



# ANNUAL REPORT

IWHR 

China Institute of  
Water Resources and  
Hydropower Research  
中国水利水电科学研究院



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# WELCOME MESSAGE

## Annual Report 2019

CHINA INSTITUTE OF WATER RESOURCES AND  
HYDROPOWER RESEARCH



  
KUANG Shangfu, Ph.D.  
President of IWHR

The ravaging COVID-19 pandemic loomed the whole world from the beginning of the year 2020 during the Spring Festival which is the most cherished traditional holiday of family reunion for Chinese People. Instead of jubilation and happiness, this holiday was filled with stress and heaviness imposed by the overlapped crisis threatening the whole world. To control the spread of the disease, many cities are locked down, plenty of schools are closed, and people are practicing social distancing. Many international events and activities are postponed or canceled including the Olympic Games. All these have reminded us how valuable the old days are when we could communicate with each other face to face with no distance or limits. It also makes our achievement in the past year even more precious when we look back now.

The year 2019 is an important milestone in the history of the People's Republic of China, as it is the 70th anniversary of the country. It is again a fruitful year for IWHR. We received 309 foreign visitors, and 283 experts of IWHR set their footprints on 40 countries and regions all over the world for technical exchanges and cooperation. We organized the Forum on Ecological Flow and Ecological Hydraulic Engineering, the Belt and Road Forum on Irrigation and Drainage Development and Sci-Tech Innovation, the 16th IWHR-KICT Joint Seminar, the Sino-Japan Technical Communication on Dam and River Environment Management, and a bunch of domestic symposiums. We actively involved ourselves in the activities of WWC and AWC and won the bid for the 4th World Irrigation Forum in 2022 and produced another chairperson of international organization with Mr. Ning Duihu being elected as the new president of the WASWAC. We have also affirmed our collaboration with four overseas agencies respectively in Spain, Portugal, Serbia and Malaysia through the signing of MOU.

In 2019, IWHR achieved consistent growth in R&D achievement. Newly-signed contracts of the year totaled CNY 1.715 billion, among which about 25.1% were sponsored by the state. Throughout the year, IWHR had 677 papers, 59 monographs, 285 patents, 21 standards and 42 major awards (including one national prize) added to its accomplishments.

IWHR's research capacity has been more widely recognized by the international community, with its engineering sciences and environmental and ecological sciences both ranking among the ESI top 1% of the world.

IWHR also played important role in supporting the major national development strategies, including the Ecological Protection and High-quality Development of the Yellow River Basin, the coordinated development of the Beijing-Tianjin-Hebei region, the drafting of the 14th Five Year Development Strategy of Water Science and Technology. It has also conducted the national survey on rural water supply and other regional investigations and provided technical services in multiple locations.

The year 2020 has come in an unexpected way with multiple and overlapped challenges and crisis. Nobody could live on its own and detach itself from the interconnected world. As a community of shared future, we need to join our hands with others to rise up to these global challenges. As the Chinese saying goes *The going is difficult when doing it alone, but easier when doing it with many others*. It is our firm belief that, with our concerted efforts, we could always build our world into a better place for all.





# ***HISTORY***

Annual Report  
**2019**

CHINA INSTITUTE OF WATER RESOURCES AND  
HYDROPOWER RESEARCH





# IWHR IN MAPS

China Institute of Water Resources and Hydropower Research (IWHR) is a national research institution under the Ministry of Water Resources of China, and is engaged in almost all the disciplines related to water resources and hydropower research.

With over 60 years of development, IWHR has grown into an indispensable think tank of the Chinese government for decision making and a backbone technical consultant in water related areas. It is at the same time the host of multiple international organisations or their Chinese branches, including WASER, WASWAC, IAHR, ICFM, ICOLD, ICID, IAHR, GWP, IHA and ARRN.

With 11 research departments and four affiliated enterprises, IWHR is endowed with research capacity in: hydrology and water resources, water environment and ecology, flood control, drought relief and disaster reduction, soil and water conservation, river and lake management, water resources in rural and pastoral areas, hydraulics, geotechnical engineering, hydraulic structures and materials, earthquake engineering, hydro machinery and electric equipment, automation, engineering monitoring and examination, renewable power resources, water history and informatisation and remote sensing technology.



Department of Water Resources for Pastoral Areas (Hohhot, Inner Mongolia)



Tianjin Institute of Hydroelectric and Power Research (Tianjin)



The map of Beijing here is modified from Beijing Tourist Map (2016) by © Beijing Municipal Commission of Tourism Development



Scan to find IWHR Headquarters (South) in Google Maps



Scan to find IWHR Headquarters (South) in Baidu Maps



IWHR Headquarters (South)



IWHR Headquarters (North)



Daxing Experimental Base



Yanqing Experimental Base





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2019



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# Annual Report



CHINA INSTITUTE OF WATER RESOURCES AND  
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## Vision and Strategy

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The Nierji Water Control Project in Northern China



## Vision

### Vision



Striving to be the pioneer for creation and innovation of water related frontier science and technology

### Mission

Supporting China's water resources and hydropower development to improve people's livelihood

Pioneering the world's development in water related science and technology

### Spirit

Innovation

Practicality

Devotion

Dedication

## Strategy

### 1 Goal

- To join in 2020, to become one of the best in 2035 and to lead in 2050 the club of world-class research institutes of water resources and hydropower

### 2 Priorities

- Strategic, overarching, forward-looking and fundamental problems of water sciences
- Key technological problems incurred in huge hydro projects

### 3 Capacities

- Innovativeness in science and technology
- Competitiveness in market
- Competency in international arena

### 4 Bases

- Scientific and technological innovation
- Research, development and industrialization
- Training of top professionals
- International cooperation and academic exchange

### 5 Developments

- Human resources
- Relevant disciplines
- Research infrastructure and facilities
- Institutional settings
- Organizational culture

### 6 Excellences

- Research team
- Disciplines
- Facilities
- Management
- Technical achievements
- Socio-economic benefits



# Annual Report



CHINA INSTITUTE OF WATER RESOURCES AND  
HYDROPOWER RESEARCH



## Mission Achievement

IWHR Innovation	16
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The Baishan Hydropower Station in Northeastern China

# IWHR Innovation

## Key Technology of Precise Drip Irrigation and Its Product Development and Application

The Team of XU Di and GONG Shihong,

Key words: Precision drip irrigation, technology and product, technical application mode

### Theory and Method

The team has systematically established the design theory and method for different key equipment including root-intrusion avoiding emitter, anti-clogging emitter, low pressure and high uniformity emitter and wide-range pressure regulator. For the first time, the team found out the key structural parameters, sensitive sizes and optimized combination range which affect the high uniformity irrigation of the emitter and therefore systematically constructed the design theory of surface drip irrigation emitter of high uniformity and subsurface root-avoiding and anti-clogging emitter, proposing a reverse design method which determines the flow channel structural parameters directly based on the emitter performance, with a deviation rate of less than 2.5%. The project reveals that the main structural parameters affecting the performance of the pressure self-adjusting device are spring stiffness factor, the initial amount of compression, size of regulator unit, etc., and is the first to propose the design method of low pressure regulator based on which the pressure regulator realized a low voltage start-up at 6m for the first time. The establishment of the design theory of precise drip irrigation fills the domestic gap, and the key products were independently designed, which is a great leap forward.

### Technology and Product

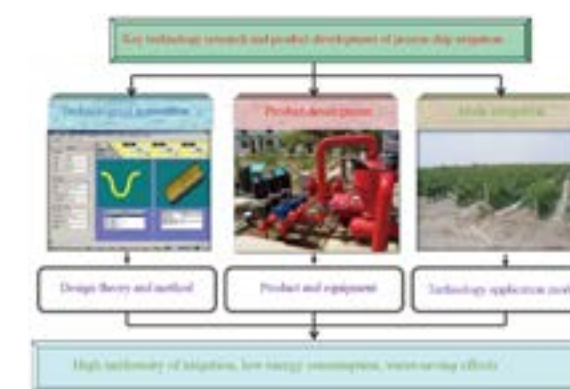
The project has developed the key technology products and manufacturing equipment for precise drip irrigation with independent intellectual property rights and cost effectiveness. Besides, a series of pressure-compensated precision emitters have been designed for surface, subsurface and complex terrains, meeting the world leading standard, with the flow uniformity 10% higher than that of similar emitters. With the localization and large-scale production of precise driplines which is more cost-effective than that of similar foreign products, it breaks up the monopoly of foreign technology and equipment in this field. The team has developed a series of auxiliary product such as devices of wide-range flow and pressure self-adjusting, self-cleaning filter units, cost-effective and safe pipe fittings. The performance is up to the international advanced level, and the price is less than 50% of the imported equivalents. The project has invented the technique and device for the flotation and regeneration of waste plastic water which increases the recovery rate of drip irrigation pipe racks by more than 30% and addresses common problems of auxiliary products such as high price, short service life and recycling difficulty.

### Technology Application Model

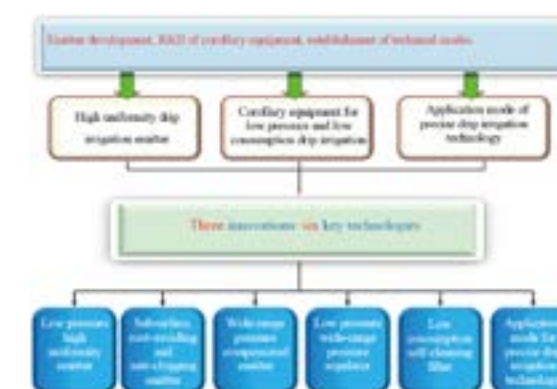
The technology integrates three kinds of application modes of precise drip irrigation technology respectively suitable for field crops, cash crops and fruits in complex terrain. Among which, the low-pressure and high-uniformity surface drip irrigation technology, applied to the densely planted crops in rain-fed areas like corn, has raised the irrigation uniformity by 8%-10% and reduced the system energy consumption by 16.8%. The wide-range pressure compensation drip irrigation technology, applied to fruit crops in desertification and hilly regions increases the pressure accommodation amplitude by more than 10m year on year, and reduces project investment by 25%. The root-avoiding and anti-clogging subsurface drip irrigation technology, applied to perennial cash crops such as alfalfa and sugarcane, reduces investment per mu by 30%-50%, and increases the yield more than twice. These achievements effectively solved problems such as high energy consumption, low irrigation uniformity in complex terrain as well as huge investment.

## Achievements

The project achievements and technical products have been industrialized. A serialized whole-set technical equipment system has been established catering to various regions, crops, phenological and economic conditions. In cooperation with domestic enterprises, 9 production and R&D bases have been established in several places including Jiuquan, Wuwei and Dingxi in Gansu, Wuqing in Tianjin, Urumqi in Xinjiang, Jining in Inner Mongolia, Xianyang in Shaanxi, Changchun in Jilin and Nanning in Guangxi. Those bases are equipped with an annual production capacity of 2.6 billion meters of drip irrigation pipe (stripe) and related water-saving equipment, as well as facility production, engineering construction and technical service capacity catering to water-saving farmland of 2 million mu. The achievements have been widely used in field crops, protected agriculture and economic forest fruit. The techniques have been popularized and applied to 13.966 million mu farmland in 16 provinces and regions, including Gansu, Xinjiang, Inner Mongolia, Qinghai, Ningxia, Shaanxi, Henan, Hebei, Tianjin, Beijing, Jilin, Liaoning, Heilongjiang, Guangxi, Guizhou and Yunnan with a domestic market share of over 33.67%. The water saving amount per mu reached 35.1%, the increased revenue and reduced expenditure reached 440.4 RMB per mu, the direct economic benefits reached 6.223 billion RMB, and water saved added up to 29.778 billion m<sup>3</sup>.



Technology Roadmap of Achievements



Block Diagram of Core Technical Achievements



High Uniformity Emitters



Pressure Regulator Low Pressure Self-cleaning Filter

Development of Core Equipment



Technical Mode Applied to Subsurface Drip Irrigation of Sugarcane



Technical Mode Applied to Field Corn



# Representative Researches

## Theory, Method and Practice of Research on Mechanical Properties of Rock Mass Engineering

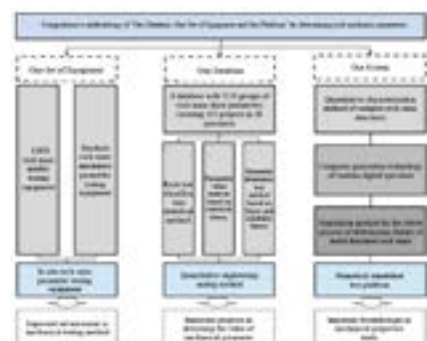
Main Participants: WANG Xiaogang, WANG Yujie, ZHAO Yufei, LIN Xingchao, CAO Ruilang, PI Jin, SUN Ping, LING Yongyu, DUAN Qingwei, JIANG Long, LIU Lipeng, SUN Xingsong, ZHANG Qiang, FU Ruizhi

### Background

In rock mass engineering, reasonable determination of rock mass mechanics parameters is the premise and foundation for carrying out all other work. Different from the artificial material like concrete, the rock mass is a complex structure with long-term geological formation and a lot of joints and fissures. Therefore, its mechanical parameters cannot be directly obtained from small-scale laboratory tests and limited field tests. At present, the acquisition of these parameters mainly rely on personal experience, without effective means, which has become the bottleneck of rock mechanics. In view of such problems, the project team developed new test equipment, improved engineering experience method, and established a simulation test platform, gradually forming a method system to comprehensively determine the characteristic parameters of rock mass engineering mechanics.

### Contents

- Researching and developing the equipment and methods that could be used to rapidly detect and identify the rock mass quality along the path during conventional geological boring; developing the in-situ test equipment and method for fast estimation of shear strength and elastic modulus of rock mass at different depths during conventional geological boring;
- Comprehensively collecting and collating the indoor and outdoor rock mass mechanics test data of important domestic projects, and on this basis, researching the quantitative empirical method for determining rock mass parameters based on mathematical statistics and reliability theory;
- Researching and resolving key technical problems such as the rapid generation of rock mass numerical samples, the whole-process simulation of rock mass deformation and failure, and the numerical simulation test of jointed rock mass, developing a large-scale numerical simulation test platform that can reflect the structural characteristics and failure mechanism of complex rock mass.



Method for Determining the Parameters of Rock Mass Engineering Mechanical Properties and the Application Technology Framework



Application of New LWD Rock Mass Equipment in the Songhua River Water Diversion Project

### Achievements

- Having developed borehole shear elastic modulus instrument and the LWD (Logging While Drilling) rock mass quality evaluation system, established a set of new equipment and method for fast detection of rock mass and in-situ fast test of mechanical characteristics, providing a new method and means for the fast measurement of rock mass parameters and quality without further workload of site investigation;
- Having established a database system containing 1174 groups of rock mass shear parameters in 103 projects and an empirical method for determining rock mass mechanical parameters based on the theory of mathematical statistics;
- Having improved the rock mass structure plane network simulation technology, realized the whole process accurate simulation of deformation, failure and expansion evolution of complex jointed rock mass, and developed a large-scale numerical simulation test platform that can reflect the structural characteristics and failure mechanism of rock mass.

### Application

Based on this project, 11 national patents have been developed and 3 monographs published. The achievements of this project have been popularized and applied in more than 30 projects including the Three Gorges, Longtan, Xiaowan and Jinping I, showing good effect and important social and economic benefits.



Equipment and Main Indicators for Borehole Shear Elastic Modulus



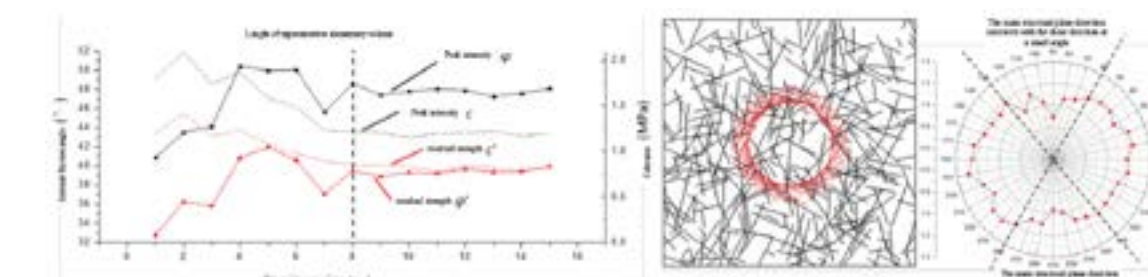
New LWD Rock Mass Quality Testing Equipment and Prototype



Established a Numerical Simulation Test Platform for Mechanical Properties of Jointed Rock Mass



Engineering Analogy Quantitative Method of Rock Mass Mechanical Parameters Based on Bayes Theory



Engineering Mechanical Characteristic Parameters of Anisotropic Rock Mass Considering Size Effect

## Formation and Mitigation of Clogging in Drip Emitters and the Efficient and Safe Use of Reclaimed Water

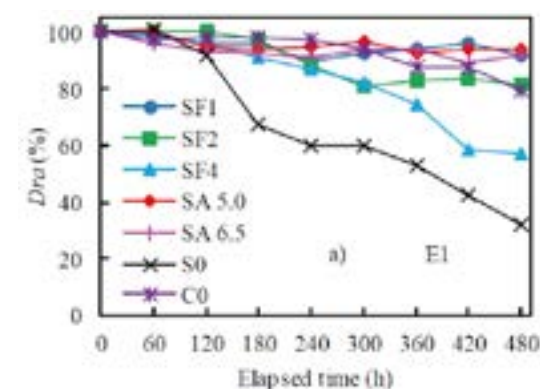
Main Participants: LI Jiusheng, LI Yanfeng, LI Yunkai, WANG Zhen, ZHAO Weixia, WANG Jun, ZHOU Bo, ZHANG Hang, WEN Jie, GUO Lijun, HAO Fengzhen, QIU Zhenjie, HU Yaqi, LI Yan, XIAO Yang

### Background

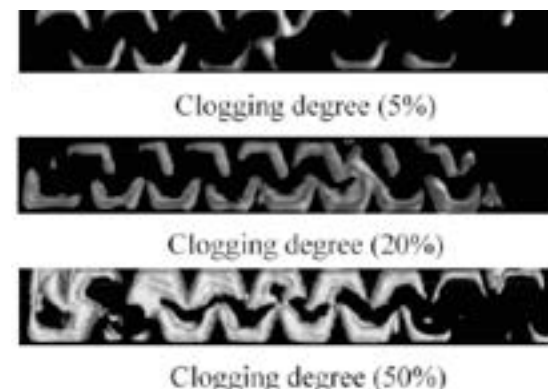
Drip irrigation with reclaimed water is an effective way to ease the contradiction between water supply and demand around the world, which has been applied to an area of over 40 million mu in China. The reclaimed water is rich in nutrients for crops but also contains a certain amount of harmful substances that might cause ecological pollution of farmland. Efficiently utilizing the nutrients in water while reducing the pollution risks have become the most concerned issues in reclaimed water irrigation. Drip irrigation has incomparable advantages over other irrigation technologies in unconventional water source irrigation, but the operational safety and environmental pollution risk are the main constraints for its application. Aiming at the goal of safe and efficient use of reclaimed water, the project explored the influence of reclaimed water irrigation on irrigation systems performances, environments and agricultural products through laboratory experiments, field experiments, and numerical simulation.

### Contents

- Researching on the clogging mechanism, clogging mitigation mechanism and anti-clogging optimization design of the drip emitter with reclaimed water given that the clogging is the key factor affecting the safety of the drip irrigation system;
- Researching on the dynamic process of the environmental impact of drip irrigation with reclaimed water oriented by the environmental behavior characteristics of typical pollutants and the problem of pollution risk evaluation in drip irrigation with reclaimed water;
- Researching on the nutrient absorption and utilization mechanism as well as the efficient and safe regulation mechanism of drip irrigation with reclaimed water regarding the previous problems such as insufficient consideration of nutrient and safety indicators in the regulation of irrigation with reclaimed



a. Temporal Variation of Emitter Discharge



b. Spatial Distribution Crystallization Fouling

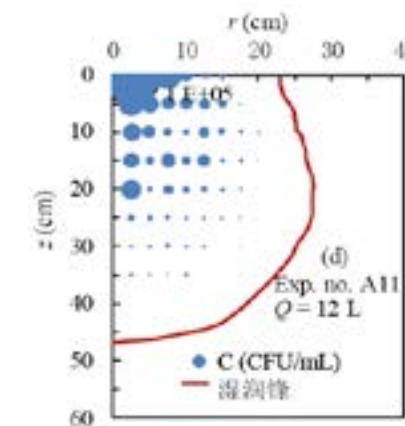
Research on Emitter Clogging Mechanism of Drip System Applying Reclaimed Water

### Achievements

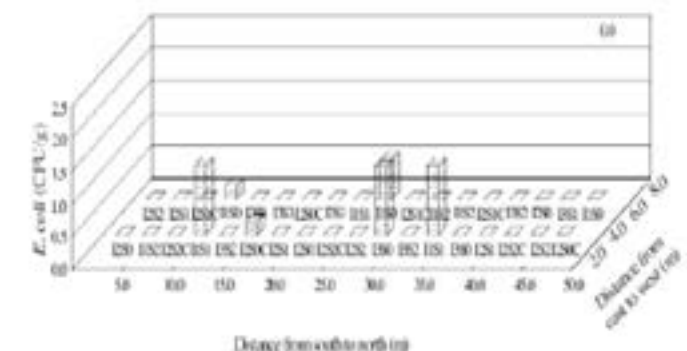
- Having revealed the inducing mechanism of emitter clogging under the interaction of chemical and biological clogging and the clogging control mechanism, and interpreted the microscopic mechanism of the clogging and the macroscopic characteristics of its influence;
- Having established the dynamic description method of pathogen behavior in drip irrigation with reclaimed water, providing a tool for scientifically evaluating the pathogen contamination risk of reclaimed water irrigation and eliminating the public doubt;
- Having for the first time quantitatively evaluated the nutrient availability in reclaimed water, providing a basis for the formulation of water quality standard and optimization measures for nutrient in reclaimed water.

### Application

The project won the first Ward for Outstanding Contribution to Agricultural Water-saving Technology. The achievements have been applied to farmland of over 15,000 mu, saving averagely 60m<sup>3</sup> fresh water and 13% fertilizer per mu, playing an important role in improving the performance of drip irrigation system, controlling sewage discharge and reducing non-point source pollution, showing significant economic and social benefits.

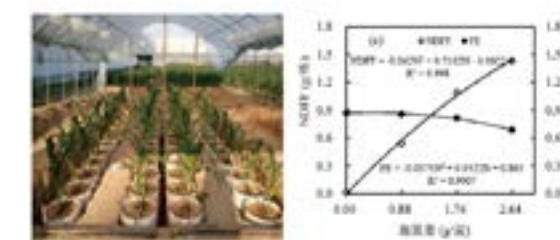


a. Transportation of *E. coli* in Soil

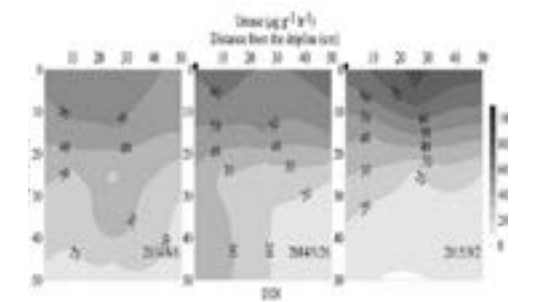


b. *E. coli* Residuals on Leaves of Crops

Research on the Dynamic Process of Typical Pathogens (*E. coli*) in Soil-crop Systems



a. Pot Experiment and Nitrogen Availability Analysis



b. Soil Enzyme Activities

Research on the Availability of Nitrogen in Reclaimed Water to Maize Compared to Synthetic Fertilizers under Drip Irrigation



## Study on Fluid-Structure Coupling Model Seismic Experiment and Numerical Analysis for IRWST of Nuclear Power Plant

Main Participants: HU Xiao, ZHANG Yanhong, GAO Jianyong, YANG Chen, CHU Meng, XU Ting, DI Qingshuang, WANG Haibo, LI Chunlei, XU Lianghua, ZENG Di, ZENG Xinxiang, LU Wei, ZHANG Lihong, XING Guoliang, WANG Quanzhu

### Background

Fluid-structure coupling model seismic experiment and numerical simulation of complex IRWST is an important and difficult field of inter-disciplinary research at home and abroad. It is also one of the main technical directions of structural analysis and design. However, it has been difficult to achieve its effective and real simulation due to the various rigorous experiment requirements and calculation conditions. In this project, based on CAP1400 IRWST and its key equipment, pipes and structures, combined with shaking table experiment and numerical simulation, the fluid-structure coupling effect of IRWST with complex flow field under seismic condition was studied.

### Contents

- Analyzing and demonstrating the similarity relationship of the structural parameters and fluid parameters of the IRWST and its rationality, proposing the research method with similarity criteria of inertia force and Froude Number;
- Simulating the external boundary conditions of the IRWST and the fluid-structure interactions of complex pipelines and equipment with water by three-dimensional finite element model, calculating the dynamic characteristics and corresponding seismic response of the IRWST;
- Systematically studying the seismic response of the IRWST and its equipment under a variety of conditions such as with or without tank cover, with or without tank absorber, and different water levels on shaking table.
- Analyzing the effects of several absorber schemes with the three-dimensional finite element method and comparing with the experimental results, putting forward the effective damping measures for the practical projects and developing the seismic fluid-structure coupling analysis method of complex tank.



CAP1400 IRWST Prototype



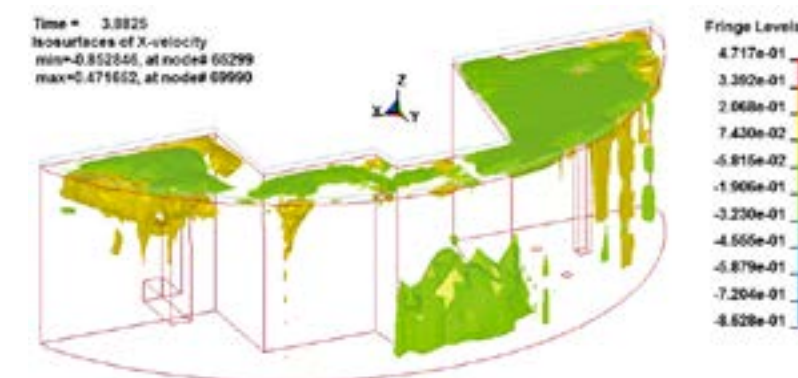
CAP1400 IRWST Fluid-Structure Coupling Model

### Achievements

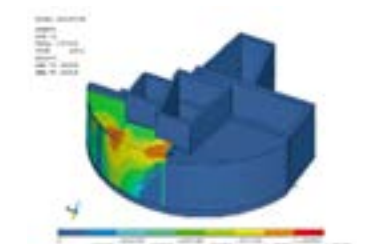
- Having proposed the similarity criterion of structure-fluid-equipment dynamic experiment for complex tank structure, explaining the similarity of dynamic model experiment on shaking table;
- Having studied the stress characteristics and key influencing factors of the equipment in the complex tank through the multi-condition experiment, innovatively proposed the scheme of setting absorber inside the tank for attenuation, effectively reduced the sloshing effect of the fluid level and the hydrodynamic water pressure of the equipment in the tank;
- Having studied the dynamic characteristics of the tank, the top impact effect, the coupling of equipment and other problems by combining experiment and numerical calculation, formed a reasonable and reliable fluid-structure coupling analysis method for complex tank, and effectively improving the current design level.

### Application

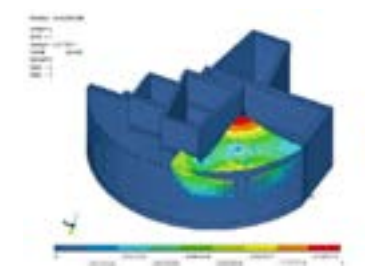
Research results of the project have been successfully applied to the construction control of Hekou Village Reservoir, Jilin Taiyiji Hydropower Station, Shanshandian Reservoir, Qianping Reservoir and other projects, ensuring the normal construction of the projects and bringing great social, economic and ecological benefits, with a total profit of 951 million RMB over the years.



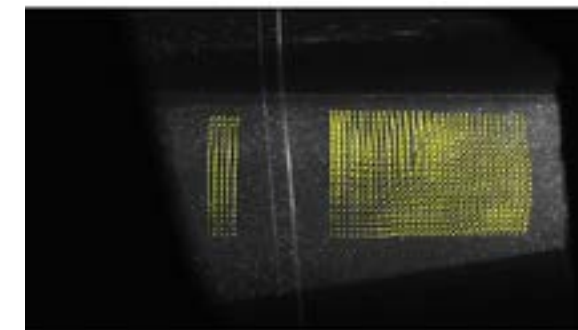
Numerical Simulation of Water Flow Field (unit: m/s)



a. Fluid Sloshing Mode (0.157 Hz)



b. Fluid Sloshing Mode (0.268 Hz)  
Dynamic Characteristics of Different  
Water Zone with Intermediate Absorber



Cross Section Flow Field Vector Measured  
by Particle Image Velocimeter (PIV)

## Measurement and Estimation of Soil Erosion in Production and Construction Projects

Main Participants: NING Duihu, LIU Xiaoying, CHENG Dongbing, DU Pengfei, QU Liqin, GUO Qiankun, LUO Han, LIU Benli, QIN Wei, WANG Wenlong, XIE Yongsheng, QU Jianjun, ZHANG Pingcang, ZU Ruiping, SHAN Zhijie

### Background

An accurate knowledge of the artificial soil erosion volume in production and construction projects is a prerequisite for reasonably planning soil and water conservation and effectively preventing and controlling human induced soil erosion, hence can provide scientific support to the supervision enforced by the water authorities. Such kind of knowledge is consequently urgently desired. Compared with the research on soil erosion on natural conditions, the research on soil erosion in production and construction projects starts late, has not yielded specific outcomes and experiences, and lack comprehensive and systematic qualitative and quantitative measurement and estimation. As a result, there are few basic theories and technologies for the measurement of soil erosion in production and construction projects at globally, and there isn't a complete and effective methodology for the measurement and estimation.

### Contents

- Establishing a classification system of soil erosion types in production and construction projects;
- Analyzing the soil erosion mechanism in production and construction projects;
- Building a series of estimation model for soil loss in production and construction projects;
- Formulating the standard of the water industry regarding the measurement of soil erosion in production and construction projects.



Artificial Rainfall Experiment  
of Soil Erosion on Engineering  
Excavation Surface

### Achievements

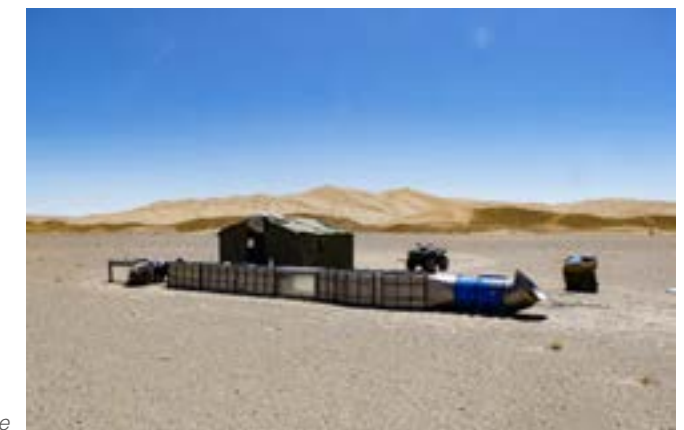
- Having for the first time conducted a blanket survey on soil erosion in production and construction projects nationwide and established a systematic and scientific classification system targeting soil erosion in China;
- Having built a modeling system for the measurement and estimation of both water and wind erosion with respect to three disturbance types of generally disturbed land surface, bare slope due to the excavation and congeries of project as well as 8 sub-types, filling in the blank of the research on the measurement of human induced soil erosion;
- Having created a national environmental database regarding water and wind erosion, covering soil erodability, monthly and annually rainfall erosivity, wind erosion rate per unit area for all counties of China;
- Having formulated the industrial standard for the measurement of soil erosion in production and construction projects, and developed a systematic application platform serving diversified users.

### Application

The achievements have been successfully applied to soil erosion prevention and control in more than 30 large production and construction projects including Lanzhou-Xinjiang Railway, demonstrating sound scalability. The pertinent water industry standard based on the achievements is promulgated and implemented in 2018. The following large and medium production and construction projects have introduced this achievement to make soil and water conservation plan to monitor soil loss during the process of construction.



Congeries of Project Set in Field to Measure  
Soil Erosion Amount



Wind Tunnel Experiment for Disturbed Surface



## Research and Application of Sediment Regulation in Upper Marsyangdi A Hydropower Station of Nepal

Main Participants: DENG Anjun, SHENG Yuming, WANG Dangwei, ZHANG Guolai, SHI Hongling, YU Xiangrong, JI Zuwen, BAI Cunzhong, GUO Qingchao, JIN Yong, LU Qin, YAN Hongwei, PENG Kun, HOU Zhong, DONG Jiangbo

### Background

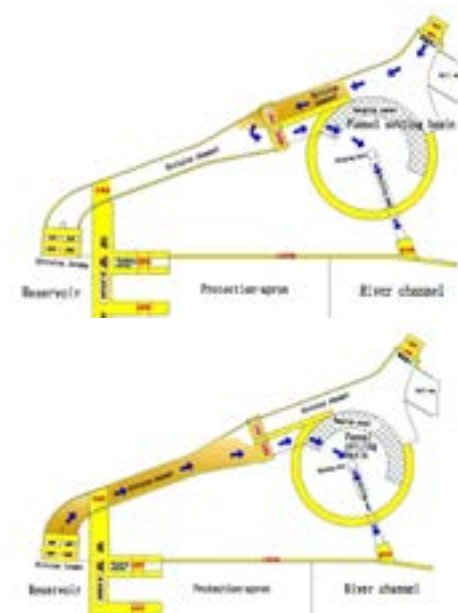
Located in the upper reaches of Marsyangdi River at the southern foot of the Himalayas, the Upper Marsyangdi A Hydropower Station is the first Nepalese hydropower project invested by China. The reservoir has a total storage capacity of about 700,000 m<sup>3</sup> and a regulation capacity of 70,000 m<sup>3</sup>, and the installed capacity is 50MW. The river reach where the project sits is a typical mountain reach with a bottom slope of 1.25%, and is featured by concentrated water head and abundant water energy, and also by large amount of sediment, especially the coarse sediment. Owing to the limited space for installing setting basin, sediment treatment is key to the safe operation of the hydropower station. Focusing on reservoir sedimentation, water diversion for sediment control, as well as sediment passing through the turbines, the research team has conducted a systematic study on the whole chain of sediment movement from the reservoir to the diversion channel and to the setting basin.

### Contents

- Conducting research on the sedimentation process and the timing of desilting in the reservoir;
- Conducting research on the sediment transport process in the diversion channel and its influence on diversion water flow;
- Conducting research on the applicability of funnel settling basin and its efficiency;
- Conducting research and development of a technological system for sediment regulation.



Plan Layout of Upper Marsyangdi A Hydropower Station



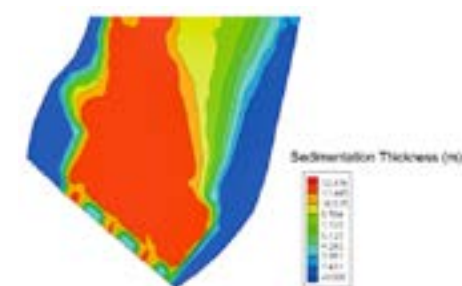
Sketch Map of Forward and Reverse Sediment Flushing

### Achievements

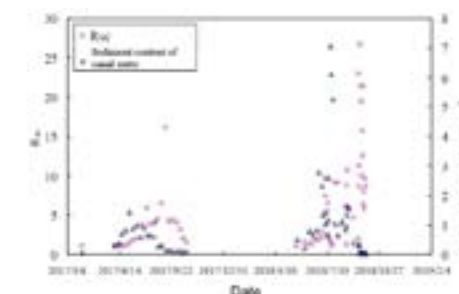
- Having revealed the water and sediment transport patterns of a run-of-river hydropower station characterized by steep slope, high sediment content and coarse sediment, and clarified the vertical sediment discharge mechanism with a three-dimensional complex flow pattern in the funnel settling basin, hence effectively addressing challenges in water and sediment simulation and type-selection of sediment control facility in a mountain river;
- Having improved the water and sediment simulation for mountain rivers, developed reverse and forward sediment flushing technologies, optimized the layout of the flushing sluice and the diversion intake, and resolved a key technological bottleneck of water diversion safety of run-of-river hydropower stations on sediment-laden rivers;
- Having established an indicator threshold system of reservoir water diversion and sediment control as well as the multi-dimensional coordinated sediment regulation technology, including the upstream monitoring, the reservoir sediment drafting, the water intake sand control, the diversion channel flushing, the funnel basin washing out, hence ensuring the long-term safe and efficient operation of the hydropower station.

### Application

- Adopting the funnel settling basin has saved about 10.7838 million RMB of construction cost, and the application of sediment control technologies has helped increase the annual power generation by more than 10%.
- The project has helped Nepal address its power shortage and unstable power supply, and has been applauded by Nepal National Power Development Agency, Nepal National Power Bureau and Nepal National Grid Dispatching Center.
- The effective and successful sediment regulation at the Upper Marsyangdi A Hydropower Station has attracted more than 100 visitors from China Harbour, Sichuan Province Investment Group, Xinhua Hydropower and other companies, holding a huge potential for wider application.



Distribution of Sedimentation Elevation and Arrangement of Diversion Channel Upstream of the Dam



Relationship between the Sediment Content of Discharge and of Channel Inflow



Certificates of Acknowledgment from Nepal National Power Bureau and National Grid Dispatching Center in 2018

## Key Technology Research and Application of Whole-Process Intelligent Temperature Control on 200m-High RCC Dams

Main Participants: ZHANG Lei, ZHU Zhenyang, ZHANG Yan, QIU Yongrong, MA Xiaofang, XIN Jianda, LEI Zhengqi, LUO Xiangyu, WANG Juan, HOU Wenqian

### Background

Crack control is key to the construction of concrete dams and a prevalent challenge in the engineering world. The subject of research is an RCC dam with a bottom width of over 160m. The construction site is subject to harsh and difficult conditions, which pose grave challenges to temperature control. There exhibit four major cracking factors (i.e. large temperature difference, steep cooling range, fast cooling rate and wide temperature gradient), four prevalent management challenges (i.e. information access is untimely, inaccurate, cooked or fragmented), as well as two discrepancy control risks (i.e. to control the discrepancy between design and actuality, and the discrepancy between construction and design).

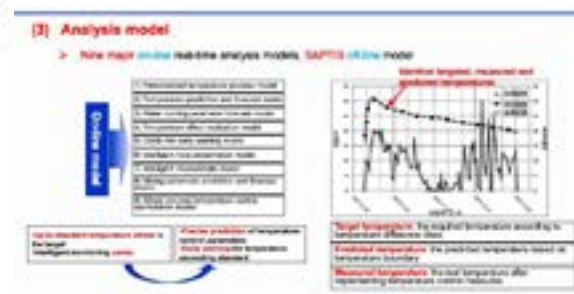
Intelligent temperature control during dam construction is an emerging means to ensure dam safety. Addressing the characteristics of the subject of research, the team has developed a set of standardized and scalable intelligent temperature control technologies and system for 200m-high RCC dams.

### Contents

- Key analysis and decision-making modelling of whole-process intelligent temperature control for 200m-high RCC dams;
- Pertinent equipment development;
- Pertinent software research and development;
- A new methodology for tracking, inverse and simulative analysis of dam concrete temperature control and developing its software interface.



System Functions Composition



Nine Major On-line Real-time Analysis Models and SAPTIS Off-line Model

### Achievements

- Having established a set of whole-process intelligent temperature control methods for high RCC dams, enabled the real-time sensing and data connectivity of control factors, intelligent analysis of cracking risks, and whole-process feedback and control during concrete construction;
- Having established a data acquisition and early warning model of whole process intelligent temperature control for RCC dams, thereby enabling the first time automatic data acquisition, management, analysis, evaluation and early warning of whole process temperature control for RCC dams;
- Having innovatively proposed and established a prediction model of intelligent water cooling solutions (e.g. flow, water temperature and water flow direction) covering multiple stages like concrete temperature rise and temperature drop, effectively enabling intelligent water cooling control for the whole process of RCC dam construction;
- Having developed and applied a real-time concrete temperature data acquisition equipment with wireless transmission technology and the Remote Terminal Unit (RTU) with intelligent approximation program, enabling the real-time acquisition and fast and accurate control of numerous temperature control factors for RCC dams;
- Having developed and integrated a whole set of software and hardware for whole process intelligent temperature control monitoring of RCC dams with independent intellectual property rights;
- Having developed a new methodology for tracking, inverse and simulative analysis of dam concrete temperature control and its software interface, thereby revealing the actual performance of 200m-high RCC gravity dams during construction.

### Application

With its refined, scientific and intelligent working mode, the research is applied to two projects in the relevant area, which has a total concrete placing volume of more than 4.5 million m<sup>3</sup>. No temperature cracks are found throughout the dams, creating direct benefits worth more than 60 million RMB and indirect benefits of 560 million RMB. The project achievements have been applied to a dozen of water resources and hydropower projects.



Data Collection Equipment



Mass Concrete Dynamic Crack Prevention ITC System



## Research on the Key Technology of Stability Analysis and Application of High Fill Engineering

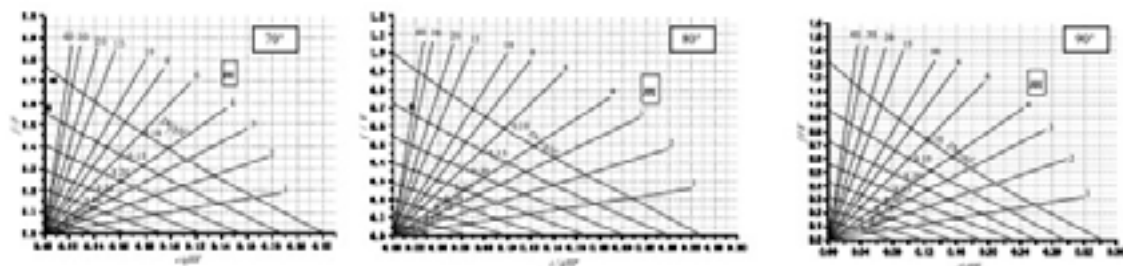
Main Participants: WEI Yingqi, CHEN Zuyu, YANG Jun, WU Shuaifeng, SUN Liming, LIU Sihong, ZHAO Jungang, HAN Wenxi, XIE Dingsong, XIAO Jianzhang

### Background

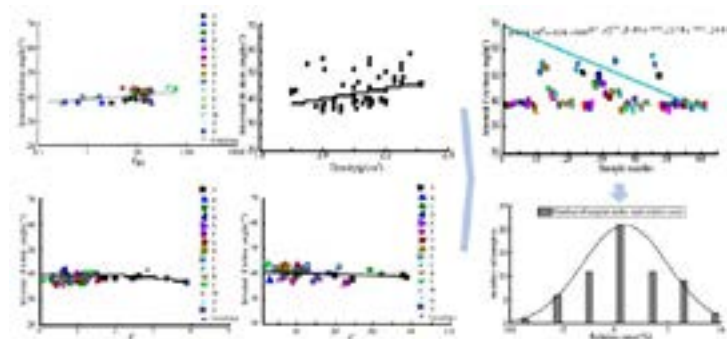
In recent years, the investment of water conservancy, civil aviation, highway, railway and other engineering construction projects in mountainous areas in the central and western regions of China has brought huge challenges to the domestic high fill engineering in terms of filling quantity, height and engineering complexity. In order to ensure the stability of the engineering construction of the high fill projects, unconventional methods for testing the strength of earth and rockfill material as well as its water weakening performance and contact surface characteristics should be considered. It is very important to clarify the mechanism of dynamic compaction of earth and rock, establish the seepage failure criterion and hydraulic fracturing mode of high fill body, put forward new theories and methods for analyzing the slope stability, and develop the method to calculate large deformation of high fill engineering projects, thus ensure the construction and long-term stability and safety of those projects.

### Contents

- Conducting research on strength characteristics of earth-rock mixture in high fill engineering projects;
- Conducting research on mechanism of reinforcement by dynamic compaction of earth-rock mixture in high fill engineering projects;
- Conducting research on hydraulic fracturing characteristics in high fill engineering projects;
- Conducting research on theories and methods for analyzing the slope stability of high fill engineering projects;
- Conducting research on slope failure mode in high fill engineering projects.



Quick Obtaining of Safety Factors or Reinforcement Spacing



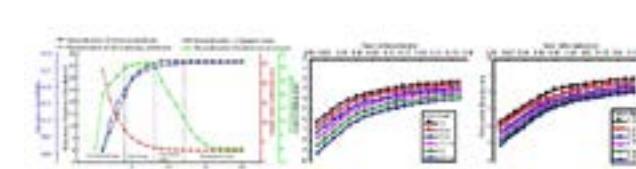
Analysis Using Limited Metacomputing

### Achievements

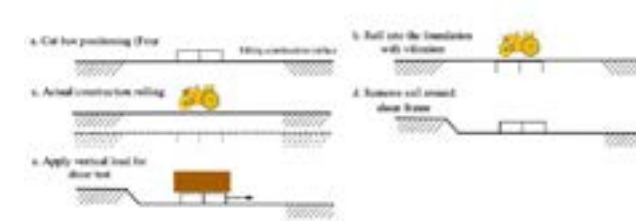
- Having proposed a method for stability analysis of reinforced soil slope based on upper-bound solution and horizontal division bar, developed and improved the module to calculate safety factors of reinforced earth retaining wall based on EMU program, illustrated the safety design chart of reinforced soil slope with multiple slope degrees, with relevant achievements included in normative application;
- Having revealed the fact that the dynamic compaction only generates two forms of wave – the shock wave and vibration wave – inside the high fill earth-rock mixture, built a 3-parameter nonlinear model for subsidence in dynamic compaction, proposed the concept and calculation method of threshold elastic vibration velocity of soil reinforcement, proposed the four-stage mechanism of reinforcement by dynamic compaction, extending the current unidirectional reinforcement mechanism to a cyclic one;
- Having developed new equipment and method for on-site stretch-draw direct shear test, improved the control standard of slit width in direct shear test of coarse earth-rock mixture, quantified the strength component of earth-rock mixture, proposed a 4-parameter strength prediction method based on grading curve and dry density, built a 3-parameter calculation model of water weakening of soft rock strength, and revealed the influencing mechanism of the base-rock contact surface characteristics on strength;
- Having proposed three hydraulic failure modes of high fill instability, revealed the influence mechanism of filling structure type on hydrologic response of slope, proposed a method to determine the most unfavorable slope stability based on the coupling of slope permeability coefficient and rainfall, proposed the 2d and 3d A-I-D (Antecedent-Intensity-Duration threshold surface) method to determine the threshold of slope risk in rainfall;
- Having proposed a finite element calculation method based on generalized nonlinear strength criterion. Having for the first time applied the material point method to the simulation of large deformation of high fill engineering projects, realizing accurate simulation of large sliding deformation of high fill engineering projects. Having proposed a method for evaluating the stability failure of high fill engineering projects based on risk theory.

### Application

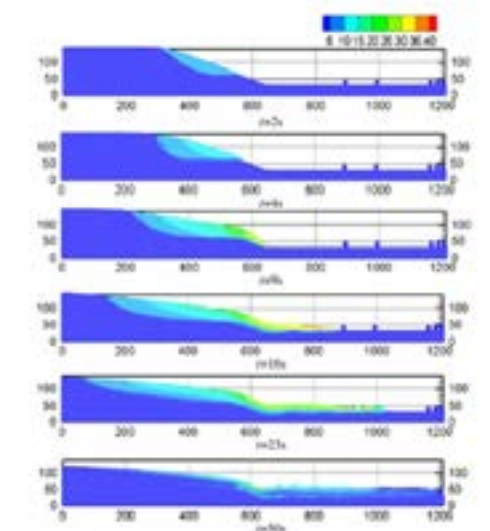
Based on this project, three patents have been developed and the achievement of the project has been included in one standard. The achievements have been successfully applied to the construction control of high fill engineering projects such as Libo of Guizhou Province, Tengchong of Yunnan Province, Kangding Airport of Sichuan Province, and Changzhi-Linfen Expressway in Shanxi Province.



Contour Map of Displacement Increment and Sliding Direction



Operation Procedure of New On-site Direct Shear Test



Wide Distribution of High Fill Engineering Projects in Central and Western China

## Innovation and Application of Hydraulic Technology for Vertical Slot Fishway

Main Participants: SUN Shuangke, LIU Haitao, ZHENG Tiegang, LI Guangning, XIA Qingfu, QIAO Mingqiu, SHI Jiayue, JIAO Jian, ZHAO Zaixing, BIN Hongxiang, CHEN Qing, LI Helin, JIANG Hongjun, WU Zhong, BIAN Yonghuan

### Background

With the ecological protection and restoration of environment elevated to the national strategic level, the fishway, as one of the main engineering measures, plays an irreplaceable role in mitigating the effect of dam block and protecting fish resources, and has become an important part of the sustainable development of water conservancy and hydropower. China's research on fishway has been interrupted for nearly 30 years due to historical reasons, and the lack of mature experience and a large number of practical needs have become the driving forces for the development of research on fishway hydraulics.

Since 2006, the project team has conducted systematic research on the hydraulics of vertical slot fishway by combining hydraulics with fish behavior, marking a new stage of fishway research in ecological protection of rivers in China.

### Contents

- Research on division of flow pattern zone of different pool shape layouts based on the conventional pool shape layout of vertical slot fishway;
- Research on the unconventional pool shape layout of vertical slot fishway, including the rest pool, turning section and bifurcation section;
- Research on the layouts of the inlet and outlet section of vertical slot fishway based on the large fluctuation of water levels in upstream and downstream of hydropower station;
- Research on the technology to aggregate and lure fish in the inlet area of vertical slot fishway based on the new technology of fish aggregating and luring using jet flow.



Model for Comparison Experiment of Fish Migration



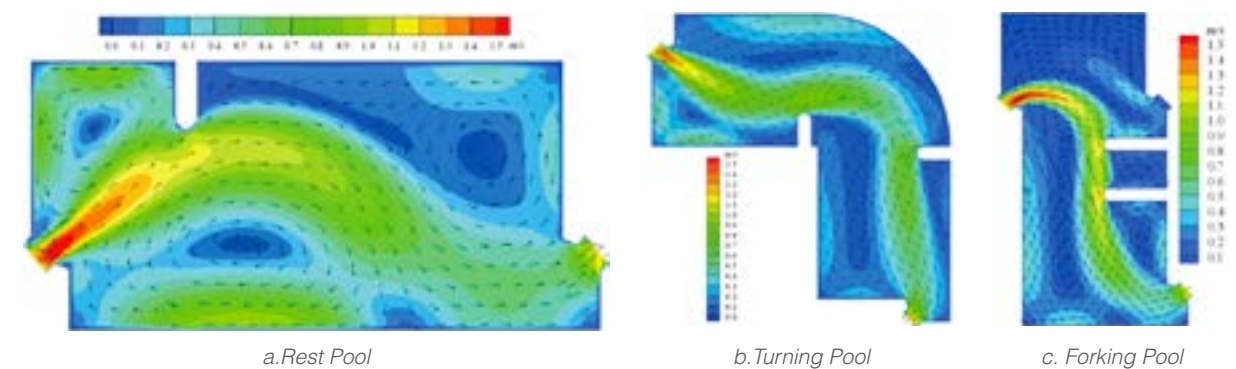
Fishway of Duobu Hydropower Station on Niyang River, Completed in 2016

### Achievements

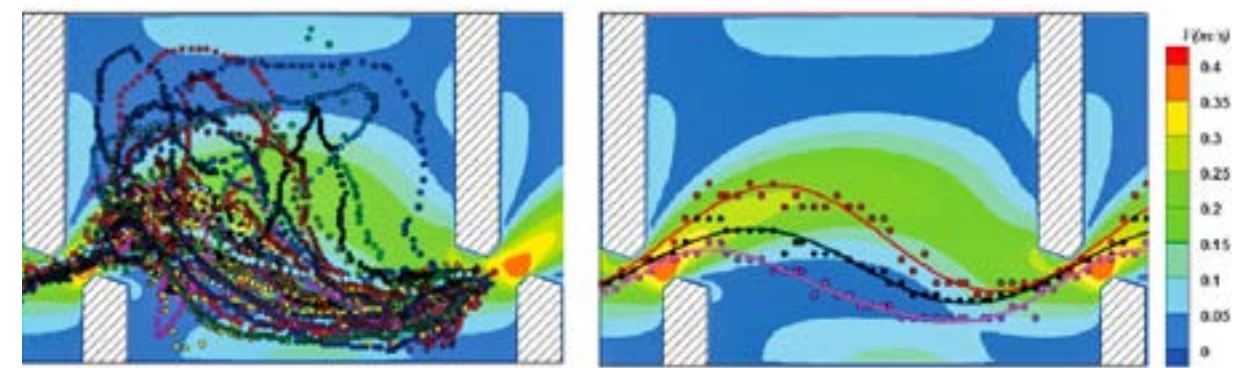
- Having proposed the reasonable range of conventional pool layout parameters of vertical slot fishway, filling the gap of domestic research in China;
- Having proposed the optimized layout plan of unconventional pool, solving the problems in the design and arrangement of long-distance fishway with high water head;
- Having developed the layout plan of brakeless control for the inlet and outlet sections of fishway which is self-adaptive to water level variation, solving problems in fishway arrangement and distribution under drastic change of water level;
- Having for the first time proposed the new technology for fish aggregating and luring in the inlet section of fishway through improving hydrodynamic conditions with jet flow and river regulation;
- Having proposed the design principle of vertical slot fishway pool structure, namely "keeping main stream centered and backflow areas on both sides basically symmetrical";
- Having proposed the optimized layout of the detailed structure of conventional pool from the perspective of improving fish passing efficiency.

### Application

The achievements fill the technical gap in the field of fishway hydraulics in China and have been applied in the design and construction of fishway of more than ten hydropower stations. One set of industry codes has been compiled based on these achievements, bringing remarkable economic, social and environmental benefits with a broad prospect of application.



Optimized Layout of Unconventional Pool



Trajectory of Fish Migration Extracted from Water Flow Structure II (Guide Plate Length  $P/B = 0.25$ )



## Demonstration and Roll-out of Balanced Water-Forage-Livestock Management and Water-Saving and Efficiency-Enhancing Technology of Artificial Grassland in Northwestern Pastoral Area

Main Participants: LI Heping, TONG Changfu, ZHENG Hexiang, WANG Jun, LU Haiyuan, BAI Bateer, CAO Xuesong, SHI Kuanzhi, LI Bo, MIAO Ping

### Background

China's pastoral areas account for more than 40% of its total land area, and most of them are in the arid and semi-arid regions in the northwest. These areas are the short board for China to realize the goal of building a moderately prosperous society in an all-round way given the scarce water resources, fragile ecological environment, and relatively lagging-behind socio-economic development.

Developing water conservancy in pastoral areas is an important measure to protect grassland ecology. It is both necessary and feasible to promote technologies for balanced water-forage-livestock management and building artificial grasslands with water-saving and efficient irrigation in northwestern pastoral areas, which can improve the yield of the animal production layers, mitigate the imbalance between nutrition supply of plant and nutrition demand by livestock among different seasons, years and regions, boost the ecological and environmental protection and sustainable utilization of water and grasslands in pastoral areas, generating significant practical benefit for socio-economic development.

### Contents

- Conducting research on water-saving and efficiency-enhancing irrigation technologies for forage lands, as well as the irrigation system in the key demonstration areas;
- Conducting research on water-saving and efficiency-enhancing irrigation technologies for forage lands as well as the irrigation system in selected representative areas in the northwestern pastoral area, based on the complex and diverse climate as well as the forage soil type in the application areas;
- Developing and applying the technology for balanced water-soil-forage-livestock management through multi-objective decision-making analysis and optimization;
- Proposing integrated model of different types water-saving and efficiency-enhancing irrigation technologies for forage lands by collecting and analyzing existing achievements and experience;
- Summarizing and proposing operation and management mode for typical demonstration projects based on the demonstration and promotion of balanced water-forage-livestock management technologies as well as the water-saving and efficiency-enhancing irrigation technologies for forage lands;
- Timely summarizing, condensing and furthering latest achievements of water-saving irrigation technologies in pastoral areas and establishing local technical standards suitable for different technologies.



Key Demonstration Area for the Subsurface Drip Irrigation Technology

### Achievements

- Having developed subsurface drip irrigation technology for perennial forage grass, including key technical parameters, all-in-one machine for seeding and pipelaying for subsurface drip irrigation, water-fertilizer-pesticides integration, and intelligent control system for subsurface drip irrigation;
- Having developed large-scale practical sprinkler irrigation technologies, integrated water-fertilizer management technology and intelligent irrigation control system for different types of forage grass;
- Having established the balanced water-soil-forage-livestock regulation and control model, identifying the threshold value for the water-soil-forage-livestock balance, and proposing a management system as well as regulation and control model for water-forage-livestock balance;
- Having amended the industrial standard of Technical Specifications for Grassland Irrigation and Drainage in Pastoral Areas (SL 334-2016).

### Application

The achievements have been applied to Inner Mongolia, Gansu and Xinjiang, with a total application area of 691,000 mu (113,833 acres). Compared to traditional irrigation technologies, these achievements have saved 23% of water, increased yield by more than 15%, with an annually increased output value of 157 million CNY (22.15 million USD). They have also provided strong scientific and technological support for the water saving and efficiency improvement as well as the ecological protection of grassland in pastoral areas across the country, with significant social benefits and huge potential for application and roll-out.



Application Area for the Center-pivot Sprinkler Irrigation Technology



National Training Program on Balanced Water-forage-livestock Management for Pastoral Areas as well as Water-saving Technologies for Forage Grasslands



Technical Training and Promotion in Xinjiang



Technical Training and Promotion in Inner Mongolia

## Research and Application of Safety Assessment, Repair and Reinforcement Technology for Aqueduct Structure in Irrigation Area

Main Participants: HUANG Hao, MA Yu, YANG Weicai, ZHANG Jiahong, XIA Shifa, LU Xiaobin, LI Shuguang, ZHEN Li, WANG Ronglu, LI Yunfeng, XU Xiao, SUN Yuelin, MENG Lijuan, YANG Shuai, CHEN Kang

### Background

In view of the problems of complex aging damages, difficulty in repair, reinforcement, transformation and upgrading, and the lack of an all-round assessment method for the aqueduct in irrigation areas, based on the S&T project conducted by the Water Resources Department of Shanxi Province, the research has made a series of original research achievements in detection technology, material development, construction technology and assessment method, established a set of complete system covering detection and assessment, repair and reinforcement, reduction of roughness and increase of flow, and safety assessment for the aqueduct in irrigation areas, which has been successfully applied to many projects in irrigation areas.

### Contents

- Conducting research on improving the traditional concrete detection results using the two methods of elastic wave and vibration detection, and on the safety assessment of concrete materials and structural real behavior;
- Conducting research on the treatment technology, roughness reduction and flow increasing technology and construction process of defect repair and reinforcement of aqueduct in irrigation areas, through indoor materials development, numerical calculation and analysis, roughness reduction plan design and field process test;
- Making comprehensive analysis and verification of structural safety assessment method and repair and reinforcement effect by means of structural test (stress/strain (deformation) sensor monitoring and digital image-related technology), performance test (pull-out test, elastic wave detection) and engineering survey (geographic topography, climate, design and construction data).



Structure Safety Analysis through Vibration Detection

### Achievements

- Having developed elastic wave and vibration detection and assessment technology, systematically established a rapid assessment method for the safety state of aqueduct structure, achieved the breakthrough from point detection to overall detection, by which the real properties of materials and structures can be obtained;
- Having systematically established a complete set of repair, reinforcement and protection technology for structural defects of the aqueduct in irrigation areas, proposed a new type of flexible water-stop structure of coated expansion joint of aqueduct structure, and developed the carbon fiber reinforcement technology, polymer fiber cement mortar repair technology, PCS anti-carbonization technology and supporting process system;
- Having developed and applied a series of coating materials suitable for the structure of the aqueduct and different environmental conditions, established the supporting construction process and quality control standards, reducing the roughness of the aqueduct by more than 20%;
- Having put forward the concept of post-repair-and-reinforcement assessment for aqueduct in irrigation areas, conducted structural inversion analysis by means of embedded sensor and digital image, improving the method of structural safety assessment and the effect assessment of repair and reinforcement.

### Application

The research achievements have been successfully applied to the safety assessment, repair and reinforcement of more than 30 aqueducts in Yumenkou irrigation area of Shanxi Province, Zhuanglanghe aqueduct in Gansu Province, and Burqin aqueduct in Xinjiang Autonomous Region, saving more than 400 million RMB in demolition and reconstruction investment, increasing economic benefit by more than 400 million RMB after the roughness reduction and flow increasing. Practicing the keynote of reform and development of the water sector "making up the shortfall in water works and strengthening supervision of the water sector", the research has greatly improved the technical level of repair and reinforcement technology of the aqueduct structures in China, demonstrating significant economic and social benefits.



Mobile Operation Platform for Aqueduct



Carbon Fiber Reinforcement Technology



Effect of Internal and External Repair of Aqueduct



## Evaluation and Key Technologies of Water Ecological Enhancement for Mountainous Small Watershed

Main Participants: MA Wei, LI Chong, MA Shiquan, HONG Jianming, ZHANG Hongsheng, BAN Jingya, LAN Ruijun, YANG Qingrui, JIANG Yan, LUO Huihuang, HUANG Yuling, FENG Shunxin, QI Dexuan, HU Xinqi, SONG Tingting

### Background

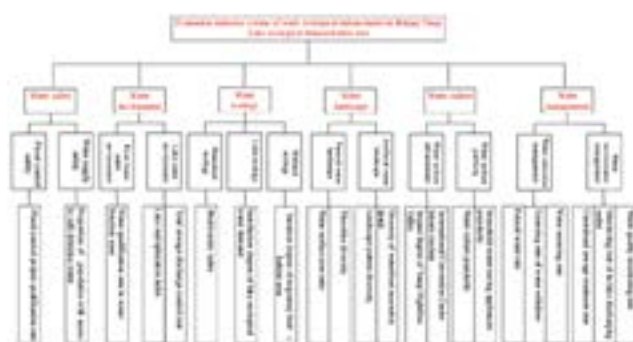
Small watershed in mountainous region is the natural ecological barrier and source of water conservation for the capital city of Beijing. The protection of water resources and the treatment of water environment in mountainous small watershed have a direct bearing on the safety of drinking water and ecological environment of the capital city. Due to the disordered development of leisure tourism, the mountainous small watershed represented by Yanqi Lake in Huairou District, Beijing, suffers from significant overloading of water resources and serious water pollution. Good water environment quality and healthy lake water ecosystem are important pre-conditions for the construction and development of Yanqi Lake ecological development demonstration area. With the purpose of realizing a clear, clean, beautiful and healthy water ecosystem of Yanqi Lake, research has been carried out on the evaluation of water environment carrying capacity and water ecological enhancement and related key technologies, in order to make water ecological improvement more scientific and effective in the demonstration area.

### Contents

- Conducting research on the evaluation indicator system of water ecological enhancement in Yanqi Lake ecological demonstration area;
- Conducting research on the evaluation key technology of water ecological enhancement in Yanqi Lake ecological demonstration area;
- Key technology demonstrating for the total control and water ecological restoration in Yanqi Lake ecological demonstration area;
- Providing evaluation and countermeasure suggestions on water ecological enhancement in Yanqi Lake ecological demonstration area.



Yanqi Lake



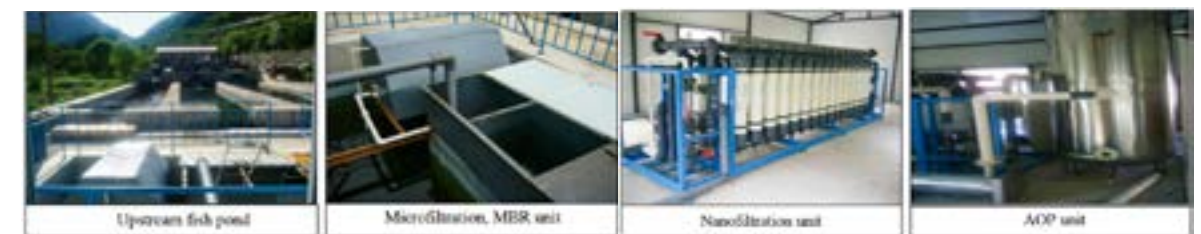
Evaluation Indicator System of Water Ecological Enhancement in Yanqi Lake Ecological Demonstration Area

### Achievements

- Having established the evaluation indicator system of water ecological civilization construction in mountainous small watershed, proposed the determination method for the threshold value of each indicator and the threshold value limit for its classification evaluation standard;
- Having built the hydrological and flood process simulation model of Yanqi Lake watershed, with the result of inverse demonstration of "Aug.15,2005" submergence in typical rainfall process indicating that the existing development pattern and intensity have a large risk of flood submergence;
- Having established the response relationships among tourist trips, fishery scale, resident population and water quality in characteristic sections of Yanqi Lake watershed, and proposed the water environment carrying capacity as well as the appropriate carrying capacity of the tourism population reception scale and fishery breeding scale of Yanqi Lake watershed;
- Having proposed the integrated technology of river riparian zone ecological management and river water ecological restoration in Yanqi Lake watershed, including zero discharge technology of fishery farming water, restoration and water purification technology of riparian zone of inflow rivers, complex wetland water purification technology of riparian zone of inflow rivers as well as water quality improvement technology of deep water area;
- Having completed evaluation on water ecological enhancement of Yanqi Lake ecological development demonstration area, with the conclusion indicating that the water ecological improvement of the demonstration area has achieved good results, offering some proposals and suggestions on reasonable control of the fishery farming scale, strengthening of end interception and purification treatment, and construction of complex artificial enhanced wetland system.

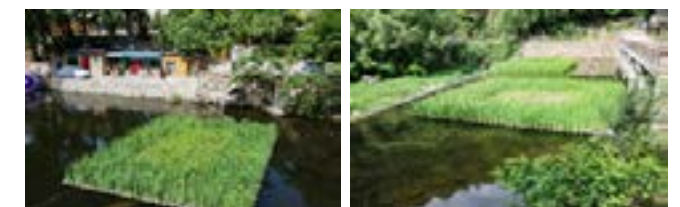
### Application

The achievements have provided scientific basis and implementation suggestions for the quantified management of the total amount of pollutants entering the lake and water ecological enhancement in Beijing Yanqi Lake Ecological Demonstration Area, and improved the working and living environment of the demonstration area. The research achievements can be mainly promoted and applied in water environment protection, providing reference for the evaluation of water ecological improvement in small watershed in mountainous areas.

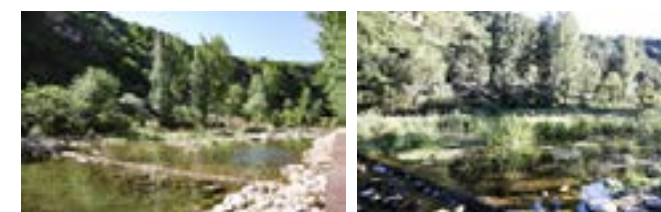


Demonstration Site

Combined Purification Technology of Fluitantes and Floating Island Plants



Before and After Water Ecological Restoration in the River Section of the Demonstration Area (Left: A long shot before restoration, Right: A close shot after restoration)



## Key Technology and Its Application on Integrated Regulation of Ecological Flow in North China

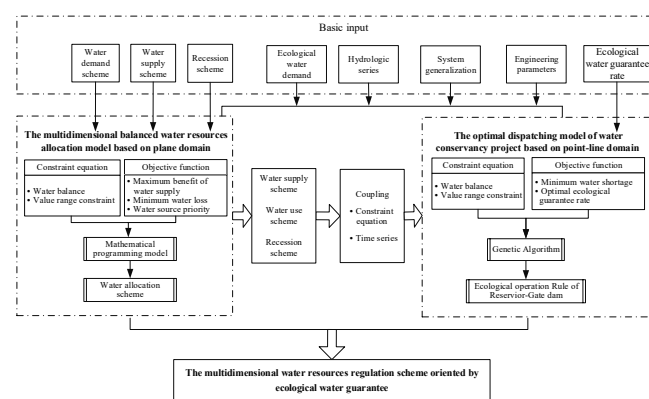
Main Participants: XIE Xinmin, MA Zhenzhen, YANG Zhaohui, YU Yifang, WANG Ting, LI Chunzuo, HE Huaxiang, WANG Junzhao, WANG Yi, CUI Yingjie, AI Yadi, WANG Zhizhang, WEI Chuanjiang, DU Jie, SHAO Mengzhou

### Background

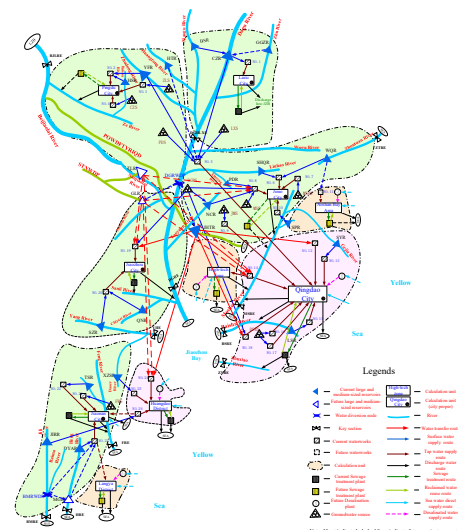
In China, the shortage of water resources in the north, the intense competition for water between ecosystem and human beings, the difficulty in guaranteeing the water demand of rivers and lakes to maintain basic ecology and environment, and the damaged ecological function of rivers and lakes, have exerted a series of negative impact on resources, environment and society. It has therefore become a hot and challenging issue that should to be urgently resolved in water resources, water ecology and water management regarding how to realize the reasonable regulation and effectively guarantee the ecological flow of rivers and lakes.

### Contents

- Establishing the protection target and management indicator system of ecological flow of rivers and lakes in Northern China;
- Conducting research on multi-dimensional water resources allocation technology for the guarantee of ecological flow;
- Multidimensional and balanced allocation model of water resources based on plane domain;
- Optimal dispatching modelling of water conservancy project based on point-line domain;
- Conducting typical case study on integrated regulation of ecological flow of rivers and lakes in North China.



The Multidimensional Water Resources Regulation Model Framework



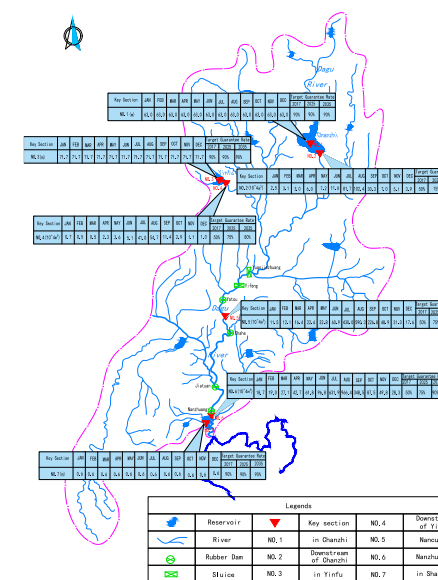
Water Resources Allocation Network Chart of Qingdao

### Achievements

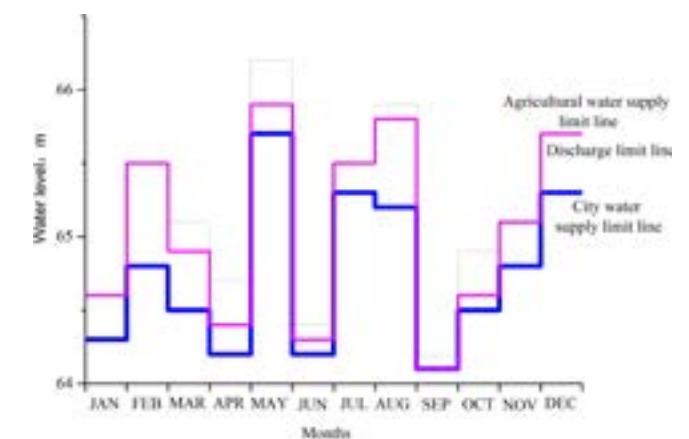
- Having introduced for the first time the concept of guarantee rate of ecological flow into management practice, taken the lead in proposing the dual-control management indicator system of “ecological flow and guarantee rate”, and set the goal of scientific and feasible ecological flow regulation in North China;
- Having developed the multidimensional water resources allocation technology for the guarantee of ecological flow, and coupled the multidimensional and balanced water resources allocation model based on plane domain with the optimal dispatching model of water conservancy project based on point-line domain, realizing the unification of multidimensional water resources allocation of point, line and plane domains;
- Having established a multidimensional and balanced water resources allocation model oriented by the process of water demand for ecology and environment in river channel and the groundwater level to maintain basic ecological needs in cities of North China, and designed a multidimensional and balanced configuration calculation process based on the “three-time configuration multi-cycle iterative method”, providing an analytical tool for defining the boundary conditions of water resources dispatching with ecological constraints;
- Having innovatively developed the ecological dispatching model for water conservancy projects, which takes the guarantee rate of ecological flow as the ecological goal, coordinates the relationship between the economic and social water use and the water use for ecology in the river channel, and adds an ecological water dispatching line on the basis of the traditional water supply dispatching line, supporting the implementation of the indicators for ecological flow management.

### Application

The key technologies developed in the research have been applied to two water-shortage cities in North China — Qingdao and Jinan. By providing the basic ecological flow and guarantee rate indicators of 14 river/lake sections in Qingdao, which are key to the ecology of the entire rivers and lakes, as well as the basic ecological flow of 12 rivers in Jinan and the groundwater level to be guaranteed to maintain the flow of springs, a series of water resources allocation plans to guarantee the ecological flow (water level) of the two cities were formulated, which has been used as the reference for Qingdao Water Authority, Qingdao Water Resources Office and Jinan Water Conservancy Bureau, achieving significant comprehensive benefits, and strongly supporting the regional ecological water management, with vast popularization and application prospect.



Ecological Water Management Index of Dagou River in Qingdao



Chanzhi Reservoir Operation Chart Considering Ecological Water



## Popularization and Application of the New UAV Rapid Monitoring Technology for Multivariate Surface Information of Soil and Water Conservation

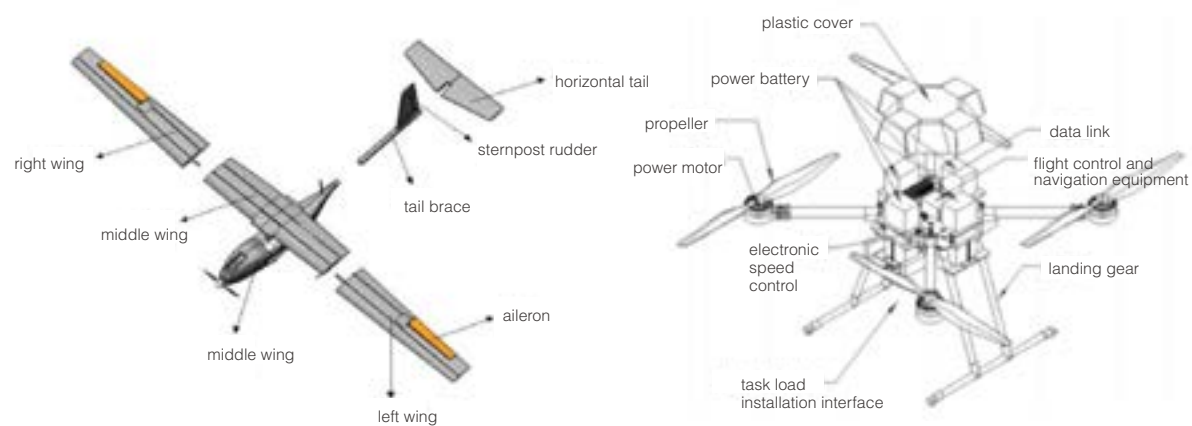
Main Participants: SONG Wenlong, SUN Tao, DU Pengfei, LIU Bing, LEI Tianjie, WANG Yousheng, YANG Xiaoqing

### Background

At present, the focus of China's water conservancy work has shifted to "Making up the shortfall in water works and strengthen supervision of the water sector", which calls for making full use of the advanced information technology for supervision. With the rapid development of UAV technology, big data and artificial intelligence technology, UAV has found an increasingly wide utilization in various fields of national economy and management such as water conservancy, agriculture, environmental protection, disaster relief and military, gaining in popularity with data acquisition, information extraction, management assistance and so on as an innovation direction. There is also a promising prospect of application of UAV in soil and water conservation. This project closely tracks the rapidly updated UAV technology and big data information processing technology to develop a small light UAV platform with longer endurance and compatible with a variety of sensors, and independently develops UAV data processing and application software system. The project aims to enhance the technical capability of collaborative acquisition for multivariate surface information of soil and water conservation, and promotes the popularization and application of UAV in water conservancy industry such as soil and water conservation.

### Contents

- Developing rotary-wing UAV and fixed-wing UAV of long-endurance and multi-load compatibility ;
- Conducting systematic research and development of software for UAV flight path planning, visible aerial photograph processing, thermal infrared aerial photograph processing, and extraction of multivariate underlying surface information for soil and water conservation;
- Carrying out proprietary intellectual property rights declaring, project incubation, publicity and training of the new technology of rapid acquisition of multivariate underlying surface information for soil and water conservation by UAV as well as the its demonstration of in a number of provinces.



Fixed-wing UAV Model FL-91 and Four-rotor UAV Model FL-82

### Achievements

- Having developed a kind of small light fixed-wing UAV Model FL-91 and a kind of four-rotor UAV Model FL-82 considering the demands of water sector such as soil and water conservation;
- Having established a full chain and system-wide methodology for the new technology of rapid monitoring of multivariate underlying surface information of soil and water conservation by UAV, which integrates our independently developed UAV platform, flight planning, data processing and extraction of soil conservation multivariate information;
- Having developed the first software system both in domestic and overseas specific to the application of UAV in soil conservation, took the leading position in the speed and capacity of aerial photograph processing compared with mainstream software in foreign countries, and integrated industry models, achieving the rapid and coordinated acquisition of multivariate underlying surface information, filling the domestic gap.

### Application

The achievements of this project have been applied to 55 small watersheds or regions of 12 provinces and cities, including Beijing, Hebei, Henan, Shanxi, Inner Mongolia, Xinjiang, Liaoning, Heilongjiang, Hubei, Hunan, Zhejiang and Tibet, supporting the local work including dynamic monitoring of soil erosion, supervision on "Sky-land Integration" of soil conservation in production and construction projection and acceptance assessment of soil conservation measures in Beijing, Henan, Shandong, Inner Mongolia, Ningxia and Hebei, and having been introduced into Henan Province as new water conservancy technology roll-out project in 2020.

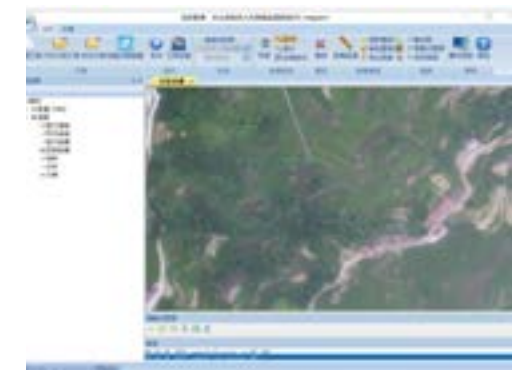
- Portable aircraft
- Simple route planning
- Intelligent aerial photo processing
- Collaborative acquisition of multivariate information
- Independent property right of core technologies
- Scalable software modules
- Strong industry application pertinence



The Technical Compositions and Advantages



UAV Intelligent Route Planning



The Interface of YC-mapper Software

## Building Beijing into the National Cultural Center with the Pillaring of Millennium Water Culture

Main Participants: WAN Jinhong, GONG Huili, DU Mei

### Background

Being the culture of people, the water culture originates from the interaction between people and water and is an important part of the traditional Chinese culture. Raised and thrived by water, Beijing has accumulated rich water culture heritages which now have become a main help for building the capital into the national cultural center.

### Contents

- Noting that water culture is the spirit and soul of Beijing Culture. The water culture heritages have witnessed the development and prosperity of Beijing, featuring “the beauty of nature, the beauty of harmony and the beauty of civilization” and “serve for the welfare of the people, the benefits of the people”. Inheriting and promoting the water culture of Beijing will boost the construction of Beijing national cultural center;
- Pointing out the “One Body, Two Wings” spatial pattern of the water cultural heritage of Beijing. “One Body” refers to the water resources cultural heritage area of the imperial gardens. “Two Wings” refers to the water conservancy heritage area along the Grand Canal Cultural Belt and the Yongding River Cultural Belt;
- Highlighting the focuses in the promotion of Beijing Water Culture, improving the legal system in the cultural sector and advancing standardized management. Increasing the investment for water culture. Strengthening the water culture research and enhancing the communication and popularization of water culture. Carrying out the general survey of water cultural heritage and developing strategies targeting at water cultural heritage protection.



Beijing Water Culture

### Achievements

- Having brought up the concept of “water culture as the spirit and soul of Beijing culture”. A number of water cultural heritages, as the witness of urban development of Beijing, laid the foundation for the city's urban texture, shaped today's urban landscape, cultivated the Beijing citizen's cultural characteristics of virtue and inclusion, and have become a significant part of Beijing Culture.
- The exploration of Beijing Water Culture is of considerable realistic significance for the construction of the national cultural center and sub-center of the city. Water culture is an important part of Conservation and Utilization of the Three Hills and Five Gardens as well as the construction of the Grand Canal Cultural Belt. Therefore, it is an essential approach for the construction of the national cultural center and sub-center of the city.

### Application

The project was awarded the second prize of Excellent Achievement Award of Philosophy and Social Sciences by the CPC Beijing Municipal Committee and Beijing Municipal Government in 2018. The proposal based on this project On Further Promoting the Construction of the Grand Canal Cultural Belt was adopted as one of the central party proposal of China Association for Promoting Democracy, and selected as the key proposal of the First Session of the 13th National Committee of the Chinese People's Political Consultative Conference (CPPCC) subject to keen promotion. The proposal Improving the Grand Canal Water Cultural Connotation, Contributing to the Construction of Sub-center of the City and National Cultural Center was adopted as a proposal of Beijing Municipal Party Committee of China Association for Promoting Democracy, submitted to the First Session of the 13th National Committee of the CPPCC, and received the official instructions from Cai Qi, Secretary of the Beijing Municipal Party Committee.



Certificate of Second Prize of the 15th Excellent Achievement Award of Philosophy and Social Sciences

Participating in the Cultural Research of CPPCC National Committee





## Best Papers

### In Journal of IWHR



#### Development and application of the CSGR dam construction quality monitoring system

JIA Jinsheng, ZHAO Chun, MIU Lun, ZHANG Dequan, LUO Zhaokun

**Abstract:** Cemented Material Dam was a new dam type of environment-friendly proposed in 2009. It is divided into three types: cemented sand, gravel and rock dam (CSGRD), cemented rock-fill dam (CRD, including rock-filled concrete dam), and cemented soil dam (CSD). In the concept of dam design, it is emphasized that "the dam structure is optimized in order to make better use of local materials" and that "proper materials can be selected for the different parts of the dam in order to realize better function of structures". This new type have the benefit of "safe and economical", "environment friendly" and "not fail even overtopping". And there are some important differences between CSGRD and Rolling earth rock-fill dam or RCC dam because of the different control elements. The overall framework and function design of the CSGR Dam Construction Quality Monitoring System according to "Technical guideline for cemented granular material dams" were introduced in this paper." Autonomous networking technology using UWB positioning system" and "Algorithm for rolling monitoring analysis" were also developed for CSGRD. The software and hardware platform was developed and used in Shoukoubao CSGRD and Shunjiangyan CSGRD. It is indicated that this system can be used not only in large projects but also in medium-sized and small projects.

**Keywords:** CSGRD; construction quality; monitoring system; UWB positioning system; mixing system; rolling

#### Mass concrete crack prevention intelligent monitoring technology and engineering application

LI Songhui, ZHANG Guoxin, LIU Yi, ZHANG Yan

**Abstract:** Crack control is an important issue in construction of concrete dams, the vast majority of concrete cracks is related to temperature stress. And so, Temperature control is the main means of crack control. After summarizing experience of dozens of concrete dam, supported by the existing temperature crack prevention theory, closely integrated the key technical problems of Mass concrete temperature control, the theoretical analysis, numerical computation, software and hardware development, laboratory tests, field tests and other means is executed, and the theory methods, models, key technologies and system are been researched. The intelligent temperature control of perception-analysis control is formed, and Mass concrete crack prevention intelligent monitoring system is developed. The technology is successfully applied in LuDiLa; ZangMu and Jinping projects. Through the concrete construction intelligent promote its fine construction, thepursues of crack prevention is reached.

**Keywords:** Mass concrete; temperature control; crack prevention; intelligent monitoring

#### Study on the safety standards of retaining structures of deep excavation in Shanghai

CHEN Zuyu, XIANG Yuanhong

**Abstract:** This paper is aimed at validating the acceptable factor of safety specified in the code JGJ120-2012. The authors proposed the recommended values of the coefficients of variability for 4 types of Shanghai soils based on 111 groups of soil testing data from 11 geological survey reports. The paper reviews the currently applied Chinese codes and proposed a reliability index of 3.7 on the basis of the code GB50153-2008 as a target to calibrate the allowable factors of safety. The corresponding criterion specified in the code JGJ120-2012 is 1.35. Deterministic stability analysis was performed based on the total stress method using Bishop's simplified method. Rosenblueth method was used to find the reliability index. Search for critical slip surface is realized using the computer program STAB which is developed by the first author. The study investigated 3 large scale deep excavation projects in Shanghai and came to a conclusion that the criterion of 1.35 based on the allowable factor of safety specified in the code is generally in compliance with 3.7 for the target reliability index. This finding provides a theoretical support to the currently available codes in our profession.

**Keywords:** Deep excavation; reliability index; coefficient of variability

#### Research on concrete hydraulic structures in the past 6 decades

CHEN Houqun

**Abstracts:** In this paper a brief introduction to major progress in the research on seismic aspects of concrete hydraulic structures, mainly high dams, conducted at the China Institute of Water Resources and Hydropower Research (IWHR) during the past 60 years, is presented. Its three development stages of starting, running after and catching up with the world frontiers are reviewed. Some major research achievements are described, such as: seismic input at dam site and defining its site specific seismic parameters, non-linear dynamic parallel analyses of seismic responses and damage-rupture process of dam-foundation-reservoir system by using high-performance 'cloud computing', quantitatively evaluating the criterion of the limit state of dam-breach, dynamic model tests on triaxial earthquake simulator with six degrees of freedom, field experimental investigation of dams and seismic monitoring at dam site, study on dynamic behaviors of dam concrete including its damage institution laws by fully-graded specimen tests and investigating its internal cracking pattern using 3-D meso-mechanics analysis and X-ray CT technology, formulating state seismic design standard for hydraulic structures, etc. Finally, some comments on updating the conventional seismic design idea and methodology are suggested.

**Keywords:** Concrete hydraulic structures; dynamic dam behaviors of concrete; seismic input at dam site; seismic responses; seismic design code; updating conventional design

## The connotation, evaluation criteria and experience model of water ecological civilization construction in China

WANG Jianhua, HU Peng

**Abstract:** Based on the analysis of the connotation of water ecological civilization, the key issues which need to be solved in the 4 aspects of ideology, technical methods, institutional solidification, and organizational implementation of water ecological civilization construction are proposed. The principle of evaluating water ecological civilization construction was put forward, and an evaluation index system of water ecological civilization was systematically constructed from the 6 dimensions of water security, water ecology, water environment, water conservation, water supervision, and water culture. The representative pilot cities such as Jinan, Suzhou, and Xuzhou were selected to concisely summarize the typical experiences and models for the construction of water ecological civilization in different types of regions and the future development of water ecological civilization in China is prospected.

**Keywords:** Water ecological civilization; system management; evaluation criteria; construction model

## Principle and application of precise regulating water and fertilizers for modernized irrigation technologies

LI Jiusheng, LI Yinong, LI Yanfeng, ZHAO Weixia, WANG Zhen, WANG Jun

**Abstract:** During the last 15 years, the Department of Irrigation and Drainage of China Institute of Water Resources and Hydropower Research (IWHR) conducted extensive studies on the precise management and regulation of water and fertilizers to meet the development needs of intensive and precision irrigated agriculture. These studies mainly focus on the water and fertilizer management for different scale fields in different ecological regions as well as regulation across multiple processes. The main findings were highlighted in this paper. The standards of micro irrigation uniformity were studied with respect to many aspects of water and solute dynamics, environmental effects, and crop yield and quality under a wide range of environments from arid to subhumid climates for typical wheat, cotton, maize and vegetable crops. As a result, new target uniformity values have been recommended. The design principles and methods of drip irrigation system were updated, considering the spatial variability of soil properties along vertical and lateral directions. We initiated the studies of variable rate irrigation (VRI) to make this new technology adapt to the water limited environments. Many efforts have been made to improve the performance of low-pressure emitters, land-scape sprinklers and fertilizer injectors. Typical efficient use modes of water and fertilizers were established in different regions to aid the extension of sprinkler and microirrigation technologies. These results have greatly contributed to updating the knowledge on water and fertilizer management and increasing water and fertilizer efficiency of sprinkler and microirrigation.

**Keywords:** Irrigation; fertigation; precise regulating; variable rate irrigation; sewage effluent

## In Journal of Hydraulic Engineering



## Regulation of water resources and operation of reservoir group in the Yangtze River basin

CHEN Jin

**Abstract:** The Yangtze River basin is facing severe issues such as shortage of water resources, degradation of water quality and water ecology. It is urgent to strengthen the strict water resources management and the optimal regulation of water conservancy system. The Large-scale water conservancy project, such as the Three Gorges, the mid-route and east-route of South-to-North Water Transfer Projects, have provided essential engineering measures for water resources allocation. Furthermore, the Three Red Lines of Water Resources Management, and other measures have improved managerial level of water resources and regulatory level of hydraulic engineering in the Yangtze River Basin. Firstly, this study reviewed the change of water resources supply and demand relationship in the context of socio-economic development, the progress of reservoir construction, water resources regulation. Secondly, the research progress and problems in the synthetic regulation technique of water resources of the Yangtze River basin have been introduced based on the water diversion project from Yangtze River to Tai Lake basin and the operation of controlled reservoirs such as Danjiangkou Reservoir on the Han River and Three Gorges on the Yangtze. Finally, the scientific, technical and administrative research which should be taken in the further comprehensive water resources regulation has been discussed.

**Keywords:** Yangtze River basin; water resources regulation; reservoir group; multiple target regulation

## Advances in hydro-meteorological forecast under changing environment

LEI Xiaohui, WANG Hao, LIAO Weihong, YANG Mingxiang, GUI Ziling

**Abstract:** With the change of global climate and underlying surface characteristics, and increasing human activities, hydro-meteorological factors such as precipitation, evaporation, and runoff, etc., are directly affected, therefore the assumption of stationarity may no longer exist. In a changing environment, the conventional run-off predicting methods become invalid, which brings challenges to accurate hydro-meteorological forecast. A review of hydro-meteorological forecast research under a changing environment is presented from the aspects of precipitation data fusion, numerical weather forecast, watershed hydrological model, parameterization, data assimilation and ensemble forecast. Much relevant research has been studied, and a lot of achievements have been achieved. The future research on hydrological forecast under changing environment will mainly focus on the following direction: (1) to further improve the accuracy and spatial resolution of precipitation forecast; (2) structure improvement and uncertainty analysis of hydrological models; (3) description methods of hydrological forecast error and reliability.

**Keywords:** Non-stationarity; hydro-meteorological forecast; numerical weather forecast; watershed hydrological model; parameterization; data assimilation; ensemble forecast



## Review on service risk analysis of dam engineering

GU Chongshi, SU Huaizhi, LIU Hezhi

**Abstract:** With the rapid development of dam construction and the continuous improvement of the productivity level, China's dam safety management is transmitting from the traditional engineering safety management to the risk management nowadays. Based on the analysis of the current situation of dam risk analysis and management in China, the research status of dam risk criteria establishment, risk identification, risk assessment and risk treatment was discussed in this paper. In order to perfect the dam risk analysis and management system in China, it should be highlighted in the future to study the dams risk criteria, social and environmental impact caused by dam-break, quantitative model of dam risk identification, dam risk calculation under multiple failure modes, non-probabilistic and time-dependent reliability analysis methods, and the risk analysis methods for dam group system and so on, which may help to ensure the long-term performance of hydraulic structures.

**Keywords:** Dam; service risk; criterion; identification; assessment; treatment

## Research review and perspective of drought mitigation

QU Yanping, LV Juan, SU Zhicheng, SUN Hongquan, MA Miaomiao

**Abstract:** Drought and its disaster occurs frequently throughout the world in recent decades. More and more researchers are aware of the significance of drought mitigation research, and carry out a series of fruitful research. In this paper, the research progress on drought mitigation will be elaborated systematically, mainly focusing on following four aspects, drought assessment, drought forecasting, drought disaster risk assessment and drought disaster management strategy. The future trends and main technical difficulties in the drought mitigation research are also put forward. Drought assessment shows tendencies from single-indicator analysis to comprehensive analysis of multi-indicators, and from single intensity analysis to comprehensive analysis of intensity-time-range. In respect of drought forecast technology development, there is a trend from forecast based on statistical methods to forecast based on a coupled atmospheric-hydrological modeling method. The drought risk assessment presents the transitions from evaluation model based on mathematical methods to evaluation model based on physical mechanism, and from static risk assessment to static and dynamic combined risk assessment.

**Keywords:** Drought mitigation; drought assessment; drought forecasting; drought disaster risk assessment; drought disaster management strategy

## Sediment reduction of warping dams and its timeliness in the Loess Plateau

LIU Xiaoyan, GAO Yunfei, MA Sanbao, DONG Guotao

**Abstract:** The sediment reducing effect of warping dams need to be discussed thoroughly due to the sharp decline of the sediment runoff of the Yellow River in recent years. Based on the observed data, this paper analyzed the relationship between the intercepted sediment quantity of warping dams and the corresponding sediment incoming reduction of the Yellow River, the timeliness of sediment intercept ability, and the erosion reduction function of the warping land. The study results reveal that the intercepted sediment quantity of warping dams is normally larger than or equal to the corresponding sediment incoming reduction of the Yellow River. The higher the basin's vegetation-terrace coverage degree and the coarser the Soil particle size

is, the smaller will be the proportion of sediment incoming reduction to the intercepted sediment quantity. The timeliness of the dams' sediment trapping function is very prominent, once the sediment storage usage limit is reached, a warping dam would lost its sediment trapping capacity. After that, the dam will continuously reduce and control the soil erosion by its warping land. The influence area of warping land in the term of erosion reduction even reaches 4 times of warping land area, if the vegetation-terrace coverage of the basin is rather poor. But with increased vegetation-terrace coverage rate, the erosion reducing quantity of warping lands will be gradually weakened.

**Keywords:** Loess Plateau; warping dams; intercepted sediment quantity; timeliness; warping land; sediment reduction

## Research on parallel dynamic programming based on feasible region search mapping

Jl Changming, MA Haoyu, LI Chuangang, LI Ningning, YU Hongjie

**Abstract:** To overcome the difficulties in selection of the constraint processing mechanism and long calculation time by using the traditional dynamic programming for optimizing reservoir group operation, a mapping model for feasible region search is developed based on knowledge of the set and mapping theory. A parallel dynamic programming algorithm is put forward on the basis of feasible region search mapping. Through construction of the feasible solution search space and a parallel computing mode, this algorithm can avoid the calculation of invalid state combinations and give full play to the power of multi-core computers, thus improving computational efficiency. As an example, the joint scheduling of three reservoirs in Lixianjiang river basin is taken for case study. In terms of annual generated energy, calculation time and other criteria, detailed comparative analysis is conducted over the improved algorithm, the traditional dynamic programming and also progressive optimization algorithm. The results show that the proposed algorithm can reduce computation time while ensuring global convergence of the solutions, which provides scientific reference for making the optimal scheduling strategy of cascade reservoirs.

**Keywords:** Mapping; feasible region; parallel computing; dynamic programming; joint operation

## Study on dynamic evaluation of vibration quality of concrete dam based on real-time monitoring

ZHONG Denghua, SHEN Ziyang, WANG Jiajun, CUI Bo, REN Bingyu, WANG Dong

**Abstract:** The vibration quality evaluation of concrete dam is an important means for the quality control of the concrete dam construction. Traditional method combines artificial experience control with postmortem finite core sampling point detection to control the vibration quality of concrete dam; in addition, the existing vibration monitoring research on vibrator only uses a single rangefinder to range and lacks evaluation method of vibration quality. Taking into account the challenges and difficulties of real-time vibration quality dynamic evaluation and feedback control in concrete dam storehouse, this paper puts forward a real-time monitoring method of the vibration quality of concrete dam considering vibration quality acceptance management based on a ranging scheme with two rangefinders, and establishes a dynamic evaluation model for concrete dam vibration quality considering parameter uncertainty on the basis of this method. The model mainly includes the following contents: (1) conducting quantitative analysis of the uncertainty of concrete characteristic parameters by introducing the "information entropy" theory; (2) proposing the dynamic evaluation method of concrete compression strength based on random forest algorithm in the case of parameter uncertainty,

and the evaluation results are applied to the whole dam storehouse surface vibration quality evaluation. The evaluation model are compared with the models built by multiple linear regression and artificial neural network algorithm, which verifies the consistency and superiority of the random forest model. The dynamic evaluation of the vibrating quality of the abnormal concrete area of a RCC dam project in southwest China is carried out by the evaluation method proposed in this paper. The results show that the method can accurately evaluate the vibration of concrete storehouse surface quality, and it also provides a theoretical basis for the vibration quality control of the concrete dam.

**Keywords:** Concrete dam; vibration quality evaluation; vibration real-time monitoring method; uncertainty; random forest

## Several key questions in the researches of runoff and sediment changes and trend predictions in the Yellow River

HU Chunhong, ZHANG Xiaoming

**Abstract:** The condition of runoff and sediment in Yellow River has greatly changed since mid-1980s. Under the new circumstances, a clear understanding in process, characteristics and the key issues of runoff and sediment changes, is of great importance to focus the key scientific problems and support the ecological civilization constructions in the Yellow River Basin. In this study, the changing process and trend of runoff and sediment in the Yellow River Basin during the period of 1950-2016 were analyzed. Meanwhile, the previous predictions and causes of runoff and sediment were reviewed and analyzed. The results show that the runoff and sediment in the Yellow River declined sharply in recent years, with unsynchronized of magnitude. Both the time duration of runoff and the amount of runoff and sediment, which are good for sediment transport, were reduced. Changes of sediment concentration were synchronized with soil and water conservation engineering. In the previous researches, the soil conservation method, hydrologic method and the physical-based modelling method were adopted in the runoff and sediment predictions. Differences of predictions in different historical period were obvious. Insufficient recognition of mechanism, absence of evaluation technique, and uncertainty of prediction conditions, were the main causes. Under the new circumstances, in order to improve predictions in runoff and sediment in Yellow River, more scientific researches need to be strengthened, including the mechanism of runoff and sediment changes, group effect of the driving factor, the credibility evaluation of runoff and sediment predictions, and management strategy of the Yellow River.

**Keywords:** Mechanism of runoff and sediment change in Yellow River; group effect; trend prediction; assembly assessment; management strategy

## Key techniques of flash flood disaster prevention in China

GUO Liang, DING Liuqian, SUN Dongya, LIU Changjun, HE Bingshun, LIU Ronghua

**Abstract:** In view of natural-social dual stress factors and the existing key technical problems in preventing flash flood disasters in China, this paper illustrates the general idea, technical system and defense modes of flash flood disaster prevention on the basis of innovative theories and studies of rainstorm flood pattern in small basins, analysis and calculation method, monitoring and early warning technologies in flood disasters mitigation in China. Technological breakthroughs and innovative achievements have been made in the characteristics of underlying surface and the rainfall-runoff generation in small watershed, rainstorm flood distribution patterns in ungauged basins, and pilot rainfall-runoff distribution model and distributed model in ungauged basins, early warning index system and risk assessment theory, real-time flash flood disaster forecast and early warning technologies in small watershed, and the national early-warning system.

**Keywords:** Flash flood disasters; flash flood disaster investigation and assessment; monitoring and early warning platform; risk zoning and regionalization; community-based prevention

## Research on ecological impacts of the joint operation of cascade reservoirs in the upstream of the Yellow River

PENG Shaoming, SHANG Wenxiu, WANG Yu, LU Jun, ZHENG Xiaokang

**Abstract:** Aiming to reveal the impacts of the joint operation of cascade reservoirs on riverine ecosystems, this study adopts Indicators of Hydrologic Alteration (IHA) to analyze hydrologic alterations in the upstream of the Yellow River in different reservoir operation periods which is based on long-term measured flow data. A multi-series contribution rate division method is developed to quantify the influences of different factors. Sediment transport rate method and cross-section deposition patterns analysis are used to show the erosion and deposition in the upstream of the Yellow River using long-term measured sediment data. The results show that reservoir operation has significant ecological impacts on both runoff and sediment transport which have been altered dramatically. The runoff has become steadier after reservoir operation: the monthly average flow has increased in the non-flood season while decreased in the flood season; the frequency and magnitude of high flow events has declined. Moreover, sediment deposition has become more and more serious in the Ningxia-Inner Mongolia reach. Besides, the typical cross-section has become wider and shallower. This study proves that reservoir operation is the most important cause of the hydrologic alterations in Lanzhou, and it is also an important cause in Shizuishan and Toudaoguai. It is revealed that the decrease of high flow events has aggravated the channel sedimentation, which can impose negative ecological impacts on this river. For better conservation of river health, it is necessary for reservoirs in the upstream of the Yellow River to adopt ecological operation, increasing water release in the rising-water season and flood season and creating high flow events. This study provides important information to the ecological impacts assessment of the joint operation of cascade reservoirs and the ecological operation of cascade reservoirs.

**Keywords:** Cascade reservoirs; flow regime; erosion and sedimentation; contribution rate; ecological operation



# Annual Report



CHINA INSTITUTE OF WATER RESOURCES AND  
HYDROPOWER RESEARCH

## Management Achievement

Highlights of 2019	56
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The Tianhuangping Hydropower Station in Southern China

# Highlights of 2019

1

IWHR was identified as one of China's top 30 research institutions in scientific innovation in 2019, with one national prize – the Grand Prize of the National Science and Technology Progress Award given to the Three Gorges Project in which IWHR has engaged for engineering research and consultancy.

2

IWHR hit another record high in 2019 in total amount of research programs, with over 1,800 new programs signed, 56 of which are international programs. The newly signed contracts worth a total of CNY 1.715 billion (USD 246.43 million), up by 10% comparing to 2018.

3

IWHR won the bid for the 4th World Irrigation Forum (2022), one of the world's most influential irrigation and drainage events, announced during the 70th International Executive Council Meeting of the International Commission on Irrigation and Drainage (ICID) in September 2019.

4

IWHR had more experts taking high ranking positions in water-related international organizations, with one being elected as the new president of World Association of Soil and Water Conservation (WASWAC), one chairing the Committee of Engineering and Innovative Technologies of the World Federation of Engineering Organizations (WFEO), one elected as the new president of Asian River Restoration Network (ARRN), and one chairing the Special Committee of Water and Climate Change of Asia Water Council (AWC).

5

IWHR made a landmark breakthrough in international student enrollment in 2019, admitting two international Ph.D. students for the first time in our history. Meanwhile, the number of graduates pursuing degree at IWHR exceeded 300, reaching a record high.

6

IWHR deeply engaged in the strategic research and technological prediction of China's "Fourteenth Five-Year" Plan, the 2021-2035 Medium and Long-Term Science and Technology Development Plan, as well as other key special projects regarding national water security, major water-related disasters and localization of key technologies and facilities.

7

IWHR made remarkable progress in developing its research platforms, receiving three "Excellent" rating in the examination of labs and research platforms conducted by the Ministry of Water Resources (MWR) of China. The field station to observe desert-grassland ecology and hydrology in Inner Mongolia was recognized as one of the first "MWR field observation and research stations".

8

IWHR passed the strict examination and was successfully recognized as a Water-Saving Public Institute in the water industry. The evaluation campaign started in 2019 in the water sector, aiming to encourage water saving behaviors in government departments and agencies.

9

IWHR launched its brand-new online office system, integrating and upgrading the previously applied systems respectively for official documents, international affairs, news, and IWHR corporations, etc. The new system will effectively facilitate the application of information technology and highly improve work efficiency while better protecting data security.

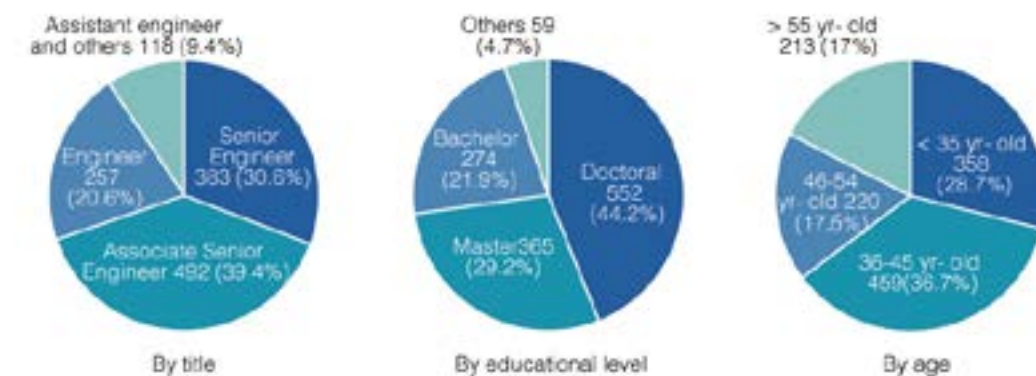
10

IWHR officially launched the "IWHR Eminent Scholar" Program, which aims to deepen international exchanges, embrace water wisdom and strengthen our talent team. Dr. Joseph H.W. Lee, Professor of Hong Kong University of Science and Technology was acknowledged as the first IWHR Eminent Scholar in 2019. He was elected in the same year as the new President of the International Association for Hydro-Environment Engineering and Research (IAHR).

# Statistics

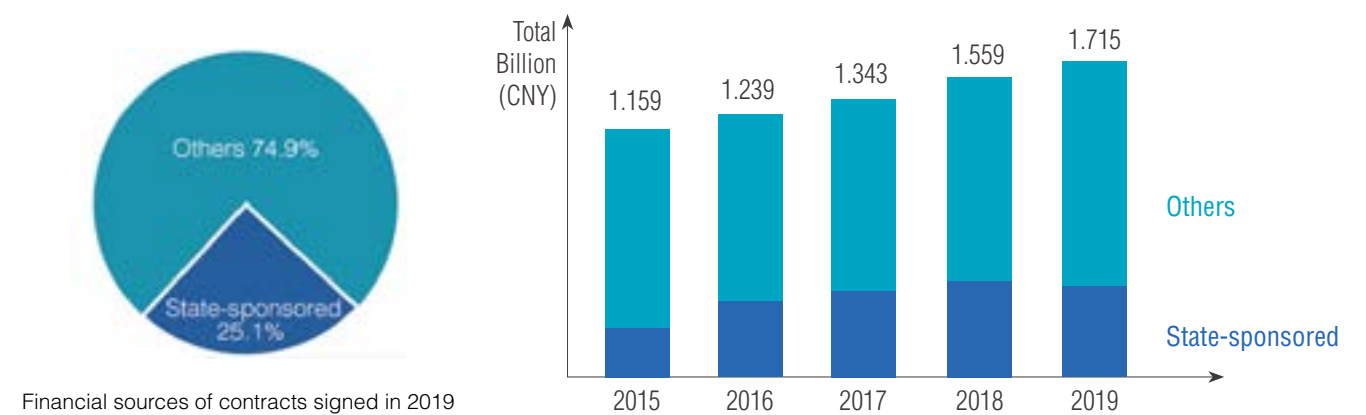
## Human resources

By the end of 2019, IWHR has 1250 technical professionals.



## Research Contracts

Research contracts signed in 2019: CNY 1.715 billion in value.





Awards

In 2019, one research project was granted with state level prize and 41 with provincial/ministerial level prizes.

Type	Amount	Grade
State level	1	Special prize (1)
Provincial (ministerial) level	41	Special prize (5)
		First prize (14)
		Second prize (17)

Some of the prized researches:




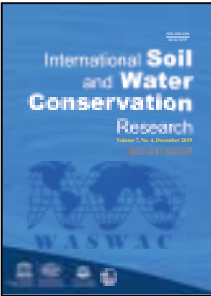

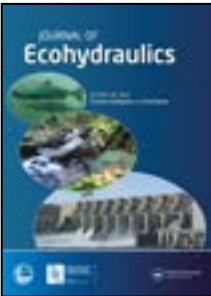
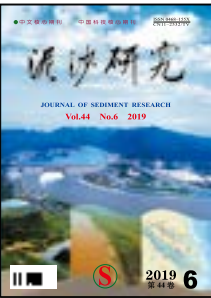

- The Three Gorges Project
- Key Technologies for Seismic Safety of High Concrete Dam in High Seismic Area in Western China and Their Application
- Key Technology of Emergency Handling and Comprehensive Treatment of Barrier Dam
- Key Technologies for Three Gorges Dam Concrete and Their Application
- Key Technology of Sediment Design for Water Complex on Sediment-laden River and Its Application
- Research and Application of the Evaluation Models and Methods for Major Natural Disasters
- All-round Monitoring of Water Circulation and Efficient and Ecological Control of Water Use in Hetao Irrigation Area
- Comprehensive Utilization of Water Resources and Irrigation Area Planning in Ahawan Water Economic Zone of Laos
- Theory and Key Technology for the New Type of Damming with Cement Sand and Gravel (CSG)
- Technology for Evaluation of National Irrigation Efficiency and Its Application
- Study on Water Circulation Mechanism and Key Technologies for Comprehensive Utilization of Water Resources in Coal Mine Subsidence Area of Huainan and Huaibei Cities
- Key Technology for Remote Sensing Monitoring of Eco-hydrologic Situation in Yellow River Basin
- Key Technologies of All-weather Multi-source Remote Sensing Monitoring for Soil Moisture in Large Regions and Their Application
- Key Technology for Smart Construction of RCC Dam in High Cold Area
- Study on Mechanism of Ice Jam Evolution and Transport and Hydraulic Regulation Technology in Long Distance Conveyance Channel
- Research and Application of Water-saving Irrigation Technique to Fourty Million Mu Farmland and Forage Grassland in Inner Mongolia
- Research and Application of Key Technologies for Comprehensive Treatment in the Downstream Channel of the Yellow River
- Key Technology for Flood Discharge and Energy Dissipation and Atomization Reduction at Jinping I Super High Arch Dam
- Innovation in Key Technologies for Sand Control with Biodegradable Sand Barrier and Their Application in Vegetation Restoration
- Key Technologies for Operation of Multi-source Multi-objective Complex Raw Water Diversion System and Their Application
- Research and Application of Drainage and Salt Control Technology in Farmland of Northwest China
- Planning Method and Practice of Modernization of Medium-sized Irrigation Areas in Southwest China
- Key Technologies and Their Demonstration Regarding Soil Erosion Mechanism and Landscape Configuration for Ecological Restoration in Semi-arid Loess Region
- Water Consumption of Forage Crop and Integrated Technologies for Water-saving and Yield Increase in Typical Areas of Tibet

Intellectual Properties

IWHR obtains 285 patents in 2019 (including 191 inventions and 94 utility models), including four new international patents, participates in the editing of 21 technical codes, and also publishes 59 books and 677 papers.

	Patents		Technical codes		Books	Papers
	Inventions	Utility models	Chief edited	Co-edited		
Amount	191	94	12	9	59	677

Journals

	<i>Journal of Hydraulic Engineering</i>		<i>Journal of China Institute of Water Resources and Hydropower Research</i>
	<i>International Journal of Sediment Research</i>		<i>International Soil and Water Conservation Research</i>
	<i>China Flood and Drought Management</i>		<i>Journal of Ecohydraulics</i>
	<i>Journal of Sediment Research</i>		<i>Mechanical &amp; Electrical Technique of Hydropower Station</i>

# International Cooperation

## International Exchanges



IAHR Executive members visited IWHR and convened executive committee meeting



WASWAC President led a delegation to IWHR Department of Water Resources for Pastoral Areas for technical exchanges



GWP new president visited IWHR and lectured at the IWHR Global Vision Forum



Bolivia's Ambassador to China visited IWHR on World Water Day



Experts from University of Evora, Portugal joined IWHR experts in discussing collaborations on water-shed cooperation for water ecology



IWHR delegation visited the Ministry of Water, Land and Natural Resources of Malaysia



IWHR took part in the 23rd dialogue meeting among China, Myanmar and Mekong River Commission



IWHR attended the 3rd World Irrigation Forum and won the bid for the 4th Forum



IWHR voted at the ICOLD executive committee meeting on behalf of China



IWHR delegation discussed student enrollment and staff recruitment with President of University of Maryland Center for Environmental Science



IWHR Vice President Dr. WANG Jianhua attended the 2019 annual meeting of the China-U.S. Technology Alliance on Energy and Water



Research and expert training on comprehensive simulation, management and evaluation of watershed river system



IWHR Vice President Dr. PENG Jing hosted the meeting of WFEO Committee on Engineering for Innovative Technologies



IWHR attended the second meeting of the China-Denmark Joint Steering Committee on Sustainable Water Resources Management



Professor Joseph H.W. Lee from Hong Kong University of Science and Technology was recognized as the first IWHR Eminent Scholar

## Partnership with Cooperative Agreements



## 2019 IWHR Global Connections





# Annual Report



CHINA INSTITUTE OF WATER RESOURCES AND  
HYDROPOWER RESEARCH

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The Waterway Project at the  
estuary of the Huaihe River



# Organizational Structure

## President and Vice Presidents

Commissions	<ul style="list-style-type: none"><li>Academic Commission</li><li>Board of Professional Title Assessment</li></ul>	<ul style="list-style-type: none"><li>Board of Academic Degree Assessment</li></ul>
Administrative Divisions	<ul style="list-style-type: none"><li>General Office</li><li>Division of Personnel, Labor and Education</li><li>Division of Research, Management and Planning</li></ul>	<ul style="list-style-type: none"><li>Division of International Cooperation</li><li>Division of Finance and Assets Administration</li><li>Division of Supervision and Audit Planning</li></ul>
Research Departments	<ul style="list-style-type: none"><li>Department of Water Resources</li><li>Research Center on Flood and Drought Disaster Reduction (including the Remote Sensing Technology Application Research Center and the Department of Water Resources History)</li><li>Department of Water Ecology and Environment Research</li><li>Department of Irrigation and Drainage</li></ul>	<ul style="list-style-type: none"><li>Earthquake Engineering Research Center</li><li>Department of Geotechnical Engineering</li><li>Research Center for Sustainable Hydropower Development (including the Department of Structures and Materials)</li><li>Department of Sediment Research</li><li>Department of Hydraulics</li><li>Department of Water Resources for Pastoral Areas</li></ul>
Division of Comprehensive Business	<ul style="list-style-type: none"><li>Graduate School</li><li>Standardization Research Center</li></ul>	<ul style="list-style-type: none"><li>Information Center</li></ul>
Enterprises	<ul style="list-style-type: none"><li>Beijing IWHR Corporation</li><li>Beijing IWHR Technology Co., Ltd.</li><li>Beijing IWHR-KHL Co., Ltd.</li></ul>	<ul style="list-style-type: none"><li>Tianjin Institute of Hydroelectric and Power Research</li><li>Beijing Zhongshui Runke Certification Co., Ltd.</li></ul>
Secretariats of International Organizations	<ul style="list-style-type: none"><li>World Association for Sedimentation and Erosion Research (WASER)</li><li>World Association of Soil and Water Conservation (WASWAC)</li><li>Chinese National Committee on Large Dams (CHINCOLD)</li><li>Chinese National Committee on Irrigation and Drainage (CNCID)</li></ul>	<ul style="list-style-type: none"><li>International Association for Hydro-Environment Engineering and Research (IAHR)</li><li>Global Water Partnership (GWP) China</li><li>China Office of International Hydropower Association (IHA)</li><li>International Conference on Flood Management (ICFM)</li><li>China River Restoration Network (CRRN)</li></ul>

# Research Divisions

## Department of Water Resources

Fundamental and applied research on the theories and applications in hydrology and water resources, including the fundamental theories and simulative technologies of water cycle, the assessment, planning, allocation, saving, regulation, management, protection and macro-strategy research of water resources, and the consulting and international cooperation in related fields.

## Research Center on Flood and Drought Disaster Reduction (incl. the Remote Sensing Technology Application Research Center and the Department of Water Resources History)

Research on key issues of flood control, drought relief and disaster reduction, including disaster formation mechanism, forecasting and warning, risk assessment, management and rescue technology of risk and emergency, application of remote sensing and other high-technologies, water resources history and water culture.

## Department of Water Ecology and Environment Research

Evolution mechanisms and simulation technologies of water environment and ecology; methods and standards of assessment and monitoring, as well as protection and recovery technologies of water environment; guarantee technologies of drinking water safety; environmental impact assessment of projects; theories and information technologies of water environment management.

## Department of Irrigation and Drainage

Strategies, planning and related standards of water resources development in rural areas; water-efficiency irrigation and management technologies of farmland water and soil environment; research, equipment development, transfer, promotion and application of water supply technologies in rural areas; quality inspection and product certification of equipment.

## Earthquake Engineering Research Center

Theories and analysis method of earthquake engineering; the arch dam and gravity dam seismic research; dynamic test of structures and equipment; monitoring and forecasting of reservoir earthquake; anti-earthquake analysis and safety assessment of electrical and nuclear power equipment.

## Department of Geotechnical Engineering

Property study of geotechnical materials; behavior simulation, safety assessment and centrifugal testing of geotechnical structures such as embankment dams, high slopes and underground tunnels and chambers.

## Department of Structures and Materials

Temperature stress and control of hydraulic structures; numerical, visual and digital simulation of projects; safety monitoring and inspection; anti-seepage, repair and reinforcement of projects.

## Department of Sediment Research

River channel evolution and improvement; reservoir sedimentation and regulation; conservation and control of water and soil; sediment issues in estuary, coastal and hydraulic projects; prevention and control of sediment disasters; fundamental theories and simulation technologies of sediment movement.

## Department of Hydraulics

Hydraulics of high-velocity flow, flow-induced vibration and project layout; hydraulic control and ice dynamics; cooling water and cooling tower research for thermal and nuclear power projects; river and ecological hydraulics; hydraulic prototype observation and equipment development.

## Research Center for Sustainable Hydropower Development

Strategies, policies, planning and key technologies of sustainable hydropower development, including the theories, methods and assessment system of hydropower sustainability (green hydropower); strategic planning of hydropower development; ecological protection and reservoir resettlement policies of hydropower projects.

## Department of Water Resources for Pastoral Areas

Water resources and water environment for pastoral areas; water-efficiency irrigation and drainage, conservation of water and soil, and ecological recovery of grasslands; clean energy development and utilization, as well as water supply equipment, for pastoral areas.



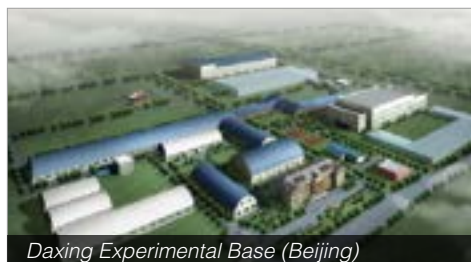
## Scientific Research Bases



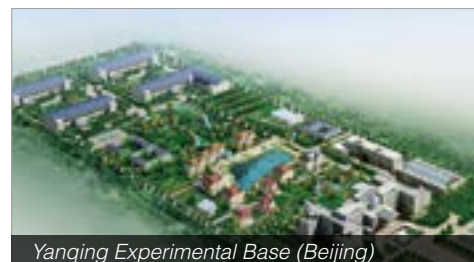
Technology Innovation Base (South, Beijing)



Technology Innovation Base (North, Beijing)



Daxing Experimental Base (Beijing)



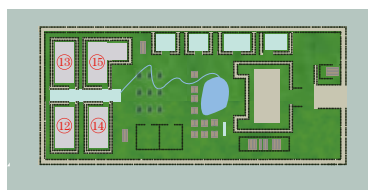
Yanqing Experimental Base (Beijing)

Base of Water Resources for Pastoral Areas  
(Inner Mongolia)Tianjin Institute of Hydroelectric and Power  
Research (Tianjin)

Laboratories in Daxing and Yanqing bases include:



Daxing Experimental Base



Yanqing Experimental Base

- (1) Laboratory of Water Cycle and Deployment
- (2) Laboratory of Water-Sediment Regulation and River Training
- (3) Laboratory of Soil and Water Conservation
- (4) Laboratory of Fundamental Theoretical Research on Sediment Transport
- (5) Laboratory of Hydraulics
- (6) National Center for Efficient Irrigation Engineering and Technology Research - Beijing
- (7) Laboratory of Rural Drinking Water Safety, NCEIR
- (8) National Center for Quality Supervision and Test of Agricultural Irrigation and Drainage Equipment
- (9) Laboratory of Hydraulic Regulation
- (10) Laboratory of River Environment
- (11) Hydraulic Machinery Laboratory
- (12) Laboratory of Automatic Control and Simulation
- (13) Laboratory of Quality Inspection and Simulation for Speed Governing System of Small Hydro
- (14) Integrated Laboratory of Engineering Technology on Water Resources and Soil-Water Conservation
- (15) Integrated Laboratory of Engineering Mechanics

## Large Equipment

Vacuum tank (vacuum percentage  
98.7%; flow discharge 1.0 m³/s)Universal test stand of advanced  
hydraulic machinery model

LXJ-4-450g-t geotechnical centrifuge

Tri-axial earthquake simulating shaking  
table with 6 degrees of freedom

15000 KN universal testing machine

Creep testing system for fully-graded  
concrete

Hydraulic flume and water tank



Eddy covariance system



Multi-functional GC-MS machine



# Application Brochure for International Students

## Graduate Education

IWHR started its graduate education in the 1950s and has excellent research facilities and equipment, a large number of cutting-edge research projects, adequate research funding, numerous literature resources, and a top-notch team of graduate supervisors (175 master's supervisors and 91 doctoral ones). After more than six decades of exploration and development, IWHR has established a complete and unique system of graduate education.



## Degree Programs in English

Eight programs for master's degree and doctoral degree:

- Geotechnical engineering
- Hydrology and water resources
- Hydraulics and river dynamics
- Hydraulic structure engineering
- Hydraulic and hydropower engineering
- Hydro-environment
- Hydro-informatics
- Water disaster and security

The applicants must satisfy one of the following language requirements:

- Graduates from universities of English-speaking countries;
- Graduates from universities where English is the official language;
- TOEFL: 68 (internet-based test)/ IELTS: 5.5.

Duration of study:

- Three years for both the master's degree and doctoral degree.

## Fees

- Application Fee: Free in 2020
- Annual Tuition: 26,000 - 39,000 CNY
- Annual Accommodation: 12,000 - 24,000 CNY
- Annual Insurance: 800 CNY

## Scholarships

### IWHR outstanding international student scholarship

In 2019, scholarships of up to 93,800 CNY per year are available for outstanding applicants, including all or part of the following items:

- Waiver of the fees of tuition, accommodation and medical insurance;
- Living stipend of up to 42,000 CNY per person per year.

## How to Apply

### General information

- Application is open only to non-Chinese citizens who are in good health.
- Educational background and age limit.
- The applicant for a master's program must be under the age of 35 and has a bachelor's degree.
- The applicant for a doctoral program must be under the age of 40 and has a master's degree.

### Application Methods

- Email to [iwhrgraduateoffice@163.com](mailto:iwhrgraduateoffice@163.com).
- Post or submit in person application documents to the Office of International Student Affairs of IWHR Graduate School.

### Required application documents

- See details at <http://www.iwahr.com/IWHR-English/index.htm>.







## History

BIC was a wholly-owned subsidiary of China Institute of Water Resources and Hydropower Research (IWHR) with a registered capital of 2 million RMB in 1992. The capital was increased to 60 million RMB in 2014. After years of development, the company now has six departments, one branch company and three holding companies. The business of the company mainly includes technical product development, projects contracting and sales.



Begin



Development



Going Global

## Main Business

- Engineering Design Research
- Safety Monitoring
- Testing and Evaluation & Anti-seepage
- Consolidation of Special Foundation
- Engineering Safety Information

### Beijing IWHR Corporation

Address: 20 Chegongzhuang west Road, Beijing, 100048

E-mail: [weixi@iwhr.com](mailto:weixi@iwhr.com)

Website: <http://www.bic-iwahr.cn/>



## Main Product

### Hydraulic Elevator Dam

This type of dam provides a solution to a series of technical problems such as safe discharge, operation in winter, operation simplicity, flotage, sedimentation, pier for dam, project cost, ground settlement and harmony with landscape. All these problems are frequently encountered in projects such as steel gates, flap gates, pneumatic gates and rubber dams.

It is widely used in water resources and hydropower projects for irrigation, reservoir capacity expansion and tide blocking.

Hydraulic Elevator Dam technology has obtained more than 20 patents for invention, and is recognized by China State Intellectual Property Office as a Model for Application and Demonstration.

This technology has been widely used in China and other countries in Southeast Asia, including Myanmar, Thailand and Bangladesh. Dozens of projects have been completed. The highest one is 5m, which is located Guizhou Province and used for increasing the water head for hydropower generation.

The longest one is 261m, which is located in Myanmar and used for irrigation. In Jilin Province in North China, there are six sets of HED along the Mudan River, which are serving as a cascade project to improve the landscape of the city.

### Main Product: Containerized Water Treatment Plant

Consultation, Engineering and Construction For:

- Municipal Sewage Treatment
- Water Supply Projects
- Water Treatment for Safe Drinking







*Gullubag Hydropower Plant in Turkey*



*Generator Floor of Gullubag Hydropower Plant in Turkey*



*Generator Floor of Kozbuku Hydropower Plant in Turkey*



*Kozbuku Hydropower Plant in Turkey*



## Beijing IWHR Technology Co., Ltd.

### History and Business Scope

Beijing IWHR Technology Co., Ltd. is an advanced and new technology enterprise, founded on Dec. 23rd, 2004, a joint venture between China Institute of Water Resources and Hydropower Research (IWHR) and China Three Gorges Corporation (CTGC). The company is formed on the basis of the original Department of Automation and Department of Hydraulic Machinery of IWHR, and the staff are the optimum composition of all technical and the management backbones.

By the end of December 2018, the number of employees in the company had reached 281, including 94 with master's degree or higher ones, 144 with bachelor degree. There are 31 professor-level engineers, 55 senior engineers and 54 engineers. One of the staff is entitled to the Special Allowance of the State Council of China and another one enlisted by the New Century Talents Project of the country.

The company's primary business are the research and development of technologies and manufacturing of facilities for computer monitoring and the centralized control of water resources, hydropower and renewable energy projects, including turbine governor, auxiliary control system, hydrological monitoring and forecasting system, reservoir dispatching automation, information application system, hydraulic machinery and electro-mechanical equipment, generation unit operation support, hydro-mechanical experimentation as well as system integration, EPC (Engineering, Procurement, Construction) and related consultancy and services.



*President Xi Jinping Listened to the Report in front of the H9000 System Monitor at the Control Center of the Three Gorges Hydropower Station*



*Vice Premier Wang Yang Investigated at the Laboratory of Computer Monitoring System*



*The Cascade Dispatching Center Controlling the Three Gorges, Chengdu City and Jinsha River*



*Meteorological Telemetry Station for Rainfall and Water Level in Yalong River Basin*



*Model Unit and Model Runner of Hydraulic Turbine*



*Test Bench for Hydraulic Mechanical Model*



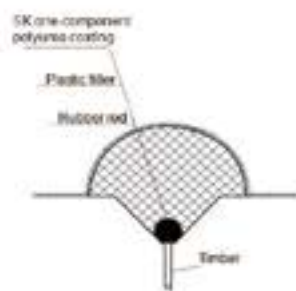
## Company Introduction

The Beijing IWHR-KHL Co., Ltd. (IWHR-KHL) was founded in 1993 as a technology-oriented enterprise. With the technical support of IWHR, the Company has developed the GB waterstop structure and the brush-coated flexible waterstop structure as well as a series of GB waterstop materials, which have been successfully applied in more than 100 concrete faced rockfill dams (CFRDs) in the world, such as Shuibuya, Zipingpu, and Liyuan in China, Bakun in Malaysia, Nam Nugm II in Laos, Mazar in Ecuador, Gelevar in Iran, Merowe in Sudan, Glendoe in Scotland.

### Typical Waterstop Structures for CFRDs



Mechanized Installation of GB Waterstop Materials



Extrusion Molding of GB Plastic Filler

### Typical GB Waterstop Materials



GB Plastic Filler



GB EPDM Composite Cover



Corrugated Rubber Waterstop

### Integrated construction technology for GB waterstop materials



Mechanized Installation of GB Waterstop Materials



Extrusion Molding of GB Plastic Filler



### Applications of GB waterstop materials at Typical CFRDs

**1** Shuibuya CFRD of 233m high is the highest CFRD in the world. The total leakage is less than 60L/s.

**2** Bakun CFRD of 203.5m high is the highest CFRD in Southeast Asia. The total leakage is less than 80L/s.

**3** Zipingpu CFRD of 156m high has successfully withstood the 2008 Wenchuan Earthquake (Ms=8.0). The total leakage after the earthquake is less than 50L/s.

**4** Liyuan CFRD of 155m high is the first one to use in large scale brush-coated flexible waterstop in the world. The total leakage is less than 30L/s.



## Introduction and Business Scopes

Tianjin Institute of Hydroelectric and Power Research was built in 1979. In 2002, according to the requirements of the reform of the national science and technology system, it was placed under the administration of China Institute of Water Resources and Hydropower Research (IWHR).

Main Business are as follows:

- High efficiency hydraulic machinery (pump) technology
- Intelligent pump and energy-saving technology
- Intelligent sensor based on IoT (Internet of things) of water conservancy
- Automation components and equipment
- Automation control system
- Network security protection technology of industrial control systems
- Inspection and evaluation of power transmission and distribution equipment, hydraulic mechanical, electrical and metal structure equipment
- Equipment and techniques for disaster prevention and rescue



泵站高效节能数字化专业实验室

High Efficiency and Energy Saving Laboratory of Pump

High Efficiency and Energy Saving Laboratory of Pump



工控系统网络安全攻防对抗展示平台

Network Security Attack and Defense Confrontation Display Platform of Industrial Control Systems



电力传输与配电设备检测与评估

Inspection and Evaluation of Power Transmission and Distribution Equipment









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# IWHR

CHINA INSTITUTE OF WATER RESOURCES  
AND HYDROPOWER RESEARCH