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SUSTAINABLE URBAN STORMWATER MANAGEMENT AND SPONGE CITIES

EDITORIAL BY ANGELOS N. FINDIKAKIS

Conventional stormwater management in urban areas is based on the principle of draining all runoff by collecting it and directing it through a network of conduits and detention and temporary storage facilities to a central system for discharge into a nearby river, lake or the sea. As cities grow rapidly, the cost of the required infrastructure for the conventional approach to stormwater management has been rising. In addition, in many cases this approach has undesirable environmental impacts and it is unable to provide adequate protection from flooding. In response to growing economic and environmental concerns, alternatives to conventional stormwater management have emerged over the last thirty years aiming at minimizing the dependence on infrastructure by mimicking natural features. Such alternatives are based on the concept of managing rainfall close to where it falls, by replicating local hydrologic processes that existed prior to urbanization, facilitating infiltration to recharge local aquifers, and improving flow and water quality conditions in nearby streams. Emphasis is placed on small-scale, low-cost, decentralized measures as opposed to the high-cost, large-scale infrastructure required for conventional urban stormwater management. Examples are bioretention areas, pervious pavements, green roofs, water harvesting, vegetated swales and other landscape features. The underlying philosophy of these measures and techniques is known as Low Impact Development (LID). The term Green Infrastructure (GI) is also used in conjunction with the approach to water management that mimics the natural water cycle, focusing on actions that enhance landscape features such as wetlands restoration and tree planting. The LID principles, whose development started with the introduction of the bioretention technology in Maryland about thirty years ago, have now been adapted in many parts of the world. For example, in the United States the Environmental Protection Agency has been providing guidance used by many cities and counties to develop and implement their own LID programs. In the United Kingdom, the Construction Industry Research and Information Association (CIRIA) published the Sustainable Drainage Systems (SuDS) manual, which describes the new philosophy and approach to managing surface runoff and provides technical details and guidance for their implementation.

Angelos N. Findikakis
Hydrolink Editor

The largest scale program for the application of LID principles is the "sponge city" initiative launched in China in 2013 aimed at providing financial support and other incentives to cities to incorporate these principles in their approach to stormwater management. The use of the term "sponge cities" emphasizes the idea that a key element of the new approach to stormwater management is maximizing water retention and infiltration, with urban areas acting essentially as sponges. In 2015 the Chinese government selected 16 cities for the first phase and another 14 for the second phase of a pilot program, during which local authorities and agencies will be testing and exploring ways for dealing with the challenges posed by introducing a totally new way of thinking about stormwater. Issues that must be dealt with include the inertia of the conventional approach to stormwater management, the coordination of the work of the many parties involved in the program, securing financing for the required projects, and capacity building for adapting the program in cities under different climatic conditions. The article by Jia, Wang and Yu in this issue of Hydrolink presents an overview of the sponge city program in China and provides recommendations for its successful implementation on the way forward.

One of the first pilot sponge cities is Xiamen on the southeast coast of China. The article by Liu, Xiang, Shao, and Luan describes the initial implementation of the program in Xiamen, which includes the use of LID methods to control surface runoff with the goal of accommodating 70 percent of the rainfall in the city, measures to increase the storage capacity of the local river-lake system, control pollution sources, improve the local aquatic environment; and the construction of infrastructure to prevent urban flooding and waterlogging. To address water pollution, which is a major problem in the city, Xiamen is exploring innovative solutions such as the use of distributed wastewater treatment facilities and ecological improvements in drainage channels.

Many of the technical and institutional issues that affect the application of the sponge city concept have been identified and are being addressed in other parts of the world. An example is the research at the Grupo de Enxeñería do Auga e do Medio Ambiente (GEAMA) of the University of A Coruña in support of Water Sensitive Urban Design (WSUD) applications in different cities of Spain, as explained in the article by Puertas, Anta, and Suárez. The problems associated with the poor coordination between multiple agencies often involved in stormwater management and the resistance to the implementation of non-structural measures and land use regulation needed for integrated flood management are discussed in the article by Paoli. The same article then describes the steps taken to overcome these barriers in the city of Santa Fe, Argentina, which had experienced catastrophic flooding in the past.

International collaboration and knowledge sharing contributes to the advancement of sustainable urban stormwater management. Special meetings such as the International Low Impact Development Conference in Beijing earlier this year provide a forum for the exchange of ideas in this field. In addition, special bilateral agreements facilitate technology transfer between countries facing similar problems. An example is the recent collaboration agreement between China and the Netherlands for further development of the sponge city concept. The Dutch living in a severely flood-prone area have developed over the years elaborate water management systems for low-lying lands, a good part of which in the western part of the country have been developed into a large metropolitan urban area. The article by Mynett and Zevenbergen discusses how the two countries are planning to work together on integrated urban water management issues.

As more experience is gained on the application of the LID/GI principles and the number of cases demonstrating their effectiveness in providing flood protection and improving environmental quality grows, more cities around the world are expected to embrace them. International organizations and associations, like IAHR, have a role to play in facilitating the exchange of ideas for finding innovative and creative ways to overcome the many challenges associated with making the concept of sponge cities a reality.

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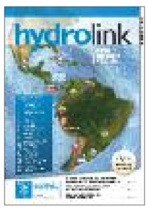

ERRATUM

The cover of issue 3 included the flag of Nicaragua instead the flag of Argentina.

Nicaragua

Argentina

OPPORTUNITY AND CHALLENGE, CHINA'S SPONGE CITY PLAN

BY HAIFENG JIA, ZHENG WANG & SHAW L. YU

Over the past decade China's urban population has grown to 52.4 percent in 2015 from 42.5 percent in 2005, and the build-up areas have increased by 17,252 km^2. This roughly equates to an addition of 165 million people dwelling in urban areas in a decade, which is extraordinary! This rapid urbanization process, sometimes lacking adequate planning and design, has led to a worsening "city syndrome" situation such as urban flooding, water pollution, heat-island effects and ecologic deterioration, etc.

The National New Urbanization Plan (2014-2020), released in 2014 by Chinese Central government, sets a target for China's urban population to rise by 1% per year to reach 60% by Year 2020. Such an ambitious plan presents great challenges to leaders of all levels of government in terms of avoiding city syndromes and achieving a sustainable urban development process.

The Ambitious "Sponge City" Initiative

In order to promote a sustainable urbanization strategy, the Chinese government announced a new urban drainage infrastructure building paradigm, branding it "Sponge City" (SC) initiative, in 2013. Deviating from the traditional "rapid-draining" approach, the new paradigm calls for the use of natural systems such as soil and vegetation as part of the urban runoff control strategy. The "six-word" principle, which includes "infiltrate, detain, store, cleanse, use and drain", forms basis of the guidelines for urban stormwater management.

In October 2014 the China Ministry of Housing and Urban-Rural Construction (MHURC) issued a draft technical manual on Sponge City construction. In October 2015 the State Council of China announced a major expansion of the SC Initiative, which is being implemented nationwide. Recognizing the limitation of Low Impact Development (LID) / Green Infrastructure (GI) facilities in controlling large or less frequent storm events, the government mandates the integration of green and gray infrastructure. The expanded SC Plan includes as its goals not only effective urban flood control, but also rainwater harvest, water quality improvement and ecological restoration. The use of LID/GI practices will be required for all new development and retrofit sites, science and commercial parks, green spaces, non-mechanical vehicle roads, pedestrian walkways, etc.

During 2015 and 2016, the China Ministry of Finance (MOF), with support from MHURC and the Ministry of Water Resources (MWR), selected 30 cities (see figure 1 for the locations of these pilot cities), among more than five hundred applicants, as pilot sites under the Sponge City Plan. Each city is to receive 400 to 600 million RMB (1 RMB ~ 0.15 $US) annually from the central government for three years, with the total investment estimated to be about 42.3 billion RMB. Local matching is required and public-private partnerships (PPP) are encouraged. Cities will receive a 10% bonus from the central government if the PPP contribution exceeds a certain percentage of the overall budget. According to preliminary estimates, the total investment on the Sponge City Plan is roughly 100 to 150 million RMB average per square kilometer or 10 Trillion RMB for 657 cities nationwide.

China's SC Initiative has attracted the attention of experts, officers and publics all over the world. This was made clear by the success of the "2016 International Low Impact Development Conference" at the end of June in Beijing, which attracted more than 1200 delegates from over 20 countries. During the conference, a declaration, "The Beijing Consensus: Low Impact Development for Urban Stormwater Management", was issued.

Figure 1. Location of the Pilot Sponge Cities

China's SC Initiative represents an enormous and unprecedented undertaking by the government for achieving urban sustainability. MHURC officials recognize that the success of the SC will require a combined and coordinated effort by many government agencies in areas such as landscape/architectural planning, construction, municipal, water, transportation, finance, environmental protection and input from other stakeholders. To finance all the sponge city projects is a real challenge. The government has listed some innovative strategies for fund-raising, which includes, in addition to government grants and subsidies, local matching and public-private partnerships. The government is also encouraging participation by financial institutions, and will allow qualified entities to issue construction bonds to finance the sponge city projects.

Challenges for the SC Plan Implementation

Significant challenges lie ahead for the SC Plan implementation. A few important ones are discussed below:

Inertia of Traditional Approaches and Measure of Success for Local Officials

First, in contrast to the traditional urban construction philosophy in China, i.e., the age-old notion of man can conquer nature, the basic concept of the SC approach is living with nature and making use of nature's abilities. Although the Central Government has mandated the SC construction and has issued technical guidelines, some provincial and local government officials are slow to act due to inertia of traditions. So far, the financial assistance does provide incentives for action. Also, the current criteria for local officials' performance evaluation does not include SC implementation. If the promotional evaluation process could be modified to include results of SC implementation, local officials would be much more committed to its success.

Inter-agency Coordination at Local Levels

Currently, there is close coordination among the key agencies responsible for implementing the SC Initiative at the ministry level, i.e., MHURC, MOF and MWR. However, at the local, or sponge city level, often many agencies are involved, such as the urban planning, construction, water conservancy, and environment protection bureaus, etc. A smooth and efficient SC implementation requires a great effort and time for inter-agency coordination. To facilitate such efforts, some SC pilot cities have created the "Sponge City Offices", which include representation from all bureaus related to urban water.

Inadequate Investment and Return Estimates

China's sponge city initiative represents an enormous and unprecedented undertaking by the government for achieving urban sustainability. In the era of budgetary constraints and competing needs, how to finance all the sponge city projects is a real challenge. The government has listed some innovative strategies for fund-raising, which includes, in addition to government grants and subsidies, local matching and public-private partnerships.

Figure 2. The 2016 International Low Impact Development Conference

Haifeng Jia **conducted his research and teaching in the fields of watershed / urban water environmental planning and management, water quality and hydrologic modelling, urban runoff control and LID BMPs, and Environmental Remote Sensing and GIS. He has finished 100 research projects. He has published more 200 peer-reviewed journal papers and conference papers, and 9 books. He has received 38 different level academic and engineering Awards and Honors. He is active in international academic activities and international collaborations. He has organized and attended many international conferences. He also serves as Member of IAHR/IWA Joint Committee on Urban Drainage.**

Wang Zheng **is a Ph.D. candidate at school of environment in Tsinghua University. His research interests are in analysis of environment system and urban runoff management and planning, and his work has been published in some different journals.**

Shaw L. Yu, **after graduating from Cornell University in 1968 Dr. Yu taught for thirty-five years at several universities including Rutgers, Tulane and the University of Virginia. Dr. Yu is recognized internationally as an expert in stormwater management, nonpoint source pollution control technology and watershed management. Dr. Yu is currently a Life Member and an Honorary Diplomat of the American Academy of Water Resources Engineers of the American Society of Civil Engineers (ASCE).**

A major current issue is how to develop a reliable, and tangible, estimate of returns on investments in the SC projects. For example, how to quantify and appraise the benefit of SC implementation is still an important question. Also, after the completion of an SC project, maintenance of the LID/GI facilities will become a crucial factor affecting project sustainability. The lack of information on maintenance requirements and costs would contribute to uncertainties in SC budget estimates.

Lack of Site-specific Technical Guidance and Product Certification

Stormwater management by nature is highly site-specific due to spatial rainfall variability and other pertinent local environmental, social-economic factors. For example, the Guiding Opinions on Advancing the Construction of Sponge Cities issued by the China State Council sets a control goal of 70% annual runoff volume for 20% of the built-up areas by 2020. In order to achieve such goals, cities in different climate regions will need different design criteria for their control practices. Also, some of the control practices, such as an underground stormwater treatment system, are manufactured by private companies. An evaluation and certification process would be highly desirable before such products are used for public projects. Furthermore, the design, construction and maintenance of LID/GI systems require professionals with appropriate background and training. Therefore, a consorted effort and time is needed for Research and Development (R/D) in SC technology in order to achieve successes for the SC projects.

The Way Forward

The SC Implementation Strategy

The current SC plan scope has been expanded to include not only dealing with the urban water runoff problem, but also with the broader management of urban water. For example, the integration of green and grey infrastructures is required for flood control, water quality improvement and ecological protection and restoration. Local governments will need to adjust their land use planning and stormwater infrastructure construction strategies to satisfy SC requirements. To effectively improve water quality, the government could consider establishing regulations similar to the National Pollution Discharge Elimination System (NPDES) and the Total Maximum Daily Load (TMDL) programs used successfully in the United States. Also, to provide a strong incentive for local government officials, the success of SC implementation could be used as a performance evaluation factor for promotion considerations.

Improving Investment and Financing Options

The SC construction represents an urbanization process of an enormous scale that requires a major financial commitment from the government. Innovative financial options, such as appropriate PPP project portfolio, credit support, loan guarantees, special construction funds and bond issuing should be considered and promoted. The government should also simplify the administrative approval process for reducing the upfront costs of PPP projects. Decentralization of administrative authority properly to local governments can help them build a tailored and flexible policy approach appropriate for local social, environmental, economic and cultural situations.

Developing Sponge City Industries

The sustainable development of SC requires a robust industrial base. The central government should consider assisting related industries and establishing a viable sponge city industry chain. Under the current economic climate of "over-capacity reduction", the SC projects can offer good business opportunities for manufacturers producing pervious concrete, permeable bricks, infiltration pipes, etc. A stable supply system will help ensure the successes of the sponge city projects. ■

The Beijing Consensus on Low Impact Development for Urban Stormwater Management Prepared during the 2016 International LID Conference

- Our ultimate goal is to manage urban stormwater in such a way to create a living environment in which humanity and nature co-exist harmoniously and a sustainable condition is maintained.
- We consider stormwater runoff as a water resource and its beneficial use should be maximized, especially in relatively dry areas. We recognize water quantity and quality are both limiting factors to water usage. Consequently, managing stormwater should emphasize both the quantity and the quality aspects.
- To mitigate the negative impact of urbanization, efforts should be made to conserve/restore the natural hydrologic processes as much as possible.
- In controlling urban runoff quantity and quality, we should consider the combined use of both natural (such as infiltration, evapotranspiration, etc.) and engineered (such as low impact development (LID) or green infrastructure (GI) practices) processes and systems.
- We realize under certain situations (e.g. extreme rainfall events), the integration of green and gray infrastructures might be necessary.
- We recognize the need to link land uses with urban water management plans. An effective and sustainable urban stormwater management requires a solid regulatory framework.
- We understand there may be consequences of urban runoff management planning and design, e.g., upstream impacting downstream (connectivity). A watershed-wide consideration is encouraged and tools for such analysis, e.g., watershed hydrologic models, are needed.
- More often than not, the urban stormwater management may involve multiple jurisdictions and agencies. Therefore it is highly desirable that a strong collaboration exists among various relevant agencies, institutions, groups, etc. (stakeholders) on a continuing basis. Moreover, setting up goals and selecting appropriate techniques for achieving them should consider local and/or regional conditions.
- We realize that urban runoff management requires a significant and long-term commitment and investment. Public-private partnerships and other cost-effective strategies should be considered. Also, life-cycle operation and management of practices, such as planning, design, construction, inspection/acceptance, etc. are needed.
- We need to make constant innovation and improvement. We will make great efforts to promote the sharing the knowledge and experiences on a continuous basis.

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SPONGE CITY CONSTRUCTION IN XIAMEN, CHINA

BY JIAHONG LIU, CHENYAO XIANG, WEIWEI SHAO, YONG LUAN

Sponge city construction is a key mission of urban development plan in China's 13th Five Year Plan, and Xiamen is in the group of 16 pilot sponge cities in China. Xiamen is located in the southeastern coastal region in China, with a subtropical maritime monsoon climate and an urban population of over 4 million. The local water resources are very unevenly distributed during the year, resulting in double threats of urban flooding and water shortage.

On September 19th, 2016, with the landing of Typhoon Meranti, Xiamen suffered winds of up to force 17 in the Beaufort scale, a short-time rainstorm, and severe waterlogging. Meanwhile, Xiamen's aquatic environment is facing great challenges. In recent years, water quality in over 80% of local streams is below Class V, the worst category in the national surface water quality standards.

In 2014, Xiamen initiated the sponge city construction project which contains 4 major parts: (1) controlling surface runoff through Low Impact Development (LID) implementation; (2) extending the storage capacity of the local river-lake system to contain stormwater through water body renovation and ecological restoration; (3) controlling pollution sources by rebuilding combined sewer systems, raising interception ratio and wastewater treatment capacity, so as to improve the local aquatic environment; and (4) building basic stormwater draining infrastructure to prevent urban flooding and waterlogging.

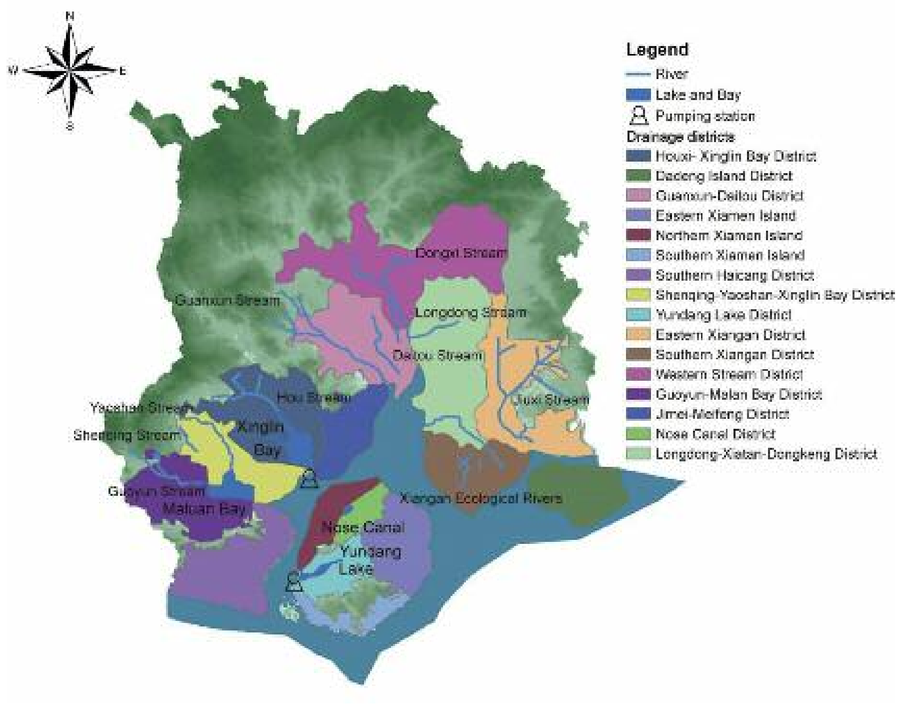

Figure 1. The drainage districts of Xiamen sponge city

Sponge city implementation in Xiamen

According to the design of the Xiamen sponge city construction project, the built-up area of the city is divided into 16 drainage districts. Sponge community, sponge roads, eco-river systems, pollution management infrastructure and drainage installations are constructed according to each district's feature. The overall objective is to accommodate 70% of the annual rainfall in the built-up region.

Low Impact Development (LID) of communities and roads

LID for residential communities and roads are also called "sponge community construction" and "sponge road construction". Currently Xiamen has launched sponge community projects in Guoyun-Maluan Bay and Southern Xiangan districts. These 2 projects cover an area of 41.76 km2, 12.9% of the city's total built-up area. Sponge community construction focuses more on vertical design. Green roofs, interception devices, high parterres, rain barrels, sunken green belt, permeable surface are integrated vertically so that rainfall would be absorbed level by level. The remaining rainfall partly infiltrates into soils, while the rest flows into bio-retention ponds or rain drainage system as runoff, and is further stored in rain pools or scenic ponds, then treated for watering and landscape water use, as well as road sprinkling. Sponge community construction also favors more green spaces in the plazas and parking lots, less impermeable pavements made of concrete, asphalt, etc. The sponge community would become a low-temperature region for LID measures, which should help strengthen local air circulation and weaken the surrounding heat island effect. Another key aspect of sponge community is green space system construction, including "green planes" and "green lines." A green plane is a park or greenbelt of considerable area, of which the surface storage capacity can be increased by sunken greenbelt construction. While green lines mainly include non-motorized traffic system (pavements, bikeways, multifunctional non-motorized roads, etc.). By remoulding non-motorized roads into permeable surfaces, and connecting them to green spaces in buffer zone, an urban "green web" could be built to filter first flush pollution and reduce runoff peak volume. So far, Xiamen has finished 5 green lines and is constructing 2 more. According to the plan, Xiamen's per capita green area ought to exceed 12 m^2 during 2014-2016. During 2017-2020, the city's green space system structure should be generally formed. The per capita green area should surpass 15 m^2 by 2020.

Sponge road construction refers to transform roads and greenbelts into sponge constructions. The primary is slope landscaping and ground slope aspect design. Curbs are lessened to only necessity, and designed to be no higher than the road, avoiding blocking the rainwater. Greenbelts along roads are combined with sunken greenbelt, bio-retention infrastructures, grassed swales and so on, while larger green spaces, such as traffic islands and flyover surroundings, are altered to rain gardens, rain water wetlands, ponds, regulation pools or sunken green spaces. Runoff over pavements is drained through underground sewers into storage devices in greenbelts.

Ecological river system construction

Ecological river system construction includes recovering water body damaged by landfill, river dredging, altering river morphology, and resuming aquatic ecological conditions, biomes, and ecological functions. By far Xiamen has initiated ecological recovery projects for 10 rivers (Guoyun Stream, Shenqing Stream, Yaoshan Stream, Hou Stream, Guanxun Stream, Daitou Stream, Dongxi Stream, Longdong Stream, Jiuxi Stream and Xiangan Ecological Rivers) and 3 lakes (Yundang Lake, Maluan Bay and the Nose Canal). Engineering measures adopted includes ecological embankment (natural slope revetment, stone-mesh revetment, vegetated block slope protection, ecological geofabriform revetment), riverbank buffers (tree belts or grassland built along riverbanks and valleys), river dredging, and ecological water supplementation with rain water or recycled water. In the Xiang'an ecological water replenishment project, stored rain water and recycled water are pumped to a scenic lake with high elevation by solar PV power, and then flow into streams by gravity. In this way, the system is able to replenish river system automatically in sunny days, and stop in rainy days when rivers are supplemented by rainfall; in a word, the system is complementary with weather.

Pollution control

Xiamen is suffering from severe water pollution induced by wastewater discharge, non-point source pollution of runoff, and waste dumping along rivers. The sponge city project applies interception infrastructures and ecological restoration techniques to solve the problem.

Figure 2. Stone-mesh revetment

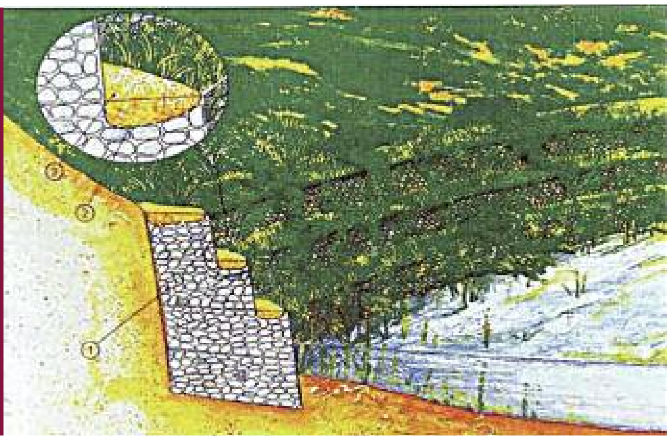

Figure 3. Vegetated block slope protection

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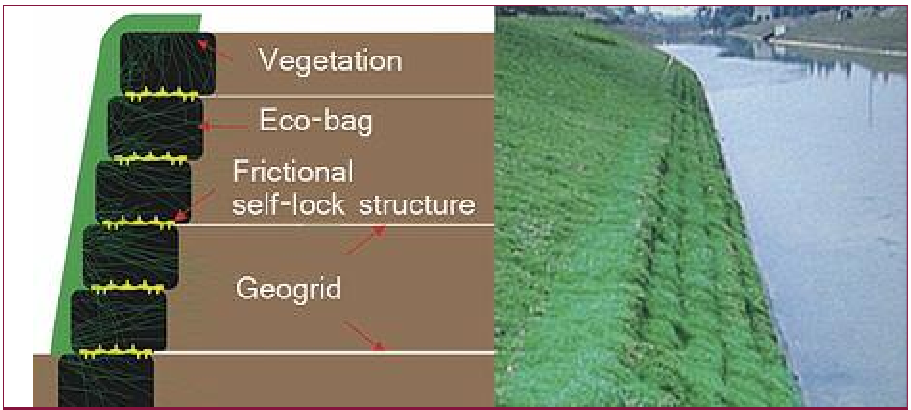

Figure 4. Ecological geotexitile revetment

To control point-source pollution, rain-sewage separated sewers are built and wastewater treatment plants are extended. For regions not reached by the sewer system yet, distributed wastewater treatment plants are built to control wastewater discharges. Non-point source pollution is reduced by constructing green roofs, rain barrels, permeable pavements, plant filters, grassed swales, infiltration swales, sand filters, bio-retention pools and other similar features. Ecological floating beds, which consume nitrogen and phosphorus, are set in rivers and lakes, to purify eutrophic waters and restrain overgrowth of planktonic algae. Waterfalls, fountains, jet currents, and other methods are adopted to increase dissolved oxygen. In the open area of lake entrances, artificial wetlands are built to purify entering water. Sediments of closed- and semi-closed lakes are cleaned regularly. Rubbish recycling is controlled more strictly, so that any waste is forbidden into river-lake systems. Measures as above would alleviate urban water pollution as well as improve the urban landscape and living environment.

Waterlogging prevention construction

Waterlogging prevention construction consists of rain-sewage diversion projects, flood discharge trenches and open channels extension, and the installation of additional drainage pumps in waterlogged lowlands. Presently projects under construction include 2 large pumping stations (Yundang Lake drainage pumping station and Xinglin Bay drainage pumping station), and 44 drainage infrastructures on sites that are particularly prone to waterlogging. Moreover, the rain-sewage diversion project of Haicang District is in the planning phase at present, planned to be completed by 2020.

Lessons for sponge city construction in Xiamen

One of the most prominent issues that Xiamen's sponge city construction faces is water pollution. To solve this problem Xiamen explores 3 distinct engineering methods:

(1) Distributed wastewater treatment devices

Due to the high cost and long duration of drainage system construction in some recently built-up regions, Xiamen applies distributed wastewater treatment devices (such as High Fiber Reinforced Plastic Tank (HFRPT) for digestion). This solution overcomes difficulties of collection, discharge, treatment and recycling in traditional centralized wastewater treatment methods. It costs less, gathers wastewater more efficiently and reuses recycled water more conveniently. Also the devices fit right into surroundings, requiring little ground construction area and less gathering-delivery sewers, producing no outlet discharges or pollution.

Figure 5. Installation site of one of the distributed wastewater treatment devices

Figure 6. Demonstration of a completed ecological drainage channel

(2) Ecological drainage channels renovation

To reduce water pollution, drainers are installed underneath flood-drainage channels to collect wastewater, which is then conveyed to the nearest underground wastewater treatment devices through sewers, and diverted to the surrounding water body after having been treated to Class IV in the national surface water quality standard. On the channel beds, suitable plants are planted, so that flood flowing would be unaffected in rainy seasons while the landscape is more appealing in dry seasons.

(3) Comprehensive management in the Nose Canal

The Nose Canal is in the mid-north region in Xiamen Island. Presently, the canal is almost a culvert. Backwash water from nearby water plants and domestic wastewater from in-city villages are discharged directly into the canal, forcing the natural waterway into local waste drainage channel. To improve local water quality, local government has initiated a comprehensive management project into the sponge city construction. Firstly, a sewage intercepting pump station is constructed to manage the first flush pollution. Then the culvert stretches are transformed into open canals, ensuring the flood discharge capacity of the canal. Meanwhile, the ecological functions of the canal are restored to ensure living conditions of fishes, amphibians and birds. Landscape design is also valued in the project. Elevation differences are managed with waterfalls. Banks are built into gentle slopes, and pavements or recreation spaces are built along.

Acknowledgement

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SINO-DUTCH COLLABORATION ON DEVELOPING SPONGE CITY CONCEPT

BY ARTHUR E. MYNETT & CHRIS ZEVENBERGEN

Rapid urban development in China

China has been experiencing unprecedented urban expansion and growth in wealth since the 1980s. The urban population has increased six-fold since 1980, and will further increase over the decades to come. A similar increase in urban population took place in Europe, but over a period of more than a century. In China, urban water problems have become very prominent in recent years. Damages caused by floods are exponentially increasing, in particular in large urban conglomerates and due to severe changes in weather patterns and rainfall intensity.

As a response to those increasing flood impacts, the Chinese Central Government called in 2013 for widespread uptake of the Sponge City approach across China and provided financial support to foster implementation of this approach in a selection of pilot cities. The Sponge City approach aims to enhance infiltration, evapotranspiration and capture and reuse storm water in the urban environment. At present, the Sponge City approach is gaining ground and becoming more and more accepted by city governments and the first best practices are being shared. However, there are still many challenges ahead.

During the process of rapid urbanization, the development and upgrading of the underground infrastructure such as the drainage system could not keep pace with the above ground infrastructure development. This also holds true for the capital city of China, Beijing, which has witnessed more than a doubling of the total land coverage in the past 10 years. As a consequence, many city areas that have been developed during the past three decades do not have a properly functioning urban drainage system. City lakes and ponds have disappeared, together with natural drainage systems and peri-urban wetlands.

Figure 1. Sponge City pilot project in Zhenjiang neighbourhood transformation

Figure 2. Bioretention through the use of swales and constructed wetlands in Jin Shan Hu Road, Zhenjiang, China

Figure 3. Sponge City concepts in Rotterdam, the Netherlands

Figure 4. Water Square recreational area on top of subsurface water storage reservoir

The Dutch experience

The Western part of the Netherlands can effectively be considered a metropolitan urban area, comparable to a medium sized Chinese city. Some 6 to 8 million people and most of the economic activities are located in that area, which is quite sensitive to stormwater flooding, since a major part of the land lies below sea level, protected by a system of dykes, dams, dunes and engineering protection works. For centuries the Dutch have been developing a sophisticated system for water management in these low lying interconnected polder areas. More recently, the Netherlands has been developing a new Delta Programme focusing on water management issues for the next century by preparing adaptation measures to deal with the effects of population growth, climate change, and land subsidence. The main focus is on flood protection and on safeguarding fresh water availability. An important component of the Dutch Delta Programme is that each year funding is set aside by the government (on the order of 1 billion euro per year for the next hundred years, which roughly corresponds to 0.5% of the national GDP). Every five years the most burning issues are identified by the Delta Commissioner and reported to parliament, which then allocates budgets from the Delta Fund to finance specific projects in order to remedy particular problems, keeping options open for future technologies or changes in driving forces.

An important part of this so-called Adaptive Delta Management (ADM) strategy as applied in the Dutch Delta Programme is to explore the various Adaptation Pathways (there could be more options that provide a solution) keeping in mind that measures taken now should not jeopardize future options. This strategy has been instrumental in informing and engaging decision makers at the local, regional and national level. Urban flooding and storm water drainage have triggered the concept of sustainable urban drainage systems (SUDS) in the 1990's. From the experience obtained since then, there are many examples and lessons-learned that help facilitate the redesign of existing cities, or new urban development. Also, use can be made of the EU Framework research programmes, where considerable attention has been paid to creating nature-based solutions, e.g. by increasing the permeability of the urban ground surface, constructing 'green roofs' to slow down storm peak discharges, and increasing temporary storage capabilities in parks, urban playgrounds, underground storage reservoirs, and other concepts that have been developed to create a Sponge City.

Enhanced collaboration

The new approaches developed in the Netherlands for city planning and urban design, take into account modern water management concepts when dealing with urban restoration and new urban development.

The Dutch have a renowned reputation in architecture and urban (re)design which has been very influential in fostering integration of urban water management into urban planning and design over the past two decades. It became evident that new cross-disciplinary collaboration between the building sector and water professionals was needed to achieve the transition of existing urban areas into water resilient and high quality environments. Urban restoration, regeneration and modernization of Dutch cities are now key priorities in the Netherlands. They are considered conditional to stimulate economic development, increase water storage capacity, and create multiple benefits. In China, the demand for urban restoration and upgrading is rapidly increasing, driven by the need to implement the Sponge City approach. Hence, collaborating on these concepts is of mutual benefit.

Sino-Dutch MoU re-confirmed

It is clear that both China and the Netherlands are heavily involved in developing new concepts for urban water management. It is also clear that there are great opportunities for collaboration and jointly advancing the so-called Sponge City concept. Based on the fruitful cooperation that already exists for decades, there is considerable respect for each other's knowledge and experience as well as for shared goals and strategies. There are ample opportunities to take the already close collaboration to a next level by introducing co-creation and joint fact-finding as a new way of working. The Sponge City concept on "integrated urban water management" is an emerging field of practical scientific research. There is increased interest in blue-green solutions for urban development, anticipatory water management, weather forecasting and real time monitoring. All of this requires the use of advanced information technologies for flood early-warning and optimal water resources allocation, which are other areas of enhanced collaboration.

These are issues of hydro-environment engineering and research that were identified and elaborated during a joint expert meeting following the signing of the third five year extension of the Sino-Dutch memorandum of understanding. The signatory protocol by the ministers of water resources and the environment took place at an official ceremony at the China Ministry of Water Resources in Beijing on 26 September this year. The IAHR Beijing Office actively took part in the event. ■

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This article is loosely based on the Scoping Report prepared by (Zevenbergen and Boogaard, 2016) for the ministerial mission on Sino-Dutch collaboration, MWR, Beijing, China, Sept. 2016.

Figure 5. Roof Park on top of subsurface water storage reservoir

Figure 6. Water sensitive neighbourhood (City of Hoorn, the Netherlands)

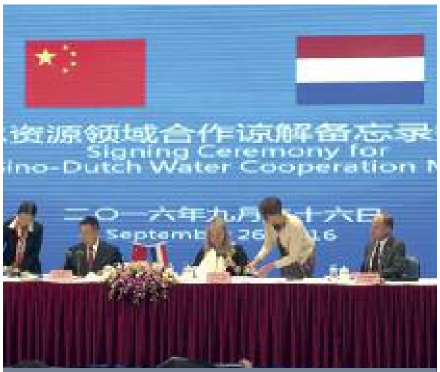

Figure 7. Signing Ceremony Sino-Dutch collaboration on Water Management

INTEGRATED FLOOD MANAGEMENT: IS THE NEXT STEP POSSIBLE?

BY CARLOS U. PAOLI

Latin America's financial losses due to flooding increase constantly. While the high frequency of extreme events gives a glimpse in the risk increase, it is the understanding of the increase in vulnerability which is most important. Integrated Flood Management is presented as a new vision in the effort to confront this challenge, but it also involves a series of difficulties, restrictions, and conditions for its efficient implementation. Different obstacles must be removed in order to advance towards implementation.

Integrated Flood Management: a better vision to mitigate damages caused by flooding

Floods account for approximately one third of the financial loss and one half of the loss of life caused by global natural disasters. Damages due to flooding have been extremely severe in recent decades and it is evident that their intensity and frequency are increasing. Economic losses have accounted for more than 250 billion US Dollars over the last ten years. Despite efforts to reduce losses, studies show that the extent of flooded areas is increasing with time and the magnitude of the associated financial losses increases similarly.
Integrated Flood Management (IFM) is "a process that promotes an integrated approach, not fragmented, in terms of flood management. It integrates the development of land and water resources of a river basin in the Integrated Water Resources Management (IWRM) context. Its objective is to maximize the net benefits of the floodplains and to reduce to a minimum the number of fatalities caused by floods" WMO (2004).

Creating an integrated flood management plan requires the following essential elements to be taken into consideration:
Adoption of the Basin as a Planning Unit (Water Cycle Management as a whole, and Integrated Land Water Management): land and water management; local measures and at the basin level; top-down and bottom -up decision making; functional integration of institutions; and cross-border management.

Adoption of an optimal combination of strategies: Adequate combination of non-structural works and measures, taking into consideration the technical, economic, social, environmental and legal dimensions.

Guarantee of a participative approach: Ensure the implementation of integral flood management planning with full public support. Ensure the sustainability of associated planning and decisions. Build a consensus and public support for the management of selected floods. Build a commitment with those involved.

Integrated Risk Management: Preparedness; response; recovery.

Difficulties faced for the efficient implementation of the IFM policy

There is a growing scientific, technical and political bibliography regarding this issue. We pose the question "Why is it so difficult to go one step further and move from theory to implementation when the theory and basic concepts are apparently widely known and accepted?"

Serious difficulties to prevent or limit the improper occupation of flooding zones

When valleys are frequently covered by flood water, public awareness is high that those valleys are flood zones and that occupation for permanent activities is not appropriate. However, when flooding is less frequent, public awareness of flooding is lessened, or is simply ignored, and land occupation and residential development in floodplains takes place, (Paoli, 2015).

As a consequence, large numbers of people (not only in big cities) live very close to rivers and streams and - as a result of urban development - the invasion of flooding valleys increases. Lack of studies for the delineation of risk areas, the absence of regulations in land use, and many times the irresponsibility of urban developers and municipal governments results in the occupation of flood-prone areas. Unfailingly, these zones are bound to be impacted by extraordinary floods.

Misunderstanding of the functionality of defence projects and level of security

Traditional solutions are part of the development of the defence against different types of floods that represent various problems. The defence mechanisms create an exaggerated sense of

Figure 1. Flooding areas around/environs Santa Fe city during year 2003

safety. Human settlements in protected zones increase and, therefore, damages are greater when the safety net fails. Maintenance and conservation of the projects is not properly implemented (highly expensive), which results in erosion problems and weaker protection. In the majority of these zones, the challenge of transporting, discharging and pumping of flood-waters has not been properly resolved.

All projects for control and protection against flooding are designed and built to withstand flooding of a certain magnitude associated with a probability of occurrence. No project can control or protect against the greatest possible flooding and, as a consequence, there is no zone absolutely safe or flood zone that "will never be flooded again". Pretending that some projects are designed to eliminate the flood risk in these zones does not make economic sense. The higher or lower level of acceptable safety depends on the expected consequences - in case the flood defence is exceeded - assumed by the project. Unfortunately, this issue is not properly understood by the public or, often-times, by the authorities. The result is pressure that constantly increases for more and better projects.

A well-developed project must have a sufficient margin of safety in order to avoid unforeseen situations. Unfortunately, many projects are neither well studied, nor well dimensioned and, therefore, their degree of vulnerability varies. In the majority of the cases, catastrophic impact assessments have not been performed for the scenario that the defence works are overtopped or destroyed. Often, the operational plan for the projects' system includes permanent monitoring. Maintenance of main and complementary works and structures and an action plan for emergency situations is often non-existent and not in place.
The higher frequency of extreme flooding and exceptionally heavy rains are certainly concrete drivers in the increase of flooding. But, these factors in no way can be thought of as unpredictable.

Resistance to the implementation of non- structural measures and the regulation of land use

Relocation, although difficult to implement, is in some cases the only option available and consists of relocating the activities developed in a high risk area and its occupants to a low risk area. Frequently, this option is rejected and opposed by the occupants to be relocated due to the fear of losing comparative advantages in the new location, or due to the cost they would incur directly or indirectly. Nevertheless, this measure must be considered along with the regulation of floodplain use.

The use of land regulations in urban zones refers to a series of actions whose objective is to guide the occupation of spaces in zones not yet urbanized, or re-orient those in the process of occupying floodplains. The following specific actions are mentioned in this context:
- The implementation of public policies that do not favour, or limit public services and infras-tructure development in floodplain zones such as: paving, energy supply, drinking water and sanitation, educational and health services, etc. The tendency of authorities seems to be in the opposite direction given that as land occupants' complaints arise, services are provided and settlements take place.

- The display of warning signs that identify flood prone areas and markings showing the historical range of floodplains. This measure is resisted by real estate interests.
- The utilization of differential real estate tax rates, very low for non-urbanized zones and very high for urbanized zones in floodplain areas. Urban planners and the Income Tax Office show resistance to this type of measures.
- The acquisition of land for parks, camping and other outdoor places. This action requires significant funds for acquisition and maintenance.

Non integration of alert and prevention systems

An Alert and Prevention System takes into account not only the prediction of river flows and expected levels, but also the availability of Contingency Plans in case a flood occurs. Actions range from identifying the first signal of conditions that would produce an overflow and cause flooding to going through the warning of predicted levels and evacuation. Actions would also cover the location and maintenance of flood defences and the maintenance actions and repairs for emergency works, known as fight against flooding.

In order to provide effective Contingency Plans many issues of vital importance must be addressed the most relevant of which are:
- Developing and implementing the legal framework that establishes responsibilities, roles and institutional relationships of municipal, provincial and national organisa-tions, directly and indirectly related to the issue of flooding.
- Developing an adequate delimitation of risk areas and a current inventory of the flood-plains allowing the forecast of overflowing water levels and critical zoning in relation to such forecast.
- Developing emergency plans and evacuation with the participation of the affected people as the only way to ensure their effectiveness.

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Lack of knowledge and distrust in other adaptation measures

The concept of these measures is to modify the structures in risk areas, their surroundings or their layout in order to minimize water damage. Also, the purpose of daptation measures is to allow the continuation of normal activities in the area with the least possible disruption during flooding and to allow a quick recovery. Among other concrete actions that could be mentioned are the following:
- Raising the level of buildings by raising the ground elevation or by using construction on pillars.
- Waterproofing of retaining walls.
- Enclosing low-lying doors and windows with protective masonry.
- Placing critical elements of structures, such as lighting, gas, other facilities, etc., well over the foreseen flooding level.
- Construction with a floating capability in the flood zone.

These measures require professional planning and must not be improvised, as improper use

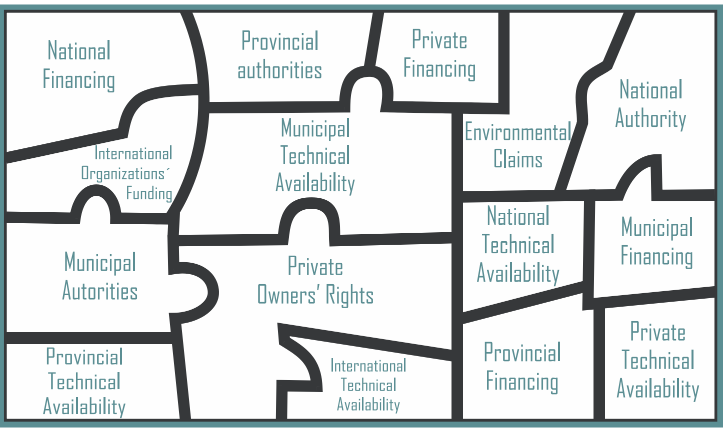

Figure 2. Solving the "puzzle" challenge to coordinate interests, responsibilities and resources at inter-jurisdictional, inter-sectorial, inter-functional levels

could cause more severe damage, or affect other neighbouring occupants. These measures are only recommended for the flooding areas with low currents, outside the flood evacuation channel.

Lack of Inter-jurisdictional, Institutional and Sectorial co-ordination

Several major issues are at play relative to the compatibility of all territorial interests at stake. For instance, questions like how are the responsibilities shared for flood zone planning? Who is responsible for decision making? How is funding sourced and distributed? As shown next, solving the current problems of flooding could be compared to the process of solving a puzzle.

THE CASE OF SANTA FE, ARGENTINA

Santa Fe has a population of 500,000 people and is located in the central zone of Argentina at the confluence of two important river systems. Santa Fe is on the right margin of the Parana River (mean flow of 17,000 m^3/s and a maximum overflow of 62,000m^3/s) and on the left margin of the Salado River (mean flow of 180 m^3/s and a maximum overflow of 4,000 m^3/s). In 1983, 1992 and 1998 the River Parana overflowed. The Salado River experienced heavy rainfall in 2003 and in 2007. The floods had catastrophic consequences in all cases: fatalities, massive evacuations and huge economic losses, with a strong social and psychological impact.

The main causes for the catastrophic effect of the floods were: deficiencies and limitations of existing works, lack of knowledge and foresight, and climate change as an important contributing factor. Furthermore, the vulnerability of Santa Fe increases because of critical risk factors, such as the absence of an alert system and the lack of a contingency plan.

After the experience of these critical situations, a paradigm change occurred and a movement towards Integrated Flood Management started. With its ups and downs, the performance and response to other situations presented subsequently have improved significantly. In summary, the most important non-structural actions put in place during the implementation of the Integrated Flood Management process are:

The response of academia

For the first time a group was formed by the region's universities and organisations of Science and Technology named Programa de Cooperación Interinstitucional Frente a la Emergencia (PROCIFE), (Inter-institutional Collaborative Program in Response to the Emergency). As a starting point, diverse assessments were made in the aftermath of the floods. Conferences and seminars referencing the subject matter with wide participation from the science and technology communities were organized and action plans were developed. The discussion allowed the elaboration of a common agenda establishing and prioritizing the research and development needed, which allowed more efficient use and management of available funding.

Change in management structure and government agenda

A Ministerio de Asuntos Hídricos (MAH) (Ministry of Water Affairs) has been created at the provincial level. Currently, the Ministry of Infrastructure is where the Secretaría de Recursos Hídricos (Water Resources Agency) is located. At the municipal level, a Dirección de Gestión de Riesgos (Risk Management Agency) has been formed as an independent entity from the office of the mayor. Creating these new organizations was an essential action that brought attention to the issue and facilitated its treatment as the main cross-cutting issue involving agencies from multiple levels of local government.

Implementation of a real-time hydrologic alert system

Rio Salado's Red Alert Flood was implemented and is currently functional using 14 pluviographic/meteorologic stations and 14 hydrometric stations.

Land use regulation for riverbanks and bodies of water

Law 11.730 is in place to zone and regulate the occupancy of valleys flooded by rivers and streams in the region.

Figure 3. Location of Santa Fe city

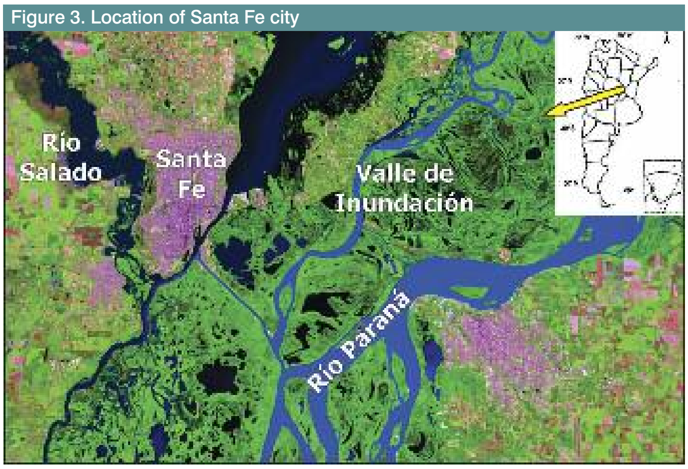

Figure 4. Preparation of contingency plans with communities' participation.

Stormwater surplus regulation system in urban zones

Regulatory mechanisms for buildings and streets as well as municipal laws were introduced to regulate the development of impermeable surfaces due to urbanization and mandate the retention of flood surplus waters.

Availability of an appropriate legal and institutional framework and a contingency plan elaborated with community's participation

A risk management municipal system was created and the development of a **Contingency Plan** was one of its first actions. Each district's vulnerability conditions were widely discussed as well as the potential damages that could be caused by different types of events. Strategies were implemented for, among other things, evacuation routes and meeting places during critical situations and methods to solve different types of conflict (Aguirre Madariaga et al, 2014).

Risk management, education and communication

A **risk communication program** was created in which sixty organizations from forty-five neighborhoods in the city participated. The program offers training seminars for teachers and community designated agents, and develops educational materials for teachers' support and flood risk management manuals. A web page has been developed where the Contingency Plan and other relevant publications, timely weather forecast, and river flow forecasts are available.

Recovering and maintenance of live memory

It is important to save images from the past that help prevent a possible future catastrophe. Photographic samples and documentaries and posting "water marks" of past floods are extremely important. A "Memorial" regarding past flooding is under development.

Recovery and set up of environmental value in marginalized zones

The degraded border area in the west of the Capital of Santa Fe is being transformed by turning it into a natural urban reserve. The transformation has been done with the support of the French Fund for Global Environment (FFEM). Multiple uses are being contemplated for the green space, reducing the ecological and social vulnerabilities while improving the quality of life in the neighbouring areas.

Recognition of the efforts expressing the pride of the authorities and communities.

Santa Fe was the first city in Argentina to join the Global Campaign of the United Nations Office, the United Nations International Strategy for Disaster Reduction (UNISDR). UNISDR's mission is "Developing Resilient Cities" to promote the implementation of the "Hyogo Framework for Action". The proactive engagement of Santa Fe has resulted in it being named "an exemplary Model City" and, in 2011, it was awarded the Sasakawa Prize. ■

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Translated from Spanish by Maria S. Horta

WATER-SENSITIVE URBAN DESIGN IN SPAIN

BY JERÓNIMO PUERTAS, JOSE ANTA & JOAQUÍN SUÁREZ

The application of Water-Sensitive Urban Design (WSUD) approaches is an emerging issue in the field of urban water system management. In Spain some pilot actions have been applied in the last few years, but a more integrated vision of such actions and strategies is still needed. The development of new national regulations for water quality assessment is an opportunity to meet the more demanding European standards according to the Water Framework Directive philosophy.

The Integrated Water Resources Management (IWRM) approach may be applied in urban environments, including the catchment unity and water governance concepts. The traditional urban water cycle framework (water supply, sewerage and wastewater treatment services) has to be replaced by a holistic and systematic approach (the urban water system), and water may be associated with urbanism and sustainability policies (Suárez et al. 2014). The practical expression of this whole cluster of interactions is beginning to take shape in several countries, with the definitions of Low Impact Development (LID), Green Infrastructures or Water-Sensitive Urban Design (WSUD) strategies, which will probably lead the activity in urban water systems in the next decade.

The Water and Environmental Engineering Research Group (known by its Galician acronym GEAMA, which stands for Grupo de Enxeñería do Auga e do Medio Ambiente) of the University of A Coruña (UDC, Spain) has been working on some of the aspects of WSUD, both in its research projects and in supporting decision makers in the implementation of these strategies in Spain.

WSUD: the work of GEAMA

The GEAMA research team is working in several areas related to WSUD. Research is combined with consulting services to water companies and hydraulic administrations, and support to the development of new regulations and policies.

The most relevant research projects are related to the analysis of combined sewer systems and Combined Sewer Overflows -CSOs- (with a vast experience over more than 20 years), the analysis of stormwater tank hydraulic and

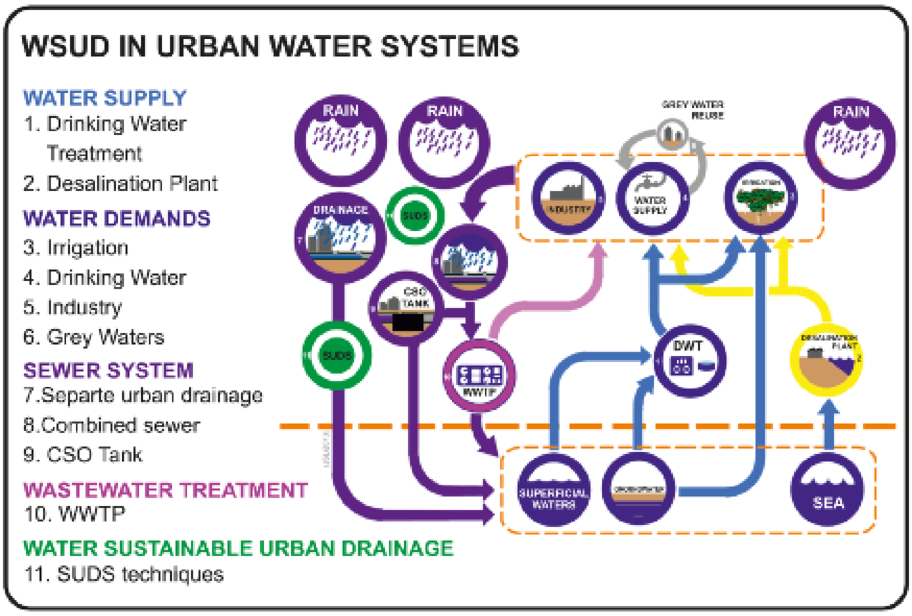

Figure 1. Urban Water System

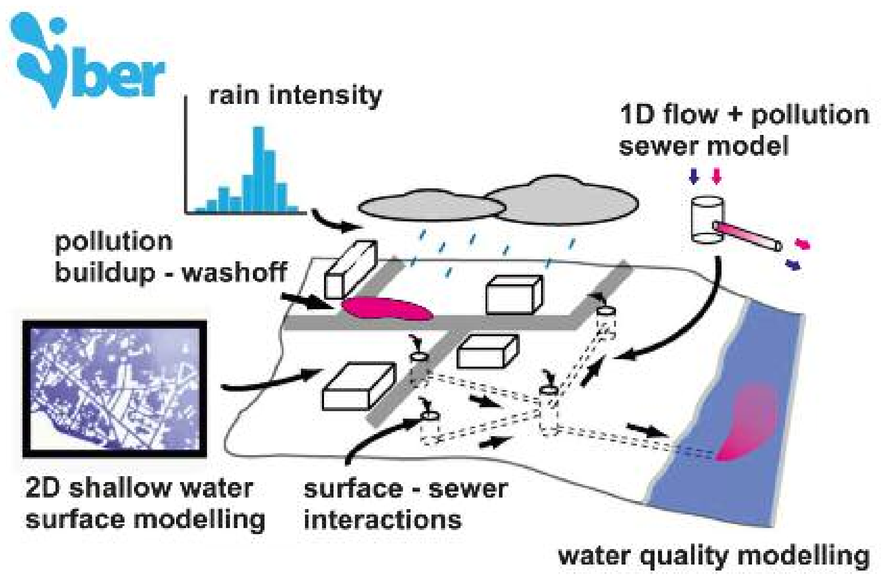

Figure 2. Iber dual-drainage model conceptualization

pollution removal efficiency, and urban runoff characterization in terms of pollutant mobilization, both in urban areas and highways.

Field work is complemented with the development of numerical models. The Iber software (www.iberaula.es) has been developed by the GEAMA team (UDC) and the Instituto Flumen of the Polytechnic University of Catalonia (UPC), with the collaboration of Centro de Estudios y Experimentación de Obras Públicas (CEDEX) of the Spanish Ministry of Public Works and Transport. The latest versions of the Iber software include a 2D shallow flow and turbulence model, with water quality and sediment transport models. New features for urban drainage modelling are being implemented in Iber, including a dual drainage model to evaluate urban flooding, and specific formulations to analyse pollutant build-up and transport in streets, gully-pots and sewer pipes. These model developments are being validated and calibrated at the hydraulic lab managed by the GEAMA at the Centro de Innovación Tecnológica en Edificación e Ingeniería Civil (CITEEC-UDC) facilities. Furthermore, another hydraulic flume fed with real wastewater at A Coruña Waste Water Treatment Plant is being used to monitor combined sewer sediment accumulation and transport processes.

The application of the WSUD concept has materialized in collaborations with different public entities. For instance, in the town of Fene the first Spanish stormwater sand filter (type Austin) has been built to control highway runoff from a motorway with dense traffic. Our group has been involved in the development of the drainage management plans in the cities of Madrid, Sevilla, Arteixo or Sada. In all these plans, Sustainable Urban Drainage Systems (SUDS) techniques have been proposed or implemented at local or regional levels. We also work in reducing the impact of industrial activities on water bodies. Noteworthy is the Water Master Plan of the INDITEX group (the first textile industry in the world), with GEAMA as the reference group for this multinational company.

Regarding the development of policies and regulations, the GEAMA group has collaborated with the Galicia regional water authority in the elaboration of its technical guidelines, incorporating water quality assessment concepts for CSO tank design and SUDS application. At national level, our expertise in stormwater monitoring and management will enable us to collaborate in the development of the forthcoming Spanish standards of stormwater tanks.

The Spanish challenges

Notwithstanding the work already done by GEAMA and other research teams in other regions, such as in University of Cantabria or Polytechnic University of Valencia, Spain faces the challenge of adopting the principles of Low Impact Development, moving from pilot or specific actions to a more integrated approach. The development of the new national urban

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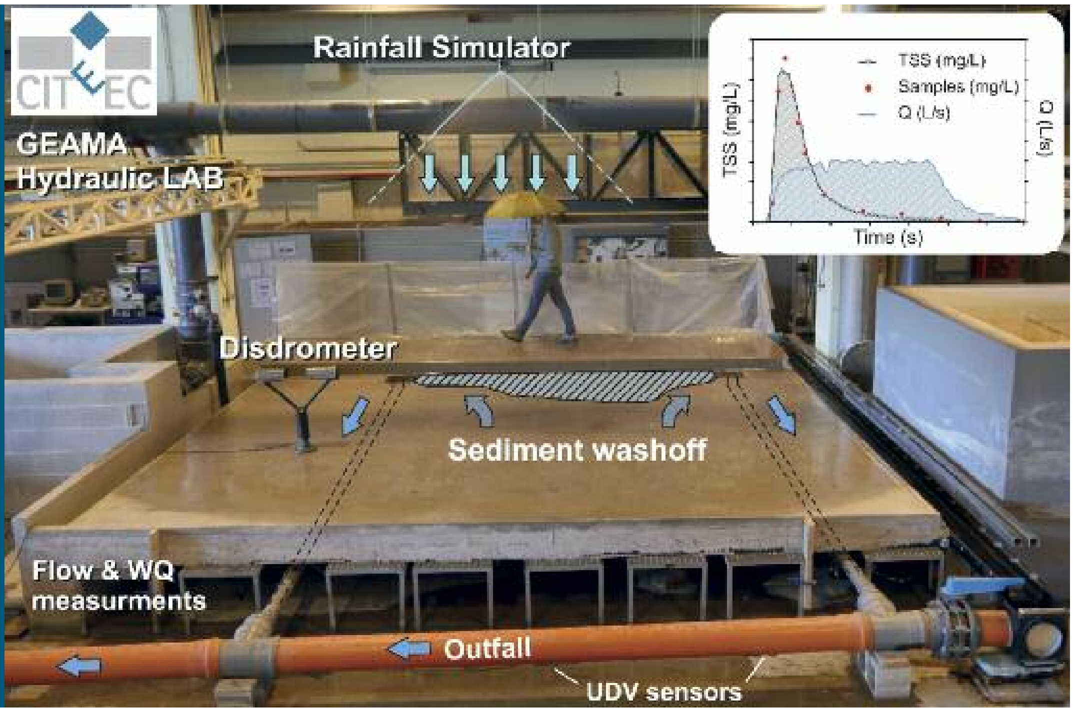
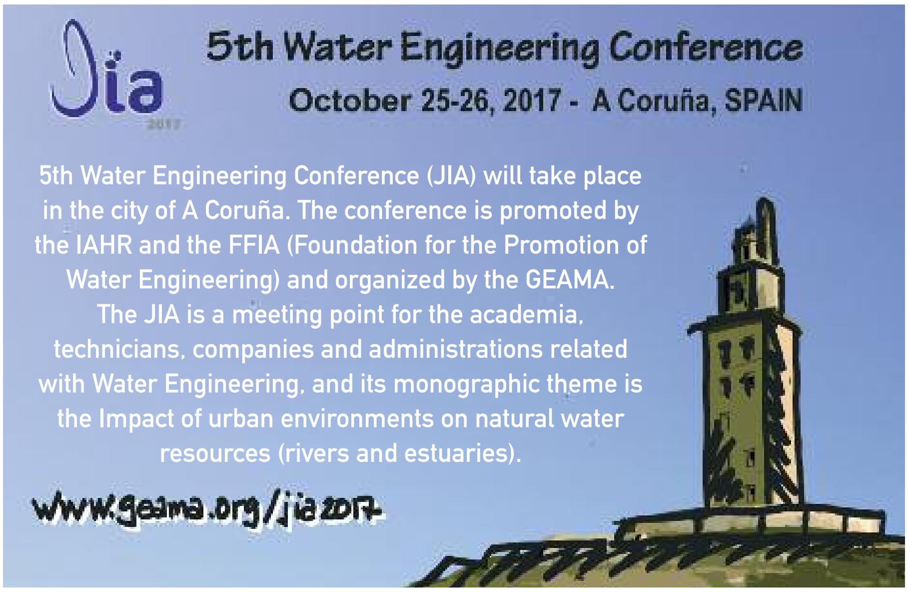


Figure 3. Full scale street physical model at the CITEEC (UDC)

drainage standards for CSO tank sizing and SUDS techniques in line with the most demanding European standards will certainly contribute to such a change.

In addition, municipal officials are increasingly interested in this topic, thanks to the information dissemination by research groups and some private companies. They have already promoted conferences and forums at national level in which real applications in Spanish cities have been presented. This is a topic in which a multidisciplinary approach involving architects, urbanists, water engineers, economists, sociologists and ecologists, becomes indispensable.

On October 25th and 26th, 2017 the 5th National Water Engineering Conference will be held in A Coruña, organized by the GEAMA group through the IAHR Spanish National Committee and FFIA. This meeting point is the largest forum of technicians, academia, companies and administrations of this discipline in Spain. Each biannual edition proposes a monographic theme. In the next edition the focus will be the impact of cities on fluvial and estuarine environments. Galicia, the region where A Coruña is located, has a large coastline and a very



specific conformation in estuaries called "rías". These estuaries, rich in fish and shell fish, and with various levels of environmental protection, must be protected from the impacts of cities.

This is one of the main reasons why Galicia has developed its water quality assessment regulations closely linked with WSUD concepts. The adaptation to climate change and its implications for the design of measures to mitigate urban pollution impacts is a matter of particular concern to GEAMA and is at the heart of our agenda for the next few years, just as it is for Spanish decision makers. ■

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Winner of the IAHR 2016 Latin America Heritage Award

TIPON – A TESTAMENT TO INCAN WATER MANAGEMENT

BY MIKE APPLEGATE

Tipon is an ancient Incan water temple that has outstanding examples of the hydraulic engineering capabilities of the Incan empire. It is a good place for engineers to visit to remind us of the importance of water to society both then and now.

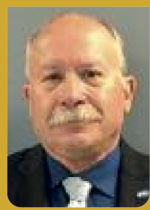
I recently made a trip to visit Peru for the XXVII Latin American Conference on Hydraulics. This also gave an opportunity to see some of the structures of the Incan Empire and learn more about the history of specific sites. One of the sites called Tipon and is located near Cusco, Peru. Tipon is a sacred water temple built by the Incan Empire in the 15th century. It is in remarkably good condition and is a testament to the ingenuity the Incan people had in water management and hydraulic design.

Figure 1. Tipon Water Channel and Drops

The hydraulic performance of the water features are impressive. The open channels, drops, energy dissipation structures and fountains are well designed and continue to function even after centuries of use. Tipon also represents the social significance that water was viewed by this empire. The architectural layout of the walls and terraces seamlessly incorporated the hydraulics of the water features. It is breathtakingly beautiful.

Water was the foundation of the Incan agrarian culture. But the Incans apparently also placed huge societal value on other aspects of water. The sight and sound of the water flowing through the various features in Tipon makes this ancient temple have a very connected and spiritual feeling to nature and the earth. I had the good fortune of visiting the site in early morning when very few people were there. The quiet peaceful background sound of bubbling and splashing water was very soothing. The visual beauty of the water drops and fountains still performing after centuries of use was stunning. The panoramic view of the valley below added to the experience. I could understand why the Incas considered this a sacred ground.

When the Incan Empire was invaded by the Spaniards, portions of this site were buried by the Incas and many artifacts such as ritual water pots were destroyed to keep what they considered sacred to their people out of the hands of the invaders. I was told that there was little silver or gold found at Tipon, so the Spanish quickly lost interest in it and moved on. Recent restoration work has slowly uncovered additional hidden water features and secrets of Tipon. The archaeological discoveries continue to reveal the ingenuity of these ancient hydraulic engineers.



***Mike Applegate, PE, CCE* is President and founder of Applegate Group, Inc. Mike has 42 years of consulting engineering experience in water resources working with clients in the power industry, agriculture, mining and government. This includes water resources planning, water rights evaluations, river basin modeling, infrastructure design and construction management. Mike has served on the Board of Directors of the Northern Colorado Water Conservancy District since 1991 by judicial court appointment. His duties at Northern Water as President and Chairman include guiding policy for operation and management of the largest trans-basin water project in Colorado.**

There have been many other investigations of Tipon that are far more detailed and better technical reviews than this article. The durability and simplicity of their ancient design speaks to us as engineers. The fact that all this was accomplished without the technical tools we as engineers currently have at our fingertips is all the more reason to admire this accomplishment. The observation I have as a professional engineer and someone who has worked in water for many years is that we sometimes need to step back from our day-to-day work which involves the technical aspects of water. Tipon amplifies the emotional, spiritual and social aspects of water that touches everyone. We as water professionals need to keep an appreciation for a life giving resource that transcends hydraulic formulae and theory. ■

ARTELIA - A ONE CENTURY LONG TRADITION OF PHYSICAL SCALE MODELLING

BY LUC HAMM, OLIVIER CAZAILLET, PIERRE-ETIENNE LOISEL & PATRICK SAUVAGET

Laboratoire Dauphinois d'Hydraulique was created in Grenoble in 1917 to support the industrial development of hydroelectricity in the French Alps. Since the first river physical scale model with rigid bottom which was implemented in 1923, continuous progress was made and experience accumulated to model with increasing accuracy water and sediment transport processes thanks to physical scale models.

ARTELIA inherited this tradition and operates presently a 10,000m^2 laboratory to perform its consulting engineering activities: in this facility, about 25 physical scale models are constructed every year to carry out engineering studies including the design of harbor protection structures, barrages and hydropower production equipment, canal locks, pumping stations, bridges and flood culverts in river valleys, etc. Long term sediment transport processes and morphological evolution of coastal inlets and rivers is also a specialty of the laboratory which has been applied to prestigious sites such as the Mont Saint-Michel Bay, the Loire river estuary or the Seine river estuary to design the extension of Le Havre harbor. Environmental integration of development projects is a constant preoccupation to which physical scale models contribute deeply.

From model to reality

The basic aim of hydraulics scale modeling is to build a model of a natural site - possibly including man-made development projects -at a reduced scale that adequately reproduces all the main physical processes involved, such as fluid discharge, water surface elevations, flow patterns, sediments dynamics, and forces on structures. The sophistication of the physical model l varies with the design or study objectives.

A physical model is a three dimensional tool that is very helpful for engineers and scientists to understand the relationships between the various components of a particular design, how various structures of a whole scheme interact, or to imagine new solutions. However, in a broader sense, the usefulness of a physical model can be seen in four areas: (1) technical: to ensure an appropriate and efficient design; (2) economic: improve project optimization and cost savings; (3) safety: lower risk for both the hydraulic structures and the potentially impacted populations; and (4) communication: convey concepts and designs to technicians, residents, non-governmental and governmental organizations and others, as necessary to aid in the understanding and acceptance of the project and of its hydraulic impacts.

Most physical modeling studies can be easily justified from an economic standpoint. In most cases the cost of physical model design, construction and tests is typically only a small percentage of the total project costs and the benefits are in many cases very high (e.g., simplifying and optimizing the design, improving safety, reducing total project costs).

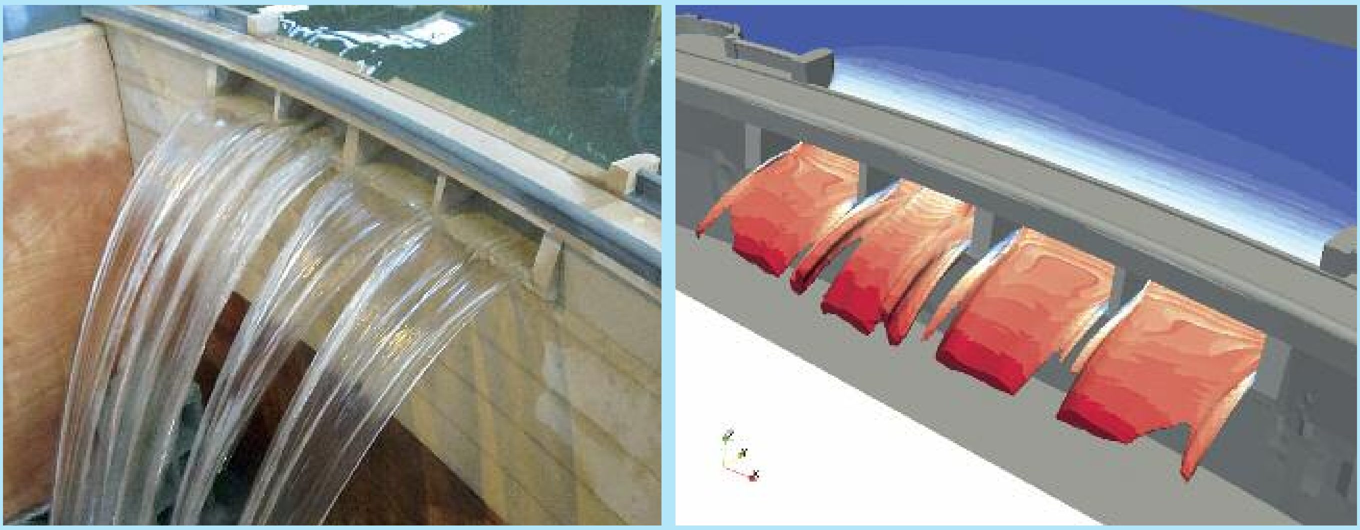


Figure 1. Comparison of CFD and physical modeling of the flood spillway of Cammazes dam (ARTELIA R&D study)

Figure 2. Scale modeling of dam rehabilitation projects with upgrading of flood spillways

Figure 3. Scale model of a 30 m lift lock with 5 saving basins and of hydropower scheme surge shafts

Figure 4. Scale modeling of sedimentation in reservoirs (Jirau dam, Karnali dam, Inga headrace canal)

It is important for engineers, project managers and owner/operators to understand the type of problems for which a physical scale model is a useful and, sometimes, unique tool. The field of scale model use is wide:

- Hydraulic structures studies and river engineering
- High dams and run-of-river dams
- High lift height and complex lock
- Storm water hydraulic structures
- Pumping stations
- Coastal and harbour engineering
- Sediment transport studies, both aiming at forecasting morphological evolution of natural sites under various constraints and at studying the stability of man-made equipment, for a wide variety of water bodies: torrents, rivers, dam reservoirs, estuaries, deltas, coastal shorelines, lakes, etc.
- Environmental studies, with the specific case of gravity-driven flows (thermal and salinity plumes)
- Navigation training (Ship handling training using manned models)

There is a close and complementary link between the numerical and the hydraulic scale modeling approaches. In some cases a numerical model and a physical scale model can be coupled and operated simultaneously in the time loop to reproduced globally physical processes. More commonly, the two approaches contribute to different objectives of a global project. As an example, a large scale numerical model will be used to analyze processes at geographical scale and will also supply boundary conditions to a physical scale model which, in turn, will allow to study precisely narrow field hydraulics and to supply parameterization useful to the numerical model.

To illustrate this close interaction between physical and numerical approaches, let's mention the R&D study carried out by ARTELIA in 2014-2015 on the comparison of both tools for the estimation of the discharge capacity of the free surface flood spillway of Cammazes dam (France), as shown in Figure 1 (Loisel et al., 2015). This comparison led to very satisfactory results, although it was shown that the Computational Fluid Dynamics (CFD) model always needs a trusted calibration point to reach the same level of accuracy as the physical model.

Hydraulic scale modeling of dams and hydropower hydraulic works

ARTELIA has always been involved in the field of hydropower and has developed an expertise in the design of the complex hydraulic works which are often encountered in such projects like Piano Key weirs, Fusegates, labyrinth weirs, shaft spillways, vortex shaft as well as more conventional spillways and dissipation basins which are always crucial structures for the dam safety. An increase of scale model studies is observed in hydraulic laboratories due to the dam ageing and the necessary upgrading and rehabilitation, and also as a consequence of the strengthening of regulations in many countries.

Unsteady flows, varying very rapidly, are observed in the surge tanks with complex shapes of hydropower schemes or in high lift locks with various saving basins. It is possible to reproduce these flows in scale models thanks to

Figure 5. Scale models of pumping station (with surface air core vortex), stepped drop shaft and vortex drop shaft on a urban drainage network

the improvement of the laboratory equipment operated in few milliseconds with perfect simultaneity.

Sedimentological models are probably the most sophisticated scale models. Various models of this type have been recently built by ARTELIA to study the Jirau reservoir flushing operation (Brasil, Energia Sustentavel do Brasil), the INGA 1 & 2 headrace canal sedimentation and cleaning (Democratic Republic of Congo, SNEL) the future Upper Karnali Hydrpower Project (Nepal, GMR), the recreation of a natural delta of the Rhône river in Lake Geneva (Switzerland).

Scale modeling of industrial or urban hydraulic structures

Numerous scale models of industrial or urban hydraulic structures are also studied in ARTELIA's laboratory, such as "classical" pumping stations, but also urban drainage networks, drop shafts. The local constraints in the cities due to the limited available space often lead to complex and unique hydraulic design that fully justify the need for a scale model validation study.

Trends in physical scale modeling applied to maritime hydraulics

In the maritime part of the laboratory, the trend in the classical wave stability studies for port and coastal structures is toward larger models covering about 1,000m2 in wave tanks due to either larger scale (shift from 1 in 60 towards 1 in 40) or very large layouts. A good example of this trend is provided by a recently completed model built in a wave tank 30 m by 40 m at a scale of 1 to 38 to study the protection of the Guggenheim Abu Dhabi museum by four

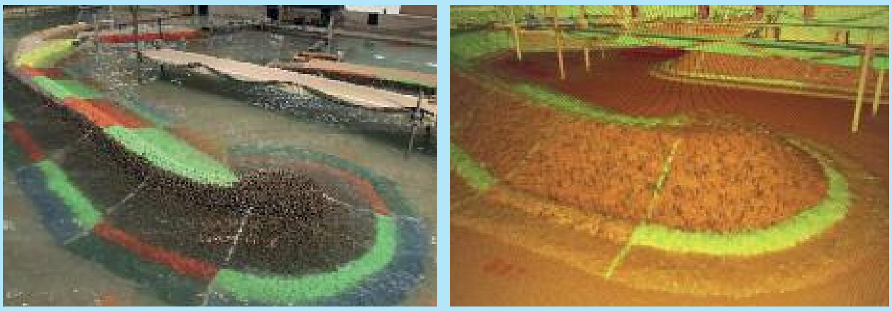


Figure 6. 3D laser scanning to follow morphological changes of a breakwater

Figure 7. 6-components strain gauge balance for measuring wave loads on a gravity-based structure (GBS) concept for offshore wind turbine development

Luc Hamm **is technical director of the Maritime and Ports branch of ARTELIA. After graduating as a civil engineer in Paris, he received a Ph.D in mechanics of geophysical environment from University of Grenoble and more recently an accreditation to supervise research in fundamental science from University of Caen Normandy. His main field since 1980 is waves, hydrodynamics, sediment transport and morphodynamics and their applications to coastal and estuarine environments and to port and coastal engineering with emphasis on physical and numerical modeling.**

Olivier Cazaillet **is a hydraulics engineer, working as project director for Artelia Eau & Environnement (formerly Sogreah) in the fields of dam hydraulic structures, development projects for rivers, delta and estuaries, morphodynamics and sediment transport, inland waterways, large irrigation canals, water resources and in protection schemes against hydrological and sedimentological risks. He managed the Hydraulics Laboratory of Sogreah during 6 years and specialized in sedimentological scale model.**

Pierre-Etienne Loisel **is a hydraulic engineer and project manager at ARTELIA. He has been working on hydraulics of rivers and structures since 2007, starting for one year as young expatriate in Oman. He has been developing a sound experience in scale modelling since 2009, by managing more than 20 projects. Mr LOISEL has been a member of the French dam committee since 2012 and published 5 papers for international congresses.**

Patrick Sauvaget **has 36 years of professional experience in the field of numerical modeling applied to the water environment. After obtaining an engineering degree in Hydraulics (INPG, Grenoble, France), he passed a master's thesis in civil and environmental engineering (University of Iowa, USA) and a PhD thesis in fluid mechanics (INPG, Grenoble, France). He is presently head of the Hydraulics department of Artelia Eau & Environnement, Grenoble, France. He acted as project leader or project director of water and environmental studies in various domains: hydraulics and water quality in rivers, coastal hydrodynamics, flood risk management, water resources management, water distribution, etc.**

detached breakwaters (Perrin et al., 2016a). The museum is built on a landmass retained by a vertical seawall with varying top elevations. One of the challenges of the study was to limit wave overtopping and negative wave pressures on the seawall while minimizing the visual impact of the detached breakwaters.

New technologies are also used in such stability models like a robotized total station for model construction and for quality control, and 3D laser scanning for monitoring morphological changes in breakwaters (see figure 6).

Measurements of forces and pressures applied to fixed structures are another important growing activity covering both breakwaters and renewable marine energy. Measurement of the impact pressures on a crest wall, induced by breaking waves, was performed on the old 19th century breakwaters of Artha and Socoa in a wave flume at a scale of 1 in 30 (Garcia et al., 2016). Measurements of such impulsive loads require high sensitivity piezoelectric pressure sensors and a very high sampling frequency, chosen in this case at 10,000Hz. Sensors, with a resonant frequency ≥60kHz, resolution of 0.69Pa and low frequency response ≥0.5Hz, were chosen to allow reliable measurements.

Figure 7 presents the case of a gravity based structure (GBS) concept for an offshore wind turbine development tested in a wave tank to get wave loads and pressures induced by extreme waves (wave height of 12 m with a period of 13 s in a water depth of 25 m). Such measurements constitute also a reference dataset for numerical modeling (Thilleul et al., 2014).

Another example is the site of Civitaveccia in Italy with measurements of hydrodynamic forces on the existing crest wall of a recently built vertical breakwater as illustrated by figure 8.

Studies of scouring at the toe of maritime structures are another field of activity presently driven by marine renewable energy developments subjected to combined wave and currents actions. They required an adaptation of our facilities to allow current generation in our wave flumes and basins. Such movable bed scale models cannot be in exact similitude with nature when natural sediments are fine to very fine sands. A long tradition in our laboratory is to use lightweight material instead of natural sand in order to represent correctly the initiation of sediment movement and facilitate suspended sediment transport. An example of this approach is the recent model of scour of bridge piers supporting a long causeway in Kuwait bay (Perrin et al., 2016b). An advanced image-based 3D modeling solution was implemented on this model by photographing the test zone from different viewpoints using a fix-lens camera (60 photographs), followed by spatially referencing (x, y, and z co-ordinates) the pixels composing each photograph using coefficients that were previously calibrated with 6 known benchmarks. A dense point cloud was then created from these 60 photographs and a 3D polygonal mesh representing the model was finally built on this basis. Quantitative evaluations of seabed morphology change can be obtained by comparing photo-scan surveyed seabed levels at the end of each test to the initial seabed levels. Figure 9 illustrates such a result for another bridge pier scour model. Such optical methods are also implemented for measuring the movements of moored floating structures by infrared stereoscopic cameras allowing motion capture. ■

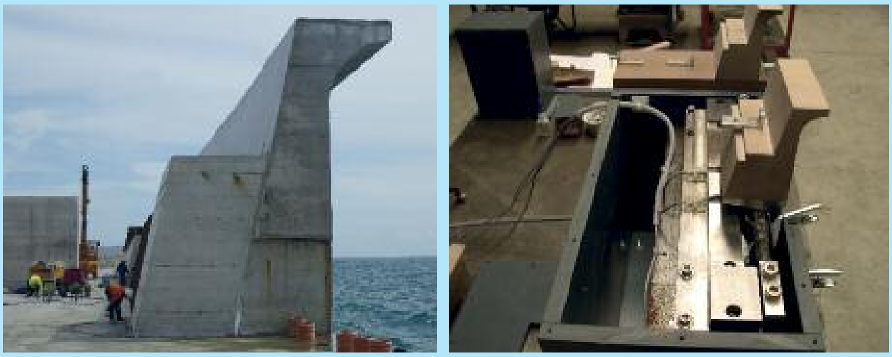


Figure 8. 3-components strain gauge balance for measuring wave loads on the crest wall of the vertical breakwater of Civitaveccia (Italy)

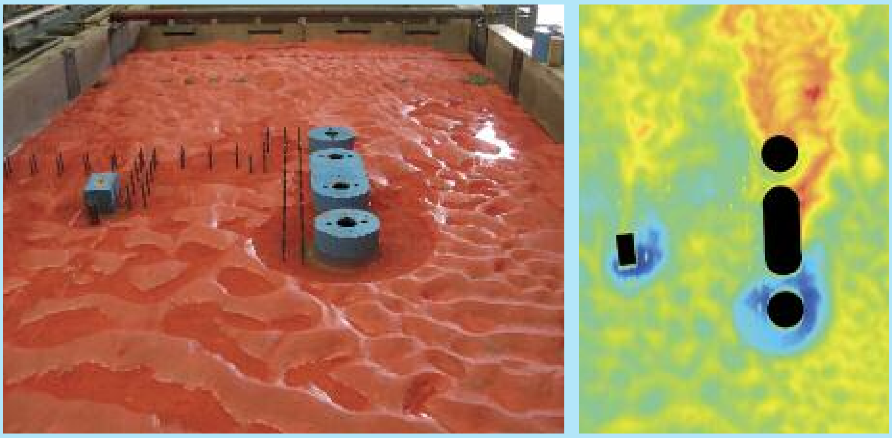


Figure 9. Erosion-sedimentation patterns around bridge piers measured by photo-scan surveying technique

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AN EXPERIMENTAL SYSTEM FOR TESTING SYNERGETIC EROSION CAUSED BY SAND ABRASION AND CAVITATION

BY LIU JUAN

The Erosion Test System for Hydraulic Machinery (ETS-HM) is designed for testing synergetic erosion due to cavitation and sand abrasion in hydraulic machinery. The system includes an integrated test rig, a control platform, and state-of-the-art measurement instrumentation. For the integrated test system, there are three test modes, Venturi-section water tunnel, rotating disc and rotating disc with jet nozzle. All key parameters such as flow discharge, pressure, sand concentration, temperature etc., can be displayed online and processed in a control platform.

General description of ETS-HM

The ETS-HM is located in the Hydraulic Machinery Model Test Laboratory of IWHR in Beijing, China. The test system is equipped with an integrated test-rig, a control platform, and state-of-the-art measurement and other instrument tools to carry out experimental research on cavitation and severe sand abrasion by simulating the operation conditions comparable to those on site. The layout of the integrated test rig is showed in the Figure 1.

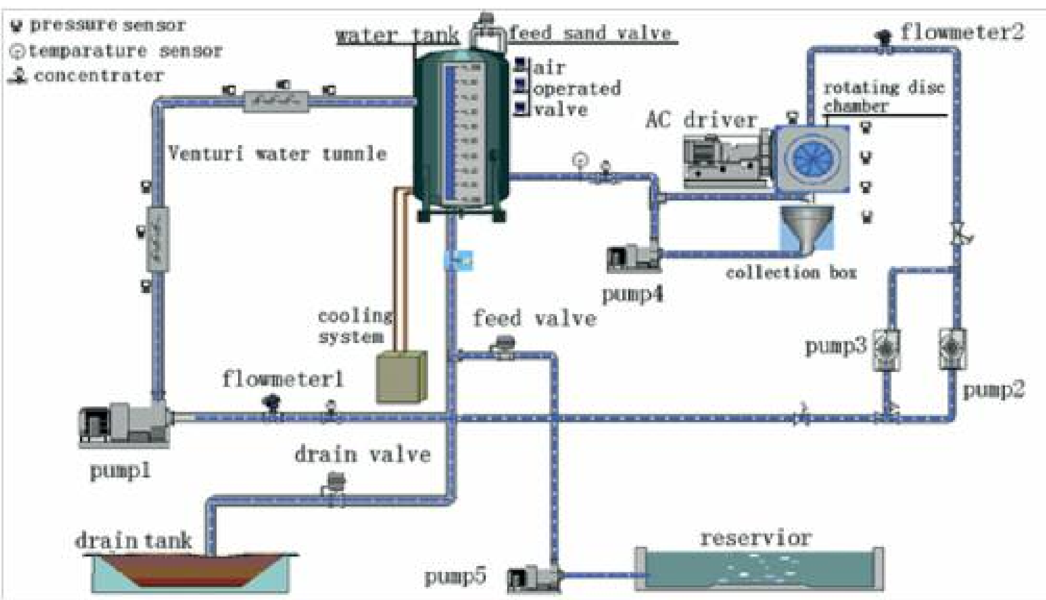
The water used in the tests is pumped (Pump5) to the water tank from an underground reservoir. For the case of sand abrasion tests, the water mixed with sand is sent to a drainage tank after the test.

The pressure in the circuit is adjusted by the air pressure in the water tank. There are three air operated valves in the water tank: an exhaust valve, a pressure valve and a vacuum valve, which can be controlled remotely in the PLC (Programmable Logic Controller) system to regulate the pressure in the tank. The pressure range of the test system can be regulated within a range from -0.09 MPa to 0.6 MPa.

The temperature of the flow in the circuit is controlled by a refrigerant heat exchanger in the water tank. The refrigerant heat exchanger is specially designed to increase the actual heat exchange surface area. In all tests, the temperature of the circulating flow can be controlled under 30℃. There are two temperature sensors in the test rig, one located in the water tank and another located in the outlet pipe (DN25) of the rotating disc chamber to monitor the temperature variations.

Liu Juan **started working at IWHR of China in 2006 after finishing her doctorate in fluid machinery at Tsinghua University. In the past ten years of her career she has been involved in research of fluid machinery cavitation and sand abrasion and has performed many experimental studies and engineering evaluation projects for hydropower stations in China. Since 2011, she has been working to develop the erosion test system for hydraulic machinery (ETS-HM) supported by the Chinese Ministry of Science and Technology.**

Figure 1. The layout of the integrated test rigs



The sand used during tests for sand abrasion is fed through a funnel inlet on the water tank and is mixed with water in the water tank. Sand feeding through the funnel can be controlled remotely using an electrically operated valve. The available measured maximum sand concentration in circuits for all test modes is 100 kg/m3. There are two sand concentration gauges in the test rig, one located in the outlet pipe (DN150) of the water tank, and another located in the outlet pipe (DN25) of the rotating disc chamber.

Choosing different test modes in the ETS-HM, different academic and engineering application research purposes can be accommodated. Research on only sand abrasion without cavitation can be conducted by the rotating disc with high speed jet nozzle test mode, of which the whole circuit is opening to the air to empty the water with sand. In this test mode, the relative flow velocity can vary from 0 to 120 m/s. For the other test modes, research on cavitation in clear water, sand abrasion without cavitation, and cavitation in water with sand can be conducted with the flow velocity from 0 to 45 m/s for the Venturi-section water tunnel test mode and the flow velocity from 0 to 80 m/s for the rotating disc test mode.

Integrated test rig

Venturi-section water tunnel test mode

The Venturi-section water tunnel test mode uses two Venturi water tunnels (vertical and horizontal), a water tank, and pump1 in the main circuit, as shown in the Figure 1. In this test mode, the effect of cavitation in clear water, sand abrasion without cavitation, and sand abrasion with cavitation on materials can be studied by changing operation condition. Research on the hydrodynamic characteristics of airfoils or cascades can also be conducted in the water tunnel.

For sand abrasion tests of material samples without cavitation, the average flow velocity in the throat section is changing continuously from 0 to 45 m/s, with the throat cross sectional area equal to 16 cm2。During sand abrasion tests the test sample of different materials is fixed at the surface of the constriction section, or at the throat section, or at the diffuser section.

Rotating disc test mode

In rotating disc test mode, there is a rotating disc chamber, an AC driver, a water tank, and pump2 in the main circuit with the DN25 pipe, as shown in the Figure 1. In this test mode, the effect of cavitation in clear water, sand abrasion without cavitation, and sand abrasion with cavitation can be studied by changing the operation condition and using a different support disc.

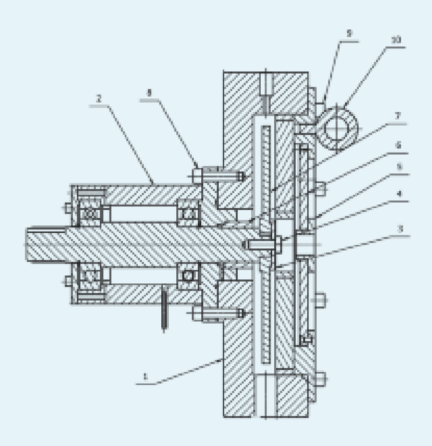


Figure 2. Structure of rotating disc chamber

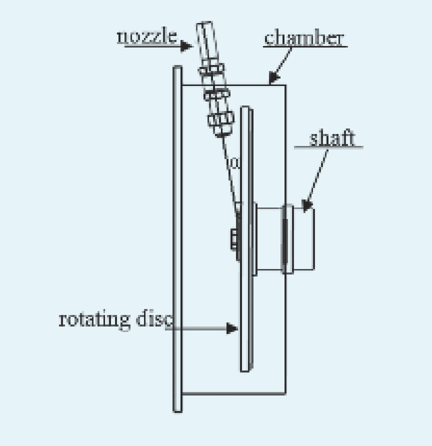


Figure 3. Rotating disc chamber with jet

As shown in Figure 2, the disc chamber is composed of 4 main parts: the back cover, marked as 1; the shaft (joint with shaft of AC driver), marked as 2; the front cover, marked as 5; and the rotating disc with the test sample, marked as 7. During the test, the disc with the test samples is rotating on a selected speed in the chamber, which is full with clear water or water with sand.

The front cover is designed with a set of cascades to simulate the plane flow around the flow passage surface of the hydraulic machinery components. The center part of the front cover is manufactured of transparent polymethyl methacrylate.

Rotating disc with high speed jet nozzle test mode

In the rotating disc with high speed jet nozzle test mode, there is a rotating disc chamber with jet nozzle, an AC driver, a water tank, and pump3, a collection box for water with sand in the main circuit with the DN25 pipe as shown in Figure 1. In this test mode, the rotating disc chamber is opening to the air to empty the water with sand. Only sand abrasion research on material can be conducted in this test mode.

The disc chamber with jet is designed with the structure shown in Figure 3. During the test, the water jet with sand from the nozzle impinges the test samples fixed on the rotating disc.

High-tech control platform

A high-tech control system PLC has been developed for the test system. All operations of pumps, valves and sensors are automatically controlled by the PLC system, and the necessary measurements such as flow discharge, sand concentration, pressure, and temperature during the test are displayed online and processed in highly efficient data acquisition and processing hardware.

Measurement and instrument tools

All necessary test parameters, such as discharge and pressure and sand concentration and temperature during testing, are measured using high-accuracy sensors or measuring devices. Besides, there are some state-of-the-art measurements and instruments, which are important and essential parts for the test system, such as the measurement tool for erosion loss of material, the analysis instrument for the sand particle size distribution and particle shape, the analysis and display apparatus for the flow field especially the two phase flow, etc.

To quantify the loss of material due to cavitation or sand abrasion or both, the high-precision electronic analytical balance (range: 220 g, readability: 0.1 mg) is used to measure weight loss of the eroded sample, and a three-dimensional auto surface profiler is applied to map the outline of the eroded surface, as well as to measure the volume loss of the eroded sample by integrating the erosion depth.

The sand particle size distribution and the sand shape are the primary parameters that determine erosion loss. The fast and high-resolution laser particle size and shape analyzer is applied for online analysis of the size and shape of sand particle circuiting in the pipe.

To measure the flow field, especially the gas-fluid and solid-liquid two-phase flow, the test rig is equipped with high-tech measurement technology and instrument, e.g. PIV (Particle Image Velocimetry) and a high speed camera system. The incipient, developing and collapse process of cavitation can be recorded by the high-speed camera system. ■

THE LOUISIANA STATE UNIVERSITY CENTER FOR COASTAL RESILIENCY KICKOFF SYMPOSIUM

BY SCOTT C. HAGEN

The global challenge of coastal resiliency requires interdisciplinary research with stakeholder involvement to yield transdisciplinary results and provide effective tools, products, and outreach. Continued advancement of computational models with integration of precipitation, overland flow, river discharge, tides, wind-waves, and surge processes is essential. However, we must go further and develop a better understanding of the dynamic, interrelated processes of natural and human systems through advanced systems-based models to assess effects of climate change and relative sea level rise.

"The best laid plans of mice & men ...

The idea of holding a symposium on coastal resiliency was first discussed by Peter Goodwin and Scott Hagen at the 2015 World Congress of IAHR. In February of 2016 now IAHR President Goodwin agreed to attend an event at Louisiana State University (LSU) later that year. On April 27, 2016 the Louisiana Board of Regents authorized the LSU Center for Coastal Resiliency (CCR) and a kickoff symposium was set for August 16, 2016. A wealth of experience was assembled in rapid succession including keynote speakers (Peter Goodwin, Center for Ecohydraulics Research at the University of Idaho; Rick Luettich, U.S. Department of Homeland Security (DHS) Coastal Resilience Center at the University of North Carolina; James Syvitski (Jai), head of the Community Surface Dynamics Modeling System (CSDMS) at the University of Colorado; and Larry Weber, Iowa Institute of Hydraulic Research (IIHR) – Hydroscience & Engineering at the University of Iowa), a panel from U.S. federal agencies (John Haines, U.S. Geological Survey (USGS); David Kidwell, National Oceanic and Atmospheric Administration (NOAA) / National Centers for Coastal Ocean Science (NCCOS); Jane Smith, U.S. Army Corps of Engineers (USACE); Richard Yuretich, National Science Foundation (NSF); and Robert Twilley, Louisiana Sea Grant College Program), and a regional panel (Michael Ellis, Louisiana Coastal Protection and Restoration Authority; Charles Groat, The Water Institute of the Gulf; Sam Bentley, LSU Coastal Studies Institute; Jeff Carney, LSU Coastal Sustainability Studio; Scott Hagen, LSU CCR; Nathaniel Plant, USGS St. Pete Lab; Suzanne Van Cooten, Lower Mississippi River Forecast Center; Clint Willson, LSU Center for River Studies; and Margaret Reams, LSU Department of Environmental Sciences). Flights and hotels were booked, auditorium reserved, flyers printed, etc. – the plans were laid.

... often go awry" – Robert Burns

The Louisiana Flood of 2016 hit southern Louisiana with the equivalent of a "1,000-year rain" over a two-day period ending at 7 a.m. on Saturday, August 13. Gov. John Bel Edwards stated that the cost of the floods were an estimated $8.7 billion, becoming the second billion-dollar flood to affect Louisiana in 2016. In addition, more than 55,000 homes and 6,000 business were affected in some way by this catastrophic event[1].

Those that flew into the Baton Rouge and New Orleans airports on Sunday and Monday, August 14 and 15, to participate in the August 16 kickoff symposium witnessed the devastation from above as displayed in the accompanying aerial photograph. Interstate 10, which directly connects New Orleans with Baton Rouge and the LSU campus, was flooded and the visitors flying into New Orleans had to cross the Mississippi river and arrive in Baton Rouge from the west. Nonetheless, all of the non-local symposium participants arrived on time. However, with the safety of the staff and attendees foremost in mind, in the afternoon of August 15 the large auditorium event (with a maximum 200 attendees registered) was cancelled.

Scott C. Hagen **joined Louisiana State University (LSU) in 2015 where he holds the Louisiana Sea Grant Laborde Chair and serves as the director of the LSU Center for Coastal Resiliency. He has joint appointments in civil engineering and with the Center for Computation & Technology. Scott, his colleagues, and their students are conducting interdisciplinary research in direct collaboration with stakeholders to produce transdisciplinary results. Together they have shifted the paradigm for hydrodynamic and ecological assessments of sea level rise, developed new technologies, and are helping coastal planners and emergency managers along the Gulf of Mexico and east coast of the U.S.**

Symposium transformed to workshop

In a matter of hours a meeting room was secured and the symposium was transformed into a workshop with all of the planned speakers (with the exception of three local leaders who attended directly to flood recovery duties) and 20 invited attendees.

In his keynote lecture Peter Goodwin remarked on the unfortunate timing of the flooding and the kickoff symposium, "It is never the wrong time to focus on resilience." Dr. Goodwin

Figure 1. Aerial photo of flooded homes near Denham Springs, Louisiana (NOAA)

incorporated examples from the San Francisco Bay-Delta in California to illustrate lessons learned on communication strategies with regards to balancing water supply reliability and ecosystem restoration. His focus was on how our research can inform policy and management. He posed four challenges to the engineering and scientific community including: Managing expectations; Monitoring to unravel system complexity; Restoration in disturbed landscapes; and, Choice of appropriate scales for experimental research. Peter concluded his talk with a quote from Alastair Smith, "At times of change, the learners will be the ones who will inherit the world, while the knowers will be beautifully prepared for a world that no longer exists."

Rick Luettich addressed the aspects of coastal resilience associated with managing risk: Quantifying it; Communicating it; and, Developing policy to reduce risk as opposed to enabling it to grow. He posed that given the nascent state of coastal resilience knowledge the time is right for investment in related research centers. In the developed world Louisiana is ground zero for coastal resiliency.

"Deltas, sinking deltas, and coastal resilience" was presented by James (Jai) Syvitski. He began his talk with an overview of CSDMS and then carefully articulated his points with data and exquisite illustrations: "when you add 50

> **"Many of the participants will reconvene at the 37th IAHR World Congress 2017 in Kuala Lumpur"**

million people to a delta (Nile), you limit channel avulsions to protect infrastructure and populations" and, "the sea is rising faster than the rate sediment could be deposited even if there were no dams."

Larry Weber reminded us that often times building coastal resilience begins in the upper basin. In the case of the Mississippi river deltaic system that beginning is thousands of river miles to the north. There he demonstrated how IIHR – Hydroscience & Engineering and the Iowa Flood Center are building resilience to flooding and transport of harmful nutrients at the source. Their approach branded as the Iowa Watershed Approach draws upon hydrologic assessment, watershed planning, real-time monitoring and detailed hydrologic models to place conservation practices (e.g. farm ponds, wetlands, perennial vegetation, etc.) throughout the watershed to reduce surface runoff during intense rainfall and process nutrients at all times.

The kickoff event and the Louisiana Flood of 2016 reminded us of a critical need that is lacking, which we need to develop to be successful in assessment and evaluation of coastal resiliency. We are and will be challenged by both hydrologic and hydraulic phenomena at the coastal land margin. Our efforts need to include better understanding of both coastal processes and improved integration of precipitation, overland flow, river discharge, tides, wind-waves, and surge processes in our future models.

Many of the participants will reconvene at the 37th IAHR World Congress to be held from August 13-18, 2017 in Kuala Lumpur, Malaysia. They will be joined by Robert Nicholls of the University of Southampton who will headline a special session entitled "The path to resiliency in low gradient coastal regions for present and future conditions." We hope you will be with us then. ■

References

1. C. Dolce. "Louisiana's Historic August Flooding Cost More Than $8 Billion, Officials Say." Internet: https://weather.com/news/weather/news/historic-august-louisiana-flooding-billion-dollar-disaster, Sep. 5, 2016 [Oct. 19, 2016].

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2017 – 2019 COUNCIL ELECTION

Nominating Committee 2017

At its meeting in Colombo, Sri Lanka in August 2016, the IAHR Council has identified a Nominating Committee (NC 2017) for the next Council election ahead of the World Congress in Kuala Lumpur, Malaysia, August 13th-18th, 2017. The Nominating Committee will be chaired by Bruce Melville (New Zealand), former IAHR Council Member, and comprises José Vargas (Chile), Christos Katopodis (Canada), Jeff Bradley (USA), Bruce Melville (New Zealand), Zhaoyin Wang (China), Ahmad Sana (Oman), Roger Falconer (UK), Teodoro Estrela (Spain) and Aronne Armanini (Italy). IAHR President Peter Goodwin (USA) is the Council contact person.

The NC collects proposals from individual and institute members, searches itself for candidates, and evaluates the performance of present Council members in view of their possible re-election. It must consider the alignment of candidates with Council composition requirements, including the question of progression of Council Members to Vice Presidential positions or to the Presidency.

It is the task of the NC to propose a list of candidates for the 2017 Council election, which includes four Executive Committee positions (President, and three Vice-Presidents) and at least four regularly elected Council members. This list must reflect a balance between the possibly conflicting requirements of:

- world-wide representation of the IAHR membership and yet at the same time a small active group which is capable to lead the Association, and to fulfil Council assignments;
- continuous renewal through new members while assuring necessary continuity;
- adequate representation of hydro-environment engineering practice.

Invitation to the membership for nomination of candidates

The Nominating Committee hereby invites all IAHR members to submit suggestions regarding nomination of possible candidates for Council. Please make your suggestions of potential Council candidates to any member of the NC 2017 before the end of January 2017, including a rationale for the suitability of the candidate proposed and an indication of the nominee's willingness to accept if elected. The Nominating Committee will give due consideration to all suggestions.

NC 2017 slate of candidates

The Nominating Committee will evaluate all proposed nominations with respect to their qualification for fulfilling the major tasks of the IAHR Council.

The IAHR Council has the task to promote the interests of the Association and co-ordinate the activities of its members serving the interests and needs of the hydro-environment engineering and research committees, both at global and at regional scale.

This includes long-range planning for the biennial World Congresses as well as co-ordination and interlinkage of activities of Regional and Technical Divisions and Committees, e.g. conferences, IAHR publications and Awards and promotion of continuing education, student chapters and short courses. Membership promotion, finances, IAHR secretariat liaison and links with institute members, industry and the profession are also important tasks, as well as relations with government agencies and other professional/technical societies and international organisations.

The Nominating Committee will develop a slate of candidates, which must be published according to the By-Laws by March 13th. This slate may contain up to two candidates for each position.

Any member wishing to receive a printed list of the slate of candidates should contact the Secretariat after this date.

Nomination by petition

If the Nominating Committee has not included your suggestion in its slate or if you have another suitable candidate not hitherto considered, all members have the option to file a nomination by petition within two months after publication of the NC 2017 slate. The new election procedure gives any group of members in the Association, which feels that its interests are not properly taken into account by the NC 2017 slate, the chance to submit nominations by petition for any of the eight regular Council member positions. A valid petition requires signatures of 15 members from at least five countries or from a group of countries representing 10% of the IAHR membership. This assures that there is support for a candidate which goes beyond a personal or national interest. All valid nominations by petition will be included in the ballot.

Nominations by Petition must be submitted to the Secretariat within two months after publication of the NC slate of candidates with a statement from the candidate, that she or he is willing to accept the nomination, a resumé including professional career, involvement in IAHR, and a statement on the planned contribution as Council member.

Ballot

The NC will submit its list of candidates to the Secretariat for publication together with any candidates "by Petition", reaching members at least two months prior to the congress. Members will be invited to elect the new Council through electronic ballot before and at Kuala Lumpur Congress, closing on Wednesday 16th August, 2017. ■

Contact:

NC 2017 Chair: Prof. Bruce Melville,
Former IAHR Council Member
b.melville@auckland.ac.nz

IAHR AWARDS
CALL FOR NOMINATIONS 2017

IAHR AIRH

Supported by Spain Water and IWHR, China

IAHR members are invited to submit nominations for the Arthur Thomas Ippen Award, Harold Jan Schoemaker Award, and M. Selim Yalin Award. These awards will be presented at the 37th IAHR World Congress, Kuala Lumpur, Malaysia, August 13th-18th, 2016.

IAHR Vice President Prof. Arthur Mynett is co-ordinating nominations received for the 2017 Award. The nominations should consist of a concise statement of the qualifications of the nominee, a listing of his/her outstanding accomplishments, pertinent biographical data, and a proposed statement of the endeavours for which the nominated awardee would be recognised. Each nomination should not be more than two typewritten pages in length.

Nominations for the three awards must be sent by January 31st, 2017 using the standard nomination form at www.iahr.org/About IAHR/Awards

20th Arthur Thomas Ippen Award

For outstanding accomplishment in hydraulic engineering and research

The Founding Statement and the Rules for Administration of the Award are as follows:

Founding Statement

The Ippen Award was established by the IAHR Council in 1977 to memorialise Professor Ippen, IAHR President (1959-1963), IAHR Honorary Member (1963-1974), and for many decades an inspirational leader in fluids research, hydraulic engineering, and international co-operation and understanding. The Award is made biennially by IAHR to one of its members who has demonstrated conspicuously outstanding ability, originality, and accomplishment in basic hydraulic research and/or applied hydraulic engineering, and who holds great promise for continuation of a high level of productivity in this profession. The awards are made at the biennial congresses of IAHR, where the most recent recipient delivers the Arthur Thomas Ippen Lecture. The Award fund, which was established by Professor Ippen's family, is authorised to receive contributions from association members and friends of Professor Ippen. The 2015 Award was made to Damien Violeau, France.

Rules for the administration of the award

The rules are published at www.iahr.org / About IAHR / Awards / 2017 IAHR Awards Call for Nominations or https://www.iahr.org/site/cms/contentCategoryView.asp?category=325

Previous Winners

D. Violeau, France (2015) for outstanding contributions in the field of fluid mechanics with special emphasis on turbulence modeling for addressing complex, real-life hydraulics problems.
G. Constantinescu, USA (2013) for outstanding contributions in the field of fluid mechanics and especially of turbulence modeling with applications to fluvial hydraulics and stratified flows.
X. Sanchez-Vila, Spain (2011) for his outstanding contributions in the field of groundwater flow and contaminant transport with application to flow modeling in heterogeneous porous media.
Y. Niño, Chile (2009) for his outstanding basic contributions in fluid mechanics with applications to sediment transport and environmental flow processes.
M. S. Ghidaoui, HK China (2007) for his outstanding contribution to research in environmental fluid mechanics.
A. M. Da Silva, Canada (2005) for her outstanding contributions in the area of fluvial processes and in particular, sediment transport.

20th Harold Jan Schoemaker Award

for the most outstanding paper in the Journal of Hydraulic Research

IAHR members are invited to submit candidates for nomination for the Harold Jan Schoemaker Award. This Award will be made for the 20th time at the 37th IAHR World Congress to the author(s) of the paper judged the most outstanding paper published in the IAHR Journal of Hydraulic Research in the issues, starting with Volume 52 (2014) no. 5 up to and including Vol. 54 (2016) no. 4. A proposal for nomination shall be completed with a clear argumentation (maximum one page) regarding its outstanding quality and why the paper is of such a specific quality that it outweighs the other papers of the considered series.

Founding Statement

The Schoemaker Award was established by the IAHR Council in 1980 to recognise the efforts made by Professor Schoemaker, Secretary (1960-1979), in guiding the Journal of Hydraulic Research in its formative years. The Award is made biennially by the IAHR to the author(s) of the paper judged the most outstanding paper published in the IAHR Journal.

Rules for the administration of the award

The rules are published at www.iahr.org / About IAHR / Awards / 2017 IAHR Awards Call for Nominations or https://www.iahr.org/site/cms/contentCategoryView.asp?category=325

Previous Winners

T. Stoesser (2015) for the paper "Large-eddy simulation in hydraulics: Quo Vadis?" (Vol. 52, 2014, Nº 4)
V. Heller (2013) for the paper "Scale effects in physical hydraulic engineering models" (Vol. 49, 2011, Nº 3)
H. Nepf (2013) for the paper "Hydrodynamics of vegetated channels" (Vol. 50, 2012, Nº 3)
U. Chandra Kothyari, H. Hashimoto and K. Hayashi (2011) for the paper "Effect of tall vegetation on sediment transport by channel flows" (Vol. 47, 2009, Nº 6)
H. Morvan, D.W.Knight, N.Wright, X.Tang (2009) for the paper "The Concept of Roughness in fluvial hydraulics and its formulation in 1D, 2D, and 3D numerical simulation models" (Vol. 46, 2008, Nº 2)
K. Blankaert and U.Lemmin (2007) for the paper "Means of noise reduction in acoustic turbulence measurements" (Vol. 44, 2006, Nº 1)
E.J. Wannamaker and E.E. Adams (2007) for the paper "Modelling descending carbon dioxide injections in the ocean" (Vol. 44, 2006, Nº 3)
A. Carrasco and C. A. Vionnet (2005) for the paper "Separation of Scales on a Broad Shallow Turbulent Flow" (Vol. 42, 2004, Nº 6)

6^{th} M. Selim Yalin Award

for significant and enduring contributions to the understanding of the physics of phenomena and/or processes in hydraulic science or engineering, and demonstrated outstanding skills in graduate teaching and supervision

IAHR members are invited to submit candidates for nomination for the M.Selim Yalin Award. This Award will be made for the 6th time at the 37th IAHR World Congress. The Founding Statement and the Rules for Administration of the Award are as follows:

Founding Statement

The M. Selim Yalin Award was established by the IAHR Council in 2006 to honour the memory of Professor M. Selim Yalin, Honorary Member (1925-2007), and Fluvial Hydraulics Section Chairman (1986-1991). Professor Yalin is remembered for his prolific and pioneering research contributions in fluvial hydraulics and sediment transport, and for his inspirational mentoring of students and young researchers.

The Award is made biennially by IAHR to one of its members whose experimental, theoretical or numerical research has resulted in significant and enduring contributions to the understanding of the physics of phenomena and/or processes in hydraulic science or engineering and who demonstrated outstanding skills in graduate teaching and supervision. The awards consisting of a certificate and cash prize are presented during the IAHR World Congresses. The Award fund, which was established by the family and friends of Professor Yalin, is authorised to receive contributions from association members and friends of Professor Yalin.

Rules for the administration of the award

The rules are published at www.iahr.org / About IAHR / Awards / 2017 IAHR Awards Call for Nominations or https://www.iahr.org/site/cms/contentCategoryView.asp?category=325once.

Previous Winners

A. Armanini, Italy (2015) for enduring theoretical, experimental and modeling contributions to the understanding of sediment and debris transport processes and excellence in graduate teaching and advancement of academic programs in hydraulic engineering.

Y. Shimizu, Japan (2013) for outstanding science and excellence in teaching and mentorship of young professionals as well as contribution to applied projects.

Prof. Ian Wood (2011) for outstanding contributions in the field of hydraulic engineering and especially in the experimental research of hydraulic structures, as well as in the teaching and supervision of graduate students from around the world.

I.Nezu, Japan (2009) for his outstanding research contributuions in both fundamental hydroscience (in particular for his pioneering work in turbulanece measurements and analysis) and applied hydraulic engineering, and for his dedication to teaching and young professional mentoring

G. Parker, USA (2007) for his outstanding achievements over thirty years in the field of sediment transport, river engineering, river morphodynamics and submarine sedimentation processes

IAHR EVENTS CALENDAR

IAHR Specialist Events

International Symposium and Exhibition on Hydro-environment Sensors and Software - HydroSenSoft
28 February 2017 - 03 March 2017
IFEMA, Madrid, Spain
www.hydrosensoft.com

4^{th} International Symposium on Shallow Flows (4th ISSF)
26 June 2017 - 28 June 2017
Eindhoven, The Netherlands
http://issf2017.tue.nl/

7^{th} International Conference on Flood Management (ICFM7)
05 September 2017 - 07 September 2017
Leeds, UK
www.icfm7.org.uk

III Latin American Meeting on Hydro Power & Systems
05 September 2017 - 07 September 2017
Quito, Ecuador
www.latiniahr.org

14^{th} IWA/IAHR International Conference on Urban Drainage (ICUD 2017)
10 September 2017 - 15 September 2017
Prague, Czech Republic
www.icud2017.org

10^{th} Symposium on River, Coastal and Estuarine Morphodynamics (RCEM2017)
18 September 2017 - 21 September 2017
Trento-Padova, Italy
http://events.unitn.it/en/rcem17

24^{rd} IAHR International Symposium on Ice
04 June 2018 - 15 June 2018
Vladivostok, Russia
Contact: mknuth@nsf.gov

7^{th} International Conference on the Application of Physical Modelling in Coastal and Port Engineering and Science (Coastlab'18)
06 June 2018 - 08 June 2018
Santander, Spain
Contact: inigo.losada@unican.es

13^{th} International Conference on Hydroinformatics (HIC2018)
01 July 2018 - 06 July 2018
Palermo, Italy
www.hic2018.org

12^{th} International Symposium on Ecohydraulics (ISE 2018)
19 August 2018 - 24 August 2018
Tokyo, Japan
www.ise2018.com

9^{th} International Conference on Fluvial Hydraulics (River Flow 2018)
03 September 2018 - 07 September 2018
Lyon, France
https://riverflow2018.irstea.fr/

29^{th} IAHR Symposium on Hydraulic Machinery and Systems
17 September 2018 - 21 September 2018
Kyoto, Japan
www.iahrkyoto2018.org

IAHR Regional Division Congresses

5^{th} Congress of the Europe Division of IAHR
June 2018 (TBC)
Trento, Italy
Contact: IAHR2018@unitn.it

21^{st} Congress of the Asia Pacific Division of IAHR
03 September 2018 - 05 September 2018
Yogyakarta, Indonesia
http://iahrapd2018.ugm.ac.id/

28^{th} Congress of the Latin American Division of IAHR
September – October 2018 (TBC)
Buenos Aires, Argentina
Contact: pspalletti@gmail.com

IAHR World Congress

37^{th} IAHR World Congress
13 August 2017 - 18 August 2017
Kuala Lumpur, Malaysia
www.iahrworldcongress.org

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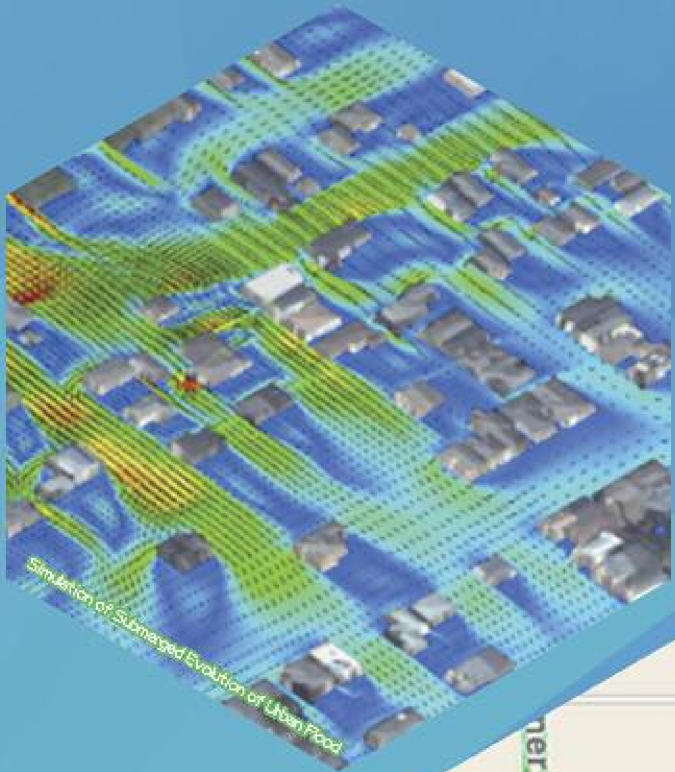

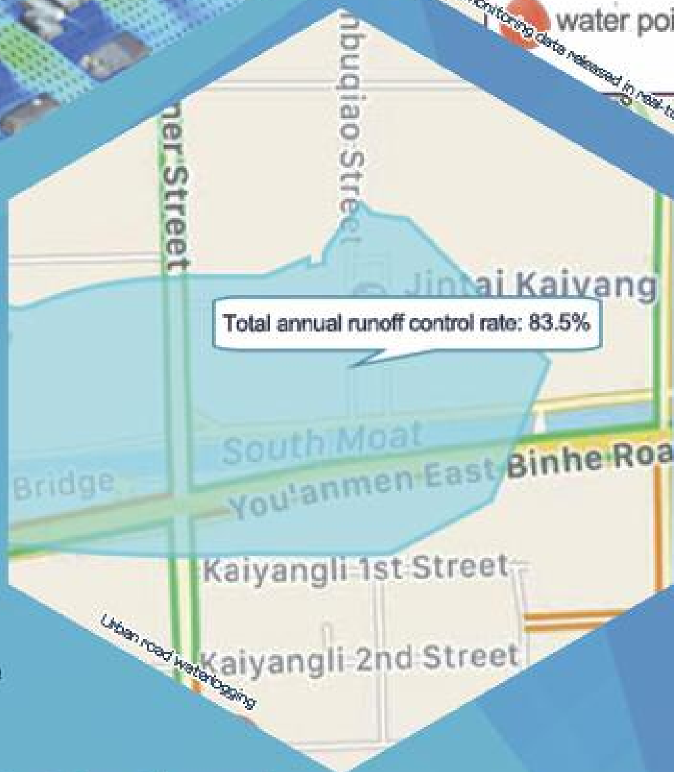

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