 mines and industrial enterprises were submerged. The Three Gorges resettlement was a world class problem. There was no precedent for the large scale resettlement of so many people anywhere in the world. The resettlement work was intertwined with a host of political, economic, environmental, social and cultural factors which made the work very hard and complicated. 20 provinces and municipalities, 10 large cities, and more than 50 ministries and commissions have provided counterpart support. More than ten provinces and municipalities received relocated residents which became a pillar in solving this world-class problem.

From the beginning, a sustainable development path was insisted upon and chosen as a basic policy in the Three Gorges' resettlement work. The basic policy of developable resettlement was decided upon. The resettlement fund was spent with overall consideration, the resources were developed in a rational manner, and environmental protection and the appropriate resettlement of residents have been carried out. The follow-up development of the resettled residents were given special attention, not only to provide a safe living environment through rebuilding new hometowns, but also to provide support for the development in terms of economic means, culture, and employment, etc. The government has continued to improve the basic infrastructure in related resettlement zones and local public service conditions in order to provide better living conditions to the resettled citizens. It has continued to improve the reservoir areas' transportation infrastructure to provide better transport conditions. It has also promoted other basic infrastructure construction and improvements to increase economic and cultural exchanges between resettled residents and the outside world. Public infrastructure constructions in health, sanitation and the provision of water in the reservoir area have all been strengthened to let relocated residents enjoy public services of higher quality. Employment opportunities were provided to resettled residents and skill training was launched to help the resettled residents become well off. In 2010, the resettlement of 1.3 million residents lasting 17 years was completed.

SIGNIFICANT ACHIEVEMENTS IN CONSTRUCTION TECHNOLOGY

BY INTERNATIONAL DEPARTMENT, THE CHINA THREE GORGES CORPORATION - CTG

Since the construction of the TGP was launched, CTG's commitment to innovation has led to a number of new world records and technological breakthroughs in hydropower construction. The following is a brief introduction to just a few of these breakthroughs.

River Closure and Deep Water Cofferdam

The TGP river closure comprised of the closure of the main river channel and the diversion channel. The difficulty of the river closure was unprecedented. The river closure was successfully achieved on November 8th, 1997 and the closure of the diversion channel was achieved on November 6th, 2002. This success demonstrated the leading position that China now holds in river closure. In the dry season after the closure, the coffer dam featuring deep water and high level was to be built. In order to avoid seepage in the coffer building process, a reliable anti-seepage structure needed to be put in place. Phase two coffer building project was a key that determines the success of the whole TPG project

Main Channel Closure and Construction of Concrete Anti-seepage Walls

The river closure and the construction of concrete anti-seepage walls were the two key technical issues in building the Phase-II earth-rock fill cofferdam.

River Closure of the Main Channel

The river closure of TGP features a number of difficulties, such as water depth, rapid flow, intense construction, tight schedule, navigation requirements during the closure process and the thick overburden layer of the dike foundation. TGP dam is situated at the backwater region of the Gezhouba Reservoir. During the closure of the river, the maximum water depth was 60 m, which is an unprecedented depth in river closure. It was absolutely essential to prevent the collapse of the cofferdam and keep the breakwater head stable during the advancing of the cofferdam. To this end, massive amount of hydraulic model tests, calculations and mechanism analysis were carried out. The conclusion was that when the water depth is reduced to 20 m, collapse can be avoided. Accordingly, it was decided to adopt a scheme of pre-leveling and backing, upstream single dike blocking, two directional

River Closure

dike advancing, and downstream follow-up are advancing. As the flow rate of the river decreased, closure dikes advanced successively. At 3:30 pm on November 8th, 1997, the main channel was closed off successfully. World records set in TGP closure are as follows: closure flow rate of 8,480 - 11,600 m^3/s, water depth of 60 m and a dumping intensity of 194000 m^3 in 24 hours during dike advancing upstream and downstream.
The design, construction technology research and engineering practice of the main channel closure in TGP was awarded the first level award for national science and technology achievement in 1999.

Deep Water Cofferdam and Concrete Cut-off Walls
The purpose of TGP Phase-II cofferdam was to guarantee year-around construction in the construction pit during TGP Phase II construction period. The scale of construction for the Phase-II cofferdam was unprecedented.

Dual-way Five-stage ship lock under excavation

The total weight of metal works and mechanical and electrical equipment of the ship lock amounted to some 40000 tons

With a water depth of 60 m, approximately 2/3 of the cofferdam was constructed underwater. The complex topographical conditions at the site made the construction of the cut-off wall even more difficult. Weathered grit was deemed as good filling material in consideration of the conditions on-site. However, its structure comes loose when dumped underwater, as it is not compact enough its physical indices are poor and deformation is highly possible. Therefore, it was imperative that construction of the wall should be completed within a single dry season. The biggest difficulty of the Phase-II cofferdam was the construction of concrete cut-off walls. Dumping weathered grit into deep water and building two 74 m dual tier concrete cut-off walls were achieved with excellent quality. The measured seepage of the cofferdam was a mere 65 l/s, which is relatively low when compared to other similar projects.

During the construction of the cofferdam, new centrifugal model tests were used for the first time, confirming that the density of dumped grit at a water depth of 60 m should be 1.75 - 1.85 t/ m^3, and underwater slope angle should be 27°. This represented the solution of a critical technical problem in the design of the deep water cofferdam. This was also the first time in a large scale project that flexible wall material made from weathered grit and construction waste and in line with the design requirements for the cut-off walls was used. An array of construction equipments and auxiliary tools were developed to solve the problem of granite layer level difference of more than 30 m, slope level of 70°- 80°, bedrock with bidirectional slopes, and difficulty to make trench for filling with weathered grit. A new record of 13000 m^2 for monthly cut-off wall construction was also set. During the removal of the cofferdam, the comprehensive inspection, sampling, analysis of the cofferdam and cut-off walls were conducted. It was proved that the survey, research, design, and construction of the cofferdam had been nothing short of a complete success and could serve as a valuable reference for similar projects.

Diversion Channel Closure
In the closure of the diversion channel, it was not easy to maintain the steadiness of the fill material on the slippery riverbed formed by a manually-placed concrete base. The overall difficulty was even higher than the closure of the main channel due to a large flow of 10300 m^3/s, a large fall of 4 m and a high flow velocity of 7 m/s. The constructors applied steel-framed gabion and alloy steel mesh as an underlay to increase the friction of the riverbed. This led to the formation of rock retaining sills that in turn reduced the difficulty of the closure and ensured the stability of the fill materials. For the closure of the open diversion channel, a scheme using two dikes to reduce the impact of the fall was adopted. During construction, the upstream dike held two thirds of the water fall and the downstream dike held one third. On November 6th, 2002, TGP diversion channel was successfully closed off.

Dual-way Five-stage Ship Lock High Slopes and Metal Works
The dual-way five-stage ship lock in TGP features the biggest water head, the maximum number of successive stages, the highest slope excavation, highest lining-type concrete slope, the highest miter gate and the heaviest gate of any major ship lock in the world.

The dual-way five-stage ship lock was cut out of the mountain side on the left bank of the hydropower complex. It has upstream and downstream approach channels that connect it to the Yangtze's main channel. It has a total length of 6442 m, of which the length of the main structures is 1607 m. Continuous high slopes are found on both sides of the ship lock. The maximum height of the slopes is 170 m and there is a 460 m long stretch in which the height is continually in excess of 120 m.

The general and local stability of the side slopes of the dual-way five-stage ship lock needed to be ensured. Furthermore, strict control on flow change was required in order to meet the requirements for the normal operation of the miter gate.
Considering the characteristics and importance of the side slopes, CTG took a series of measures including drainage from inside the mountain, blocking, cutting and discharging surface water, the installation of pre-stressed

anchor cables and high-strength anchor rods as well as support with shot concreting. During the construction, CTG strictly followed construction procedures, applied a set of controlled blasting technologies, strengthened prototype monitoring and feedback analysis and carried out dynamic analysis. Comprehensive analysis of prototype monitoring data collected from 3268 monitoring devices embedded throughout the ship lock showed that rock deformation was increasingly stable after excavation works were essentially completed in April 1999. Following the operation of the ship lock, the shift of the lock head has been less than 0.5 mm when water is filled into the lock chamber. This fully meets the requirements for the normal operation of the miter gates.

Ship Lock Metal Works

The total weight of metal works and mechanical and electrical equipment of the ship lock amounted to some 40000 tons, which presented great technical difficulties. In regard to characteristics such as high operating water head and strict requirements, CTG carried out a series of tests and conducted extensive research. An emphasis was placed on the research of torsion rigidity and measures to increase it, structures and forces of the top printle and its safe force transmission on the support blocks. It was eventually decided to place consecutive support blocks at both ends of the gate for the transmission of water pressure which would also serve as water stops. Wedge adjustment was applied at the top printle and the bottom plates were fixed to work together with the consecutive rigid support blocks. The miter gates of the first chamber are 37 m high with a maximum underwater height of 35 m. This sets a new world record for the underwater height of a miter gate. The ship lock is controlled with computers. On June 10th, 2003, TGP Reservoir reached an impoundment level of 135 m. On June 16th, 2003, trial operation of the ship lock was commenced. The ship locks officially went into service on June 18th, 2003.

The Design, Manufacture and Installation of the Generating Units

The Three Gorges Hydropower Plant is equipped with 32 sets of 700 MW super-large hydroelectric generating units. Due to the large unit size and capacity, as well as wide water head range, it should be ensured that hydroelectric generating units could maintain stable and efficient operation in case of high water head, with the operation performance taken into account in case of low water head. Therefore,

> **The Three Gorges Hydropower Plant is equipped with 32 sets of 700 MW super-large hydroelectric generating units**

the design, manufacture and installation were the most difficult throughout the world.

In the process of the installation, considering the technical characteristics of super-large hydroelectric generating units, many technical problems have been tackled on such projects as large stator assembly and welding automation technology, field stator lamination assembly technology for units large in capacity and size, rotor out-of-roundness welding and measuring technique, and magnetic yoke and plate out-of-roundness. Based on study of related national standards and the installation technology requirements proposed by manufacturers, Installation Standards for Three Gorges Hydroelectric Generating Units was formulated, whose key indicators are all higher than other standards of the same industry at home and abroad, and have filled the gap as there is no clear requirement in the similar standard. Through the use of advanced installation technology and optimized construction organization design, the overall quality level and schedule for installation of the units were ensured under the premise of shorter line installation period. In 2007, the TGP installed 7 sets of 700 MW units and put them into operation within one year, which refreshed the world record for annual total installation of large hydroelectric generating units. The monitoring results show that the units installed and put into production have been running smoothly, with all technical parameters meeting the design requirements.

Under the guidance of the state self-reliance principle for “introduction, digestion, absorption and innovation” of heavy equipment related to the TGP, by virtue of the experience in joint design, cooperative production, as well as introduction, digestion and absorption of technology targeting the Three Gorges left bank units, the domestic enterprises have harvested such core technologies with independent intellectual property rights as water power design of hydroelectric generating units, stator winding insulation and generator evaporative cooling, achieved leapfrog development in design of large generating units, boasted the capacity to compete the international hydropower giants, and been able to independently design and manufacture 700 MW super-large hydroelectric generating units.

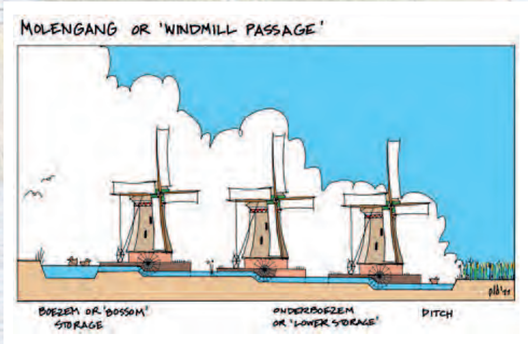
In 2004, Harbin Electrical Machinery Plant and Dongfang Electric Machinery Co., LTD respectively undertook the design and manufacture of 4 sets of hydroelectric generating units for the right bank power station during the Phase-III project of the TGP, and successfully completed the major role change from the subcontractors of the left bank units to the independent contractors of the right bank units, which indicates that China's hydropower heavy equipment has realized great-leap-forward development of 30 years, that the domestic hydropower manufacturing technology has reached the advanced level in the world, and that the era has come for China's independent design, manufacture and installation of super-large hydroelectric generating units.

July 10th, 2007, the first 700 MW domestic generating unit independently designed and manufactured with independent intellectual property rights by Harbin Electrical Machinery Plant – No.26 hydroelectric generating unit of the Three Gorges Hydropower Plant was officially put into power generation in the Three Gorges Right Bank Power Station. This unit has made major breakthroughs in two key technologies for hydropower equipment, namely, the turbine blade technology has met the world advanced level and the air cooling technology of domestic super-large generators was successfully realized. October 22nd, 2007, the second 700 MW domestic unit designed and manufactured by Dongfang Electric Machinery Co., LTD - No. 18 generating unit on the right bank of the TGP was put into operation. September 12th, 2007, 6 sets of 700000 kW generating units of the Three Gorges underground power station was contracted with 2 units respectively supplied by Harbin Electrical Machinery Plant, Dongfang Electric Machinery Co., LTD and Tianjin ALSTOM, in which the 2 units supplied by Dongfang Electric Machinery Co., LTD adopted the generator evaporative cooling technology with independent intellectual property rights.

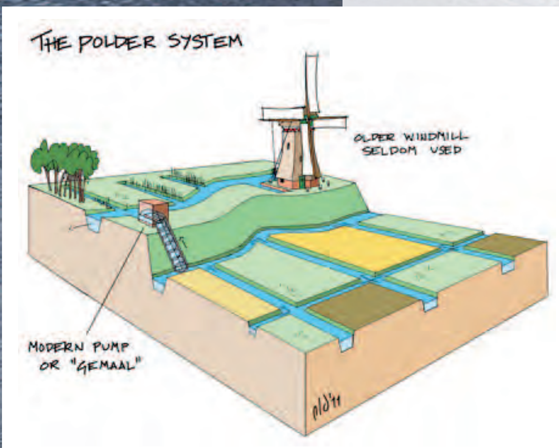
THE NETHERLANDS &

This is a selection of facts from the book **'The Dutch and their Delta – living below sea level'** by Jacob Vossestein and published by XPat Media. Reprinted with permission of the author and the publisher.

- ✓ One third of the Netherlands is actually below mean sea level, while another one third is very close to the official reference (NAP) level.
- ✓ In the past windmills were used to pump out rain water and seepage water from the low-lying (polder) areas. Nowadays, they have been replaced by diesel-electric pumping stations but still almost 1.000 windmills (out of the estimated 10.000 in the 17th century) remain.
- ✓ Dikes were originally made of soil and later of an impermeable clay core covered with a protective layer of rock (especially basalt). Today, even though modern materials (concrete, asphalt etc.) are also used, parts of the dikes are still made from original material.
- ✓ If a particular dike section were to break, only a restricted area - the so-called "dike ring" - would be flooded. But if for some reason, all dikes would break simultaneously, roughly one half of the Netherlands would be flooded.
- ✓ Downtown Amsterdam lies some 2 metres (6,5 ft) above sea level; however, Amsterdam Schiphol Airport is the world's lowest-lying airport. In fact, the train station at Schiphol lies 10 metres (32 feet) below sea level.
- ✓ The system of ditches in the polder areas are connected and pumped to a higher level and eventually, the water is discharged into a river or canal and from there to the sea. At least half of the Netherlands could not even exist without those ditches.
- ✓ "Canal" or gracht is related to the English word "grave." Canals were dug by people for defence and transportation purposes.
- ✓ No matter what the economic situation is like, cutting the budget for maintenance of dikes is never ever debated.
- ✓ The Dutch use the word "sea" (zee), and not "ocean." They feel that the ocean is far away, behind the the British Isles.
- ✓ The dunes are Holland's natural protection against the sea. That is why access is restricted in many places.



- ✓ Sea-water temperatures may reach 20°C (68°F) by late August but will be down again to just 4°C (39°F) by February.
- ✓ Living safely below sea level costs everyone residing in the Netherlands some 330 dollars per year.
- ✓ Too little water can also be a problem; with many old dikes built of clay and peat, drought can cause a dike to dry out and start cracking.
- ✓ The Water Boards (Waterschappen) are the regional water control boards and the oldest existing democratic "governing entity" in the Netherlands, dating back to the 13th century. There are 27 Waterschappen today.
- ✓ There are some 10.000 houseboats in the Netherlands and over 2.400 in Amsterdam alone, even when only a third of these are on the picturesque centre canals. Note that one of them sits in precisely the same location (Amsterdam) since 1888!
- ✓ Amsterdam's drinking water system was the first in the country, dating back to 1853. About 70% of the water comes from the Rhine river and the remaining 30% from a polder (a reclaimed catchment area) in Loosdrecht lake area.



WATER

- ✓ After several centuries of development, the land eventually subsided by human intervention. When settlements started long ago, people stuck to higher spots such as river levees, the slopes of the dunes and an occasional elevation. Between these was the wet wasteland, full of growth and wood, or holt - therefore "Holt-land," or Holland. By conquering this, i.e. pumping it dry, digging away the peat and then using it for agriculture, the land surface became lower and lower.
- ✓ Grown around a 13th century dam in the Amstel river, Amsterdam became famous for its canals (grachten), which gave Amsterdam the nickname "Venice of the North" and in 2010 also the UNESCO World Heritage status.
- ✓ "Flushing" the canals is done at night, twice a week under normal conditions and four times in periods of hot weather. Flushing is done by opening Amsterdam's system of sluices in such way that fresh Amstel water pushes the "older" water out into the IJ.
- ✓ Some building can be seen tilting. If the tilt is forward, there is nothing to worry about; it was done on purpose when the house was built, to make rainwater drip from the wooden windowsills in order to preserve them and perhaps also to keep furniture being hoisted up the facade from hitting the building. If the tilt is sideways, however, it can indicate a more serious problem.

This is a summary of the presentation given in the first meeting of the Cardiff IAHR Young Professionals Network held in November

First IAHR Young Professionals Network launched in Cardiff!
The new network which incorporates the former student chapter brings together young professionals from Cardiff University, and the local offices of engineering consultants Arup and CH2MHill.
Visit http://hrc.engineering.cf.ac.uk/iahr-young-professionals-network and follow the Cardiff YP Network on Linkedin

USING **RETRO-FIT GREEN INFRASTRUCTURE** TO **REDUCE POLLUTION** AND **FLOODING** IN LLANELLI AND GOWERTON, SOUTH WALES

BY LOUISE ELLIS & CHRIS ELLIS

Surface water inflow into the combined sewerage networks in Llanelli and Gowerton (UK) led to excessive spills from Combined Sewer Overflows (CSOs) into the Loughor Estuary, a protected shellfish water. This resulted in the threat of European Commission Infraction Proceedings for a breach of the Urban Wastewater Treatment Directive (UWWTD). Dŵr Cymru Welsh Water (DCWW), the 'not-for-profit' water and sewerage company in Wales, adopted a pioneering approach with their partners, Morgan Sindall and Arup. Extensive hydraulic modeling was undertaken to establish the root cause of the CSO spills and led to a strategy of widespread, innovative green infrastructure solutions, which provided a capital cost reduction along with social and environmental benefits when compared with the traditional solution of storage.

Introduction

Llanelli, a large town in South Wales, has a highly impermeable response to rainfall due its extensively urbanised nature and aging, predominantly combined sewerage network. Gowerton, located to the east of Llanelli, is a rural catchment and suffers from groundwater infiltration into its combined sewerage network, which is largerly laid through areas of marshlands. The two catchments are separated by the Loughor Estuary, a tidal water body protected by several environmental designations, including the Shellfish Waters Directive. Ninety-two CSOs from the Llanelli and Gowerton catchments discharge into the Loughor Estuary, with the 'worst performer' discharging over 2.36 million m^3 of combined sewage annually, exposing the shellfish waters to sewage pollution. Since 2002, a mass decline in cockle numbers within the Loughor Estuary came to the attention of the European Commission, who responded with the threat of infraction proceedings against the UK for a breach of the UWWTD. Arup, in partnership with Morgan Sindall, were commissioned by DCWW in 2010 to develop and implement a catchment strategy. The primary aim of the strategy was to reduce the number of spills to 10 spills per CSO per annum to comply with the UWWTD. In addition, there were two further drivers, addressing flooding of 115 properties and lifting restrictions on development due to sewer capacity.

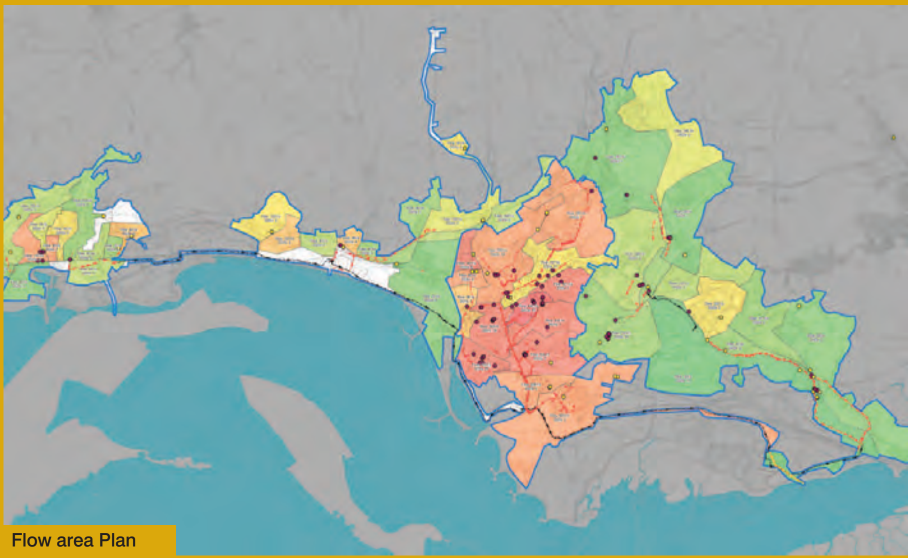
Location Plan

The overall strategy for improving the Llanelli and Gowerton catchments was divided into three distinct stages:

	Stage	Dates
1	Data Collection and Hydraulic Modelling	May 2010 – April 2011
2	Solution Development	April 2011 – Sept 2011
3	Solution Implementation	Sept 2011 – March 2020

Data Collection and Hydraulic Modeling

The existing catchment model was a patchwork of linked subcatchment models, which did not represent the observed behaviour of the catchment and as a result DCWW did not fully understand the performance and interaction of their assets.



Flow area Plan

QMW Bioswale

Louise Ellis **is a civil engineer working in the water group at Arup. She has been working on the solution development and implementation of green infrastructure schemes for Llanelli and Gowerton since 2011. She is currently based in Arup's New York Office, where she is working on the retro-fit of green infrastructure in NYC and flood resilience of the NYC subway following Hurricane Sandy. Louise has a Master's degree in Engineering Science from the University of Oxford (UK).**

Chris Ellis **is a graduate engineer working in the water group at Arup's Cardiff office. He has worked on a wide range of projects, including the implementation of green infrastructure schemes within Llanelli and Gowerton since 2012. Chris has an undergraduate degree in Civil Engineering from the University of Exeter (UK) and a postgraduate degree from Cardiff University (UK), where he developed a keen interest in hydraulics.**

In order to pinpoint the causes of CSO spills and target interventions effectively, a new 7000 node Infoworks Collection Systems (CS) model was built covering Llanelli and Gowerton, approximately 2,493 ha, with a population of 120,721. This was used to assess CSO spill frequencies, durations and volumes at all assets. Existing sewer network data was supplemented with surveys of 390 manholes and all of the CSOs and sewage pumping stations; 66 in total.

The model was verified for dry weather and storm events using DCWW's historical flooding records, spill data over the period 2000 to 2010, a short-term flow survey (308 flow monitors for 8 weeks) and a long-term flow survey (50 flow monitors for 6 months) to assess seasonal variation in infiltration and baseflow. River level gauges were placed in local watercourses to assess sewer-river interactions.

The outputs of spill frequencies, durations and volumes from the hydraulic model were transferred to a coastal dispersion model to assess the relative significance of the impact of spills from each CSO on the Loughor Estuary.

Model run times during verification and solution development presented a challenge. The model had to be run for consecutive storms rather than individual storms to assess the impact on the filling and emptying of the storage and ensure that the number of spills was not under predicted. However, for a 1 year dataset, the model run time for an individual catchment scenario was approximately 4 hours using a high specification computer. Our approach was to divide the catchment into manageable subcatchments and during solution development each scenario was tested against a representative wet month based on ten years of observed data. Once the solutions within each subcatchment were optimised, the subcatchments were stitched together and tested using the ten year dataset for final optimisation.

Solution Development

The traditional solution in the UK for reducing CSO spills within a catchment is to attenuate flows with storage tanks. Although this solution has the benefit of familiarity within the industry with design guidance and standards, there are key risks: storage tanks can prove ineffective during prolonged wet periods; the costs can be significant especially in pumped catchments like Llanelli; and treatment issues can arise due the inconsistency of the stored effluent.

We developed an alternative intervention strategy with retro-fit green infrastructure (GI) at its heart. Key elements include:

- Using GI as a stormwater management tool to mimic natural processes to manage rainwater with additional social and environmental benefits, including improved amenity opportunities and improved air quality;
- Best use of existing assets through Real Time Control (RTC) at key network locations, including pinch points, storage tanks and pumping stations, to control and divert flows to better utilize existing storage tanks and CSOs;
- Removing of land drainage connections from the public sewers as well as lining and replacing degraded sewers in areas of high groundwater infiltration; and
- Working with homeowners to encourage water re-use through the supply of rainwater harvesting units on a single household scale.

To target the solutions effectively to address the CSO spills, a number of indicators were brought together using Geographic Information Systems (GIS):

- Properties which have experienced internal (DG5s) or external flooding (SEFs) and known highway flooding;
- Assets identified by the operations team as having operational problems or limitations;
- Areas identified on the flow/area thematic map as contributing significant flow per unit of contributing area, giving an indication of where interventions to remove surface water would bring greatest benefit;
- Impact of each CSO on the water quality of the Loughor Estuary, assessed using the coastal dispersion model; and
- Proximity of a watercourse/storm network.

The model was used to test a variety of traditional and non-traditional solutions to assess the impact on peak flow reduction, CSO spills and flooding. Whilst modeling the traditional solution of storage is commonplace and much guidance is available, modeling GI elements within wastewater network analysis software such as Infoworks CS is a new concept. The intricate GI networks were simplified for modeling by using critical point storage nodes, flow controls and estimated flow removed from the collection system through infiltration and evapotranspiration.

It was found that the volume of storage required to achieve a target of ten spills per annum from the Llanelli and Gowerton catchments is 432,280 m^3, which when implementing traditional hard engineering solutions would cost around £600m with significant additional operation and maintenance costs. However, using GI it was found that the project targets could be met with only £150m of investment. Multi-criteria analysis was carried out on a number of proposed GI solutions, scoring them against the weighted criteria of peak flow reduction, flooding prevention, surface water reduction, spill reduction, ease of construction, amenity value, environmental impact, carbon footprint and whole life cycle cost. The outcome of this exercise was 180 individual schemes which together form a long term strategy for the catchment, and will be implemented over a 10 year period. The top ten schemes will be implemented by 2015, reducing peak flow for a 1 in 5 Annual Exceedance Probability by 25%.

Stakeholder Engagement

There were two key aims to the stakeholder engagement: acceptance of the strategy by key regulatory stakeholders and to gain support for the proposed interventions from the local community. Monthly technical meetings were held between DCWW and the Regulator, Natural


Glevering St Roadside Planter


Stebonheath School Education Garden

Resources Wales, to agree the modeling method, and subsequently with the Local Authority to agree the design and the arrangements for the maintenance of the individual GI schemes.
Throughout the project, drop-in sessions have been organized for local residents and businesses and DCWW involved local schools with engaging lessons on the topic of GI. As a result of the community engagement, the local community will play an active role in maintaining the vegetation associated with the GI, an added benefit for DCWW.

Solution Implementation

To date, three GI schemes have been successfully implemented; Queen Mary's Walk, Stebonheath School, and Glevering Street. Each scheme was a typical representation of the urban environment in Llanelli with roofs, car parks, roads and playgrounds, producing an urban response to storms, where rainfall arrives very quickly in the sewer system. These three sites were found to contribute in excess of 680 l/s (1 in 5 Annual Exceedance Probability) into the combined sewer network. Model predictions showed that, through implementation of GI interventions, a reduction of over 65% in peak flow could be achieved to relieve pressure on the downstream network.
The schemes are located at the top of the catchment and involve intercepting surface water to re-direct it away from the combined sewer network through overland flow channels into a selection of basins, planters and swales. These green elements remove a significant proportion of flow from the system via vegetation and trees that thrive within a moist, graded, nutrient rich soil and attenuate the remainder allowing it to return to the combined sewer at a controlled rate. The result is flood alleviation and a reduction in CSO spills downstream. In addition, the GI elements provide community and environmental benefits, resulting from improved recreational and educational spaces, and enhanced biodiversity.

Solution Performance

The hydraulic benefit of each of the schemes is being quantified with flow and depth monitors. These have shown that the responses of the individual systems to rainfall events are surpassing expectations. For instance during a typical annual storm event at Queen Mary's Walk (1 in 1 Annual Exceedance Probability), a 77% reduction in peak flow in the combined sewer was achieved, 20% greater than predicted during the design stage. This additional hydraulic benefit can be attributed to the green elements; the process of interception, evapotranspiration and soil void storage capacity.

Scheme Name	Scheme Ethos	Programme	Cost (Design & Construction)	Model Prediction for Peak Surface Water Reduction (1 in 5)
Queen Mary's Walk	Conveying surface water from roofs and roads into a 125m bioswale located in adjacent recreational grounds	Sept 2012 – Aug 2013	£813.3k	125 l/s
Stebonheath School	Several bespoke attenuation units providing additional educational benefits within a primary school site	July 2013 – Sept 2013	£447.5k	53 l/s
Glevering Street	Channelling surface water from a large, densely populated subcatchment into strategically placed roadside planters and basins	Sept 2013 – Sept 2014	£2195.5k (Projected)	326 l/s

Conclusions

The strategy of catchment-wide hydraulic modeling and detailed solution design has resulted in innovative GI solutions which provide a clear pathway to reducing CSO spills to less than 10 per annum, resulting in the EC Infraction Proceedings against Welsh Water being suspended.
The solutions not only provide a cost saving of approximately £450million when compared with traditional solutions of storage but also provide environmental benefits, such as improved air quality and greater biodiversity, and social benefits, such improved access to green space and aesthetic quality of the area. The implementation of GI in Llanelli is proving to be a catalyst for the regeneration of a historically deprived area.
This wide-scale strategy is the first of its kind in the UK and, naturally, generating client and third party confidence was difficult. However, this was overcome through attention to detail during the technical analysis and design, together with positive stakeholder engagement throughout the project. The resulting strategy is an example of best practice in the implementation of GI and will act as a blueprint for similar future projects in the UK.

IMPLICATIONS OF ESTABLISHING INSTITUTIONAL ARRANGEMENTS

BY HANS C. KOMAKECH

When there is limited availability of water for productive uses, it is necessary to define clear rules on who is entitle to use water, for what purpose, at which location, quantity at what time, for how long and how the rules will be enforced or changed. These rules can ideally be defined by governments, non-governmental organisations, water users, religious leaders etc. The crafting of new institutions requires innovative approach that can allow integrating local practices with state-led approaches. Instead of establishing new ineffective forums, effective dialogue over water allocation and management may be achieved by building on existing local practices and organisations. It is more likely that locally acceptable and environmentally sustainable practices will develop.

2012 JRBM Best Paper Award Winner

Hans Charles Komakech **is a lecturer of integrated watershed management at the department of Water, Environmental Science and Engineering (WESE), Nelson Mandela African Institute of Science and Technology, Tanzania. Komakech has conducted researches on water governance institutions in national and transboundary basins; and point of use water treatment and safe storage.**

This is a summary article of the full paper published in Vol. 10, Issue 3 2012 and available in open access at www.tandfonline.com

In Sub-Saharan Africa, most river basins are experiencing an increasing water scarcity driven by population growth, economic development and increase climate variability. Water demands are increasing due to rapid urbanisation, poverty and food insecurity, and growing energy demands. It is estimated that close to 50% of the projected 1.5-2 billion Sub Saharan Africa's population will be living in cities by 2050. The growing cities will demand a steadily increasing share of the available water resources and these poses new challenges to river basin management. Furthermore, substantial investment in irrigated agriculture in Sub-Saharan Africa is required to reduce the increasing trend of rural poverty and generate employment. However, irrigation intensification will require intervention in water control (e.g. building storage reservoirs) as lack of access to reliable water supply is one of the major limitations to crop production. In addition, increasing global energy demand has direct link to water demands and does have implications on water allocation in Sub-Saharan Africa. The rising global food and energy prices have so far attracted large scale foreign investment in Sub-Saharan Africa's agricultural land. Besides the much debated issue of land grabbing, foreign direct investment in agriculture is likely to increase agricultural water use and this could lead to further enhancement of an already stressed water situation.

The increasing water demands as described

above is likely to increase water competition and conflicts between users upstream and downstream of a catchment. This puts significant pressure on existing water sharing arrangements as well as the challenges of developing robust water institutions that can ensure equity and sustainability of the resources.

There is a general belief that state-led formalisation of water allocation and management will restore order, ensure equity with respect to access to water and leads to sustainable water management. To achieve this many governments have attempted to register water uses and users, issue water rights or water permits to users, levy annual water tax or water fee on permit holders, and created formal organisations of water users sharing a common water source, often called water user associations (WUAs). Tanzania with a strong donor support has been at the forefront of formalisation of water allocation in its river basins (see Box 1).

STATE-LED WATER RIGHTS AND ON THE KILIMANJARO, TANZANIA

Based on Komakech, H. C., Van Der Zaag, P., Mul, M. L., Mwakalukwa, T. A. and Kemerink, J. S. 2012. Formalization of water allocation systems and impacts on local practices in the Hingilili sub-catchment, Tanzania. *International Journal of River Basin Management*, 10(3), 213-227.

Box 1: historical development of state-led formalisation of water management in Tanzania

Pre-colonial (before 1880)

Farmers constructed irrigation canals (furrows) and later trade intensified irrigated agriculture and increased the need for allocation arrangements between the furrows. To cope with increased demands rotational water allocation between upstream and downstream farmers was initiated.

Colonial period 1880-1967

Formalisation of water resource management started in 1914 under German rule (1880-1919) when a first draft of a water rights ordinance was formulated. The first water rights ordinance was officially proclaimed in 1923 during British rule (1919-1967). By the 1930s, a tax was introduced which was intended to be used by government servants to control the irrigation furrows, prevent wastage by the native farmers upstream and as impartial evidence in cases of dispute. Amendments of the water ordinance occurred subsequently.

Post-independence of Tanzania: 1967- 1990

Through a government villagization program was implemented from 1973 to 1976, locally constructed irrigation furrows became village government property. In 1974 the government put in place a new Water Utilization (control and regulation) Act No. 42 that defined procedures for granting statutory water rights with priority given to domestic, livestock, irrigation, industries, hydropower, transport and recreation. The 1974 Act and its subsequent amendment in 1981 set the foundation for water management along hydrological boundaries such that mainland Tanzania was divided into nine river basins.

NGO and related development: 1990 – 2004

In 1991 the Pangani Basin Water Board (PBWB) was established. PBWB carried out an inventory of water users in the basin and established a protocol for issuing water rights and setting tariffs. It started registering water users and issuing provisional water rights. In 1991 a Water Policy was introduced which focused mainly on providing clean and safe water. In 2002 the government revised the water policy. The new policy objective was to develop a comprehensive framework for promoting the optimal sustainable and equitable development and use of water resources for the benefit of all Tanzanians.

Formalised institutional structure (after 2004)

The process started of setting up sub-catchment fora for water allocation in sub-catchments of the Pangani and other basins in Tanzania. In 2009, a Water Act was introduced and it allows for granting water use rights, with prioritisation of water for basic human needs and the environment, and subject to social and economic criteria.

Box 2: Short summary of formalisation of water allocation in Hingili sub-catchment, Tanzania

Hingilili sub-catchment (about 150km^2) is located in the South Pare Mountains. The sub-catchment covers part of eight wards in Same district. However, water is only used by the inhabitants of three of the eight wards. In the highland these wards are Vuje and Bombo and in the lowlands it is Maore ward.

The area experiences two rainy seasons per year, a long season starting in March and ending in May ("Masika") and the other a shorter season starting around October and ending in December ("Vuli"). Land tenure in the sub-catchment is customary and holdings vary from 0.5 – 5.5ha with an average of 0.8ha. The main activities are subsistence agriculture based on rainfed and supplemental irrigation, livestock keeping.

Twelve locally constructed irrigation canals (six in the highland and another six in the lowland) are used by farmers to divert water from the Hingilili river. The furrows have a water committee responsible for water allocation, maintenance and conflict management. Hingilili sub-catchment experiences water stress during the dry seasons. Increasing water demand arising from natural population growth and changes in cropping patterns (e.g. increase in ginger cultivation in the highlands) make the area a potential hotspot for upstream – downstream water conflicts.

In 2002, to solve water conflict the local district government with support from non-governmental organisation and Pangani Basin Water Office created an umbrella organisation called MUWAHI (Muungano wa Wakulima Hingilili) to manage water allocation between the furrows in the lowland. An organisation called Water users of Hingilili Highland Organisation (WHHO) was created in the highland. An apex organisation called Hingilili Irrigation Basin Association (HIBA) was created to link the lowland (MUWAHI) and the highland (WHHO). The creation of HIBA in principle operationalised the National Water Policy of 2002 but it was also an attempt to nest water institutional arrangements. HIBA was created to oversee the implementation of the agreements between the highland and the lowland. However, HIBA has not functioned and has effectively ceased to exist.

However, this is often done without careful analysis of the existing institutional environment. The way water right system has been implemented in Tanzanian's river basin does not necessarily lead to equity and sustainable water management. The finding in Pangani basin, Tanzania is contrary to the general believe that defining water use entitlements and crafting institutional arrangements to monitor its enforcement will achieve economic efficiency and social equity and will maintain or restore order in water stressed catchments. We explored and analysed the impact of the the state-led water allocation and management arrangements in the Hingilili, one of the sub-catchment of Pangani river basin, Tanzania (see Box 2).

> **Farmers seem interested in acquiring a state-sanctioned water use right only to strengthen their existing claims to irrigation water.**

Formalisation in Hingilili sub-catchment did not change the day-to-day local water allocation rules significantly. Farmers seem interested in acquiring a state-sanctioned water use right only to strengthen their existing claims to irrigation water. Although all furrow groups in Hingilili do pay the annual water user fee, none have been granted formal water rights. Water allocation is still based on local procedures established in the pre-colonial era. Water access within a furrow is based on farmers' participation in maintenance and attendance at meetings. All furrows use allocation rules that are well understood by everyone and there is a

Ginger traders in the highland

shared expectation of all users to cooperate. However, recent infrastructure rehabilitation supported by NGOs has negatively affected the existing local arrangements between the highland and lowland farmers. Following the rehabilitation of furrows in 2009 and the introduction of a new high value crop - ginger - in the highland, more water is now being used upstream. In addition, the highland farmers now claim that they need to be paid to close their furrow intakes at 4PM, while lowland farmers maintain that it is the responsibility of the former to leave sufficient water for downstream use. We note that external intervention if not carefully planned and implemented can lead to conflict and competition over water in a catchment.

Water institutions operating at the scale of Hingilili sub-catchment appear to be ideally positioned to manage and allocate water resources. To grant these types of organisations the right to issue water use permits and to levy water user fees could potentially reduce transaction costs. However, in the case of Hingilili, the institutional arrangements were not sufficiently embedded and their linkages with existing arrangements were weak. Formalisation as implemented seems at odd with the local practices and does not lead to equity and sustainability of the water resources. One of the limitations of water institutional designed approached used by the state as instrument of change is that it does not create legitimacy at the local level. If they were well integrated with the existing institutional arrangements, they would be more acceptable for small scale irrigators who have been allocating water in the past without too much outside interference.

We conclude from the study that state-led formalisation need to be re-invented, instead of defining water rights for farmers it could be good to work with the farmers to support and build on their existing practices - facilitated water management so to say. Working with the existing practices appears to be the right approach as local water users have developed over time water sharing rules deeply rooted in local customs. These rules and traditions are understood and respected by the majority of the users. To be able to support and create an effective sub-catchment organization, the Pangani Basin Water Board should build upon existing structures such as the neighbourhood committees rather than introduce new arrangements. However, this is by no means a guarantee for success - institutional arrangements are messy and often get reinterpreted and re-negotiated at the local level. Important question is whether it is possible to build on existing local institutional processes and models. Can the underlying organizational and decision making principles be scaled up to higher level institutions?

THE **RADE** PROJECT

The RADE project (**R**emote **A**ccess to **D**ata and **E**xperiments) is a Joint Research Activity of HYDRALAB IV – More than Water. Its aim is to develop a robust set of information systems to improve access to experiments and data through innovative use of modern data management, curation and communication technologies.

Traditionally, the hydraulic research community is accustomed to exchanging the results of their experiments through papers and conferences. The direct exchange of data is limited to partners cooperating in projects. The objectives of RADE are to allow research partners to access and input laboratory experiment data (including video and imagery) remotely, thereby saving on costs and on the environmental impacts of long distance travel, and also making the results of experiments more easily accessible for researchers beyond the HYDRALAB community, thus realizing synergy between different partners in Europe and around the world, while at the same time creating a climate for further innovations.
Within this framework, two methodologies are being developed by LNEC and Deltares as partners in the HYDRALAB consortium. LNEC's methodology is based upon low cost hardware and either open source software or free software, in order to be easily accessible and portable to different laboratories and universities. Deltares' methodology is more involved. It gives project teams a visual impression of a hydraulic experiment by means of a camera system that can be operated by the project leader. In addition to the visual impression, a specialized version of Delft FEWS is used as a server-client system, by means of which the measurements taken during the experiment (data) can be visualized real-time and distributed among all project members at once.

LNEC's methodology

The objective of the work performed at the National Laboratory for Civil Engineering (LNEC) is to develop simple procedures/methodologies to enable remote video access and experimental data access to laboratory experiences in LNEC's wave flumes and basins, located in the maritime and hydraulics installations of the Harbours and Maritime Division (NPE). Visualization of real-time acquisition data coming from physical experiments and online communication between partners to share results are the ultimate goals of the work being developed.

The remote video access – Image Streaming
The methodology is based on the use of a fairly simple scheme (Figure 1), composed of a low cost consumer SLR camera installed at the flume, connected to a PC computer on which the software "Microsoft Expression Encoder" resides and video (or images) is stored, decoded and sent to a streaming web server. This server will then enable real-time streaming over the internet, enabling a direct, quasi-real-time, access to video and data. This work involved the collaboration of FCCN (www.fccn.pt), the Portuguese Foundation for Scientific Computing. Figure 2 shows some aspects of the experiences obtained in the wave flume. Results from the wave basin are shown in. in Figure 3, which shows a Windows Media Player session on a client's computer of live video of the experiment. Clients were invited to access the video stream through the address
http://wms.fccn.pt/lnec_canal.

Remote visualisation of data acquisition
The methodology for remote visualisation of data acquisition is based on the use of free version of *TeamViewer©* (www.teamviewer.com). This software, besides enabling online meetings, also

Figure 1 – General scheme of a remote access experiment

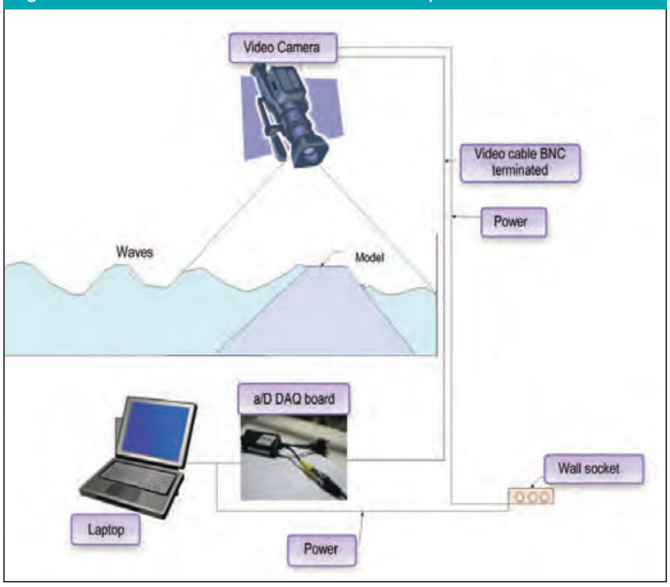


Figure 2 - Installed setup in a wave flume (left) and in a wave basin (right)

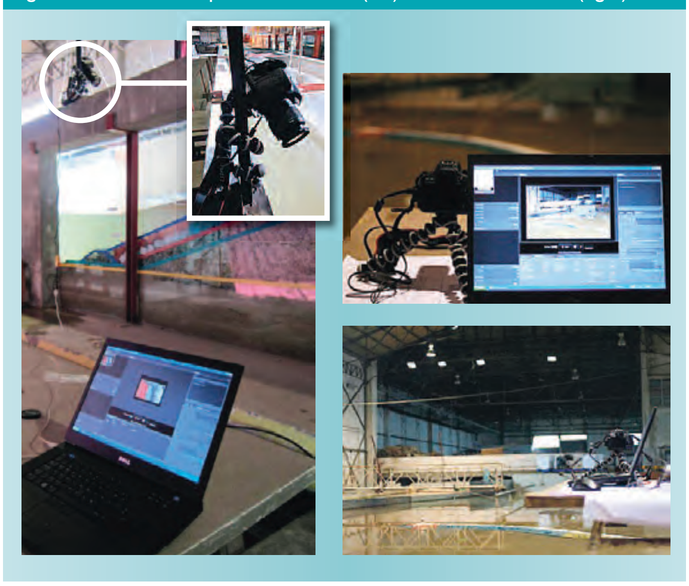


Figure 3 - Windows Media Player playing a live stream video on a client's computer

supports the remote control of client computers via internet, through a password-coded session provided by the client (see Figure 4). Therefore, project team members in a given experiment are invited to join the meeting and to remotely access experimental data, using the "Remote Control" feature. At the same time, the "Online Meeting" feature enables chat, VOIP, video and file transfer, amongst many other features, therefore avoiding time consuming and expensive travel.

Rui Capitão **is a research officer at the Harbors and Maritime Structures Division, Hydraulic and Environmental Department of LNEC with 24 years of experience in statistical analyses of sea wave climates and short-term analyses of wave records for numerical and physical simulations in laboratory environments.**

Conceição Fortes **is a research officer at the Harbors and Maritime Structures Division, Hydraulic and Environmental Department of LNEC with 25 years of experience in numerical modeling of wave propagation of coastal and harbor areas.**

Rute Lemos **is a Research Technician at the Harbors and Maritime Structures Division, Hydraulic and Environmental Department of LNEC with 20 years of experience in physical modeling of hydraulics structures. Main research interests are: inspection of coastal structures and analysis of the collected data; photogrammetric methods for damage progression in scale model tests of rubble-mound breakwaters.**

Peter Wellens **is a researcher at Deltares. His background is in Civil Engineering and he holds a PhD in numerics. His main field of research has been the development and validation of numerical techniques for simulating wave impacts on structures. Recently, he has become head of the instrumentation department. As such he works on experimental modelling and is part of the coordination group for HYDRALAB.**

Figure 4 - Remote support and online meeting software showing the initial window and session panel

DELTARES methodologies

While the system setup of LNEC was designed as a low cost system, Deltares worked on a more involved approach to visualize the experiment and also to distribute the data at the same time. Deltares bought a professional camera with high quality hardware, such as lens, CCD-chip and servo motors for motion control, with an internal server. Project team members of an experiment receive a user name and password to log on to the server. The project team leader has a special account that enables him to control the camera position (roll, pitch and yaw) within a pre-configured range. In this way, the project team is free to focus on that aspect of the experiment that they find relevant at that moment.

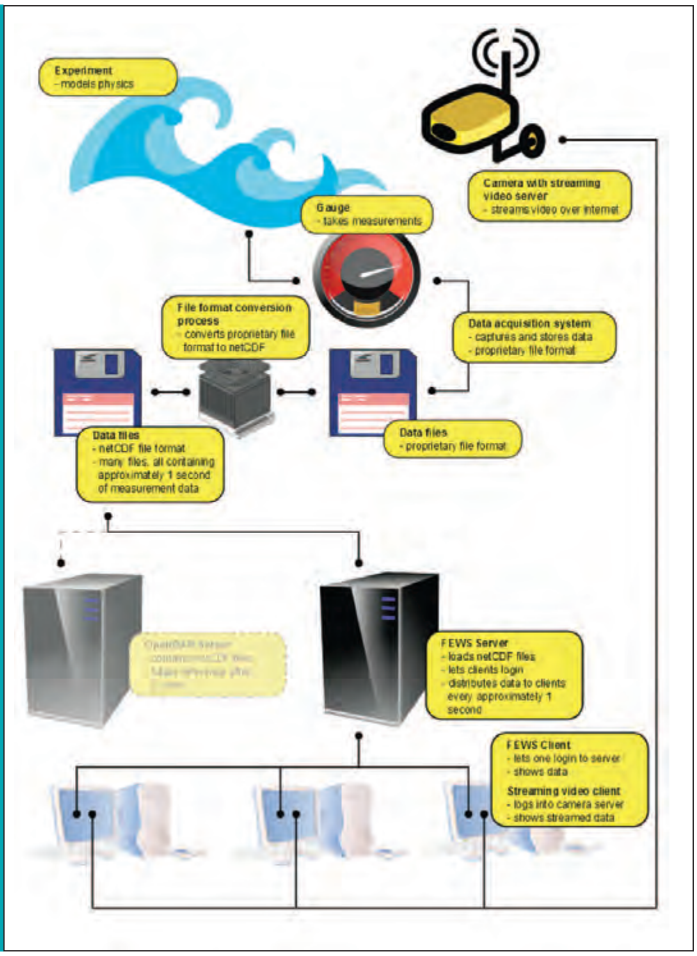


Figure 5: Deltares' system setup for remote access and exchanging data.

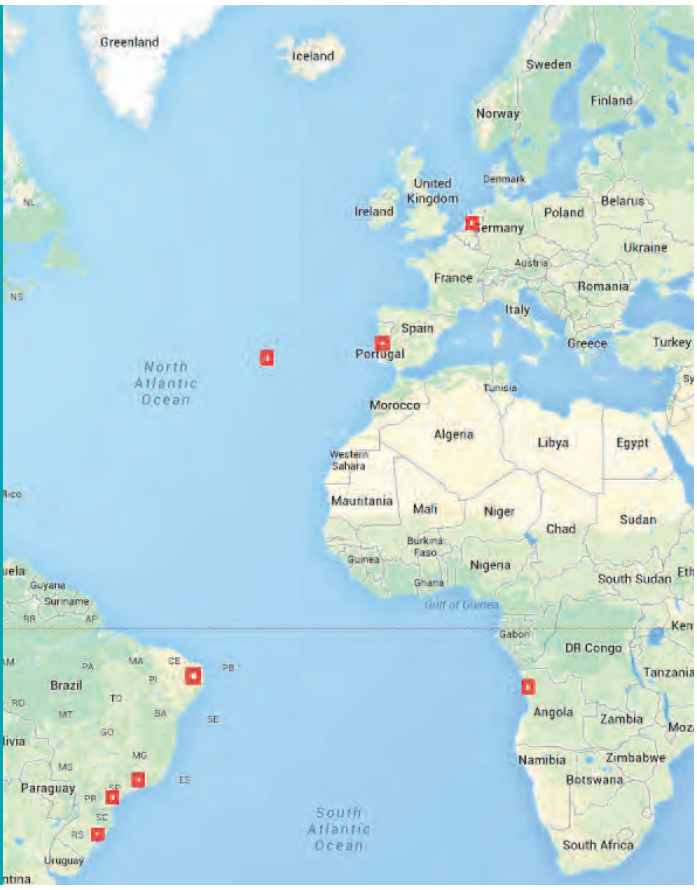


Figure 6: Map location of connected institutions to remote access experiments at LNEC

When the experiment commences, and the data acquisition system starts taking measurements, an additional process is started to distribute the data among the project team members. The process on the data acquisition system converts the data to the open NetCDF format, sends it to a server, which then synchronizes the data between the server and the clients, which are running on the computers of the team members. While the experiment is going, the data is distributed to the clients in real-time and can also be visualized real-time. The setup of the system of distributing data is shown in Figure 5. The server-client system at Deltares is based on Delft FEWS. Delft FEWS is originally a operational flood forecasting system, but is flexible enough by design to be configured as a server-client system for sharing hydraulic experimental data. The biggest challenge for Delft FEWS was the sample rate of the measurements that is orders of magnitude higher in the laboratory (between 25 and 100Hz) than in field stations (between 0.1 and 1Hz). But we dealt with this issue and the delay now was less than half a minute after a 25 minute experiment.

Applications

To test both the remote video access and the remote visualisation of data acquisition, nine experiences using LNEC's methodology were carried out at LNEC´s wave flumes and tanks, involving several institutions national and abroad, including University of São Paulo (Brazil), the Federal University of Rio Grande do Norte (Brazil), the University of Rio Grande do Sul (Brazil), the Lisbon Superior Engineering Institute (Portugal) and the consultant companies DELTARES in Delft (The Netherlands), CONSULMAR in Lisbon (Portugal), Ports of Azores (Pico island, Azores) and GestMarina in Luanda (Angola). Figure 6 shows a map with the locations of those institutions.

The main conclusions arisen from this first set of tests were that the methodology is appropriate both for 2D and 3D scale model tests and is very simple, easily portable and quite cheap to implement. However, some problems were identified such as incidental image freezing occurrences and delays.

Deltares' system was tested at Deltares. Colleagues at the premises and a colleague in the United Kingdom were asked to act as a test users. During the experiment the delay was tested by keeping a telephone connection open and mentioning every five minutes how far the experiment was in the lab. At the end of the 25-minute test the delay was less than half a

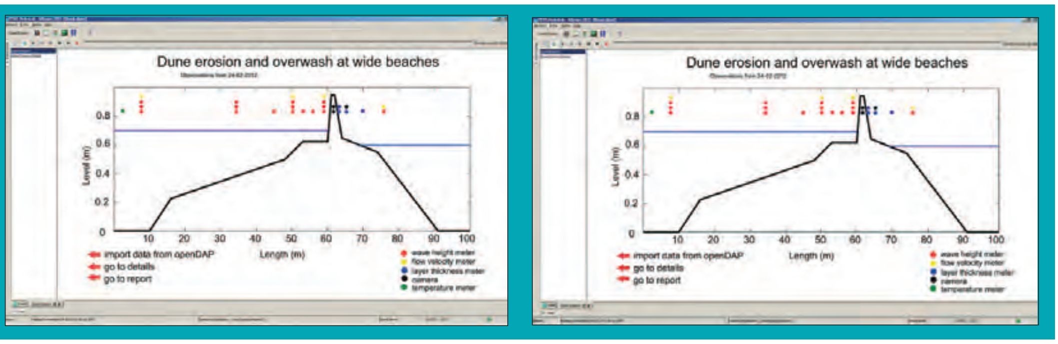


Figure 7:
Screen shots of the client software for remote access and data distribution

minute. Figure 7 gives some screenshot of the client software running at the remote locations. One screen shows a drawing of the setup of the experiment. In this screen project team members can click the locations of the instruments to see the measurements that they are interested in. After the experiment (or during) the data can be processed within the client software, because it contains many statistical functions by default. Or the data can be exported to almost any format to be processed by means of other software.

Future Developments

More experiences with European and non-European countries are planned, in order to test the methodology with partners with different network and computer characteristics.

Some aspects of the methodology are planned to be improved, as to optimize the video transmission bitrate in order to maximize image quality and at the same time avoid dropped frames, to increase LNEC's internal network speed as well as changing the server live streaming, in order to keep long-term records.

Deltares will setup their system during one of the Transnational Access experiments, in which a selected international research group received access time to conduct an experiment in one of the large facilities associated with HYDRALAB. During this experiment, experiences will be collected which we will communicate through the consortiums website at www.hydralab.eu.

Issue 3, 2014 will be devoted to

Hydralab IV

Hydralab is a European Networking Project aimed at structuring the access to unique and costly hydraulic and ice engineering research infrastructures in the European Research Area.

PEOPLE & PLACES

RiverFlow2014, HIC2014 and 13th ICUD Conference - participants benefit from a special discount on flights

IAHR has signed an Agreement with Qatar Airways as official carrier which offers discounts on their already competitive air fares to delegates attending future IAHR-sponsored conferences. Qatar Airways has been repeatedly voted "World's Best Airline".

After our World Congress in Chengdu and the ISEH Conference in Singapore, the next conferences to benefit from this agreement are:

- River Flow 2014 in Lausanne, Switzerland, September 3-5, 2014.
- 13th International Conference on Urban Drainage (ICUD 2014) in Kuching, Sarawak, Malaysia, September 7-12, 2014.
- Hydroinformatics 2014 in New York, US, August 17-21, 2014

You can find the promotional codes under News on the IAHR home page or alternatively contact Maria Galanty at office@iahr.org

Prof. Le Manh Hung New Position

He used to be the Acting Director General of Vietnam Academy for Water Resources and recently he has been appointed as deputy general director of Department of Water Resources that belongs to Ministry of Agriculture and Rural development (MARD).
The new Acting Director General of Vietnam Academy for Water Resources (VAWR) is Associate Prof. Dr. Nguyen Vu Viet.

IAHR appointed a Partner of UN-Water

IAHR has recently become a partner of UN-Water, which is the United Nations inter-agency coordination mechanism for all freshwater and sanitation related matters.

UN WATER

IAHR Events Calendar

IAHR SPECIALIST EVENTS

5th International Symposium on Hydraulic Structures
25 June 2014 - 27 June 2014
Brisbane, Australia
www.engineersaustralia.org.au/ishs-2014

22nd IAHR International Symposium on Ice
11 August 2014 - 15 August 2014
Singapore
www.iahr-ice2014.org

11th International Conference on Hydroinformatics
17 August 2014 - 21 August 2014
New York, US
www.hic2014.org

River Flow 2014 – the 7th International Conference on Fluvial Hydraulics
03 September 2014 - 05 September 2014
Lausanne, Switzerland
www.riverflow2014.epfl.ch

13th International Conference on Urban Drainage (ICUD 2014)
07 September 2014 - 11 September 2014
Sarawak, Malaysian Borneo
www.13icud2014.com

7th IAHR International Groundwater Symposium
22 September 2014 - 24 September 2014
Perugia, Italy
www.water-system.org/iahr2014

27th IAHR Symposium on Hydraulic Machinery and Systems
22 September 2014 - 26 September 2014
Montréal, Canada
www.iahrmontreal2014.org

Coastlab14
28 September 2014 - 01 October 2014
Varna, Bulgaria
www.coastlab14.com

RiverFlow 2016 - 8th International Conference on Fluvial Hydraulics
10 July 2016 - 14 July 2016
Saint Louis, Missouri, United States
www.iihr.uiowa.edu/riverflow2016

14th ICUD - International Conference on Urban Drainage
September 2016
Prague, Czech Republic

IAHR REGIONAL CONGRESSES

XXVI Congreso Latinoamericano de Hidráulica
25 August 2014 - 29 August 2014
Santiago, Chile
www.hidrolatam2014.org/

IAHR 19th Congress of the Asia & Pacific Division
21 September 2014 - 24 September 2014
Hanoi, Vietnam
www.iahr-apd2014.wru.edu.vn/

4th IAHR Europe Congress
27 July 2016 - 29 July 2016
Liège, Belgium
www.iahr2016.ulg.ac.be/

IAHR WORLD CONGRESSES

36th IAHR World Congress
28 June 2015 - 03 July 2015
The Hague/ Delft, the Netherlands
www.iahrworldcongress.org

37th IAHR World Congress
14 August 2017 - 18 August 2017
Kuala Lumpur, Malaysia

For a full list of all events visit www.iahr.org

PEOPLE & PLACES

Welcome aboard the new Young Professionals Network from the Netherlands

Welcome the new IAHR Young Professionals Network created in Delft, The Netherlands! The YP Network from Delft will be organising the Young Professionals activities at the 36th IAHR World Congress in The Hague, the Netherlands.

President
Veronica G. Minaya
UNESCO-IHE, Water Science Engineering (WSE)

Vice President
Yared A. Abebe
UNESCO-IHE, Environmental Engineering and Water Technology (EEWT)

Secretary
Maurizio Mazzoleni
UNESCO-IHE, Integrated Water System & Governance (IWSG), Hydroinformatics

New IAHR Institute Members

Universidad Panamericana
Campus Guadalajara, MEXICO
For more information: www.up.edu.mx

Bureau of Reclamation
Denver, UNITED STATES OF AMERICA
For more information: www.usbr.gov

ANDRITZ
SWITZERLAND
For more information: www.andritz.com

2014 - 2015 IAHR Europe Division Executive Committee

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Vice Chair
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Assoc. Prof. Pawel M. Rowinski, Polish Academy of Sciences, Poland
Prof. Ian Guymer, University of Warwick, UK
Mr. Mark Rieder, The T.G.Masaryk Water Research Institute, Czech Republic

The first meeting of the new Leadership Team took place during the recent 3rd IAHR Europe Congress in Porto.

Prof. Adrian John Saul from the University of Sheffield has recently retired.

Prof. Werner Zielke, Emeritus Professor from the Institute of Fluid Mechanics and Environmental Physics in Civil Engineering (ISU) of the Leibniz Universität Hannover is retired after 10 years as Emeritus Professor.

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