

**The 8th
International Conference on
Flood Management**

**“Lowering Risk by
Increasing Resilience”**

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CHAPTER 1: INTRODUCTION

Instead of ICFM8

Planning of the 8th International Conference on Flood Management (ICFM8) started at the 7th Conference held in Leeds, UK, on September 15 – 17, 2017. The proposal from IIHR—Hydroscience & Engineering at the University of Iowa, Iowa City, USA, to host the ICFM8 was accepted and preparations started immediately. Under the leadership of the Local Organizing Committee, the ICFM8 was planned for August 17 – 19, 2020, under the title “Lowering Risk by Increasing Resilience.”

And then came COVID-19. The pandemic has caused many events worldwide to be cancelled or postponed (from Olympics to professional meetings) due to imposed restrictions on travel and large gatherings. Many events have been modified to remove a live audience or be purely held over teleconference. We responded first by postponing the meeting in person for 2021 and then tried to organize ICFM8 as a virtual conference. Neither solution worked. With very hard feelings, the ICFM Ad Hoc Committee had to cancel the ICFM8.

However, not everything is cancelled: relationships are not cancelled; reading is not cancelled; dedication is not cancelled; imagination is not cancelled; conversations are not cancelled; and HOPE is not cancelled. Both years, 2020 and 2021, have been marked with reflection and change - some days feel good, and others feel strange. We are learning to work differently. We try to tune out the stress, but sometimes life still feels like a mess. We are trying to find ways to turn negatives into good and deal with new problems that we thought we never could. We are prevented from travelling and meeting in person. Our plans for ICFM8 have not been like we expected, but we’ve found new ways to stay connected. We had to make tough decisions. Things will get better because they usually do.

We decided to use this publication and one special ICFM webinar on August 10, 2021 “instead of ICFM8”. The book provides the summary of activities around the organization of ICFM8 and more than 160 abstracts accepted for the presentation at ICFM8 (out of a total 380). We are looking forward. With the publication of this book and the organization of the special ICFM webinar on August 10, 2021 we are starting the preparations for the ICFM9 in Tsukuba, Japan on February 22-24, 2023.

Thank you for ICFM8

Many people, organizations and technical staff invested tremendous effort in the organization of ICFM8. The ICFM Ad Hoc Committee would like to extend a big thank you to the ICFM8 local organizing committee:

Chair: *Marian Muste* (IIHR-Hydroscience & Engineering, The University of Iowa)

Conference co-chairs: *Gabriele Villarini* (IIHR-Hydroscience & Engineering, The University of Iowa); *Witold Krajewski* (Iowa Flood Center, The University of Iowa); and *Larry Weber* (Iowa Flood Center, The University of Iowa).

Conference secretary: *Laura Myers* (IIHR-Hydroscience & Engineering, The University of Iowa); and *Breanna Shea* (Iowa Flood Center, The University of Iowa).

Conference program team: *Allen Bradley* (IIHR-Hydroscience & Engineering, The University of Iowa); *Ibrahim Demir* (IIHR-Hydroscience & Engineering & UI Informatics Cluster); *Craig Just* (Sustainable Water Development Program, The University of Iowa); *Antonio Arenas* (IIHR-Hydroscience & Engineering, The University of Iowa); *Eric Tate* (Department of Geographical & Sustainability Sciences, The University of Iowa); *Nathan Young* (IIHR-Hydroscience & Engineering, The University of Iowa); and *Ricardo Mantilla* (IIHR-Hydroscience & Engineering, The University of Iowa).

Conference logistics & management: *University of Iowa Center for Conferences* (The University of Iowa); and *Tony Loeser* (IIHR-Hydroscience & Engineering, The University of Iowa).

The ICFM conferences always mobilize the support of our partners. We want to say thank you for your continuing support. We will continue working together on the organization of ICFM9. The ICFM8 partners:



China Institute of Water Resources and Hydropower Research (IWHR), A-1 Fuxing Road, Haidian District, 100038 Beijing, China



World Meteorological Organization (WMO), Climate and Water Department, 7bis, avenue de la Paix, CH-1211 Geneva 2, Switzerland



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The International Centre for Water Hazard and Risk Management (ICHARM), 1-6, Minamihara, Tsukuba-shi, Ibaraki-ken 305-8516, Japan



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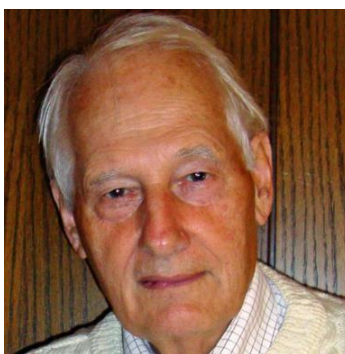
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Professor Erich Plate – in Memoriam

Prof. Dr.-Ing. Erich Plate, the founding father of the International Conference on Flood Management (ICFM) series, passed away on July 22, 2019, one week after his 90th birthday. He has brought unique contributions to flood risk management from basic theory to various applications. Since the ICFM creation in 2000, Professor Plate's vision about this conference



(1929 – 2019)

series has been maintained the same to this day: *“International Conference on Flood Management (ICFM) offers an international conference platform, hosted every 3 years, to discuss a range of flood-related issues and provides a unique opportunity for various specialists including engineers, planners, natural and social scientists, health specialists, disaster managers, decision-makers, and policymakers to come together to exchange ideas and experiences.”*

Erich J. Plate graduated from Stuttgart Technical University as a Civil Engineer in 1954 and there submitted his PhD thesis in 1964. He was appointed as professor of water resources at Stuttgart University, Colorado State University, and Karlsruhe Technical University. He was an active member and leader of the International Association for Hydro-Environment Engineering and Research.

He was a man of many talents and a visionary scientist in a number of fields. Coming from fluid mechanics, he established hydrologic engineering in Germany when he became full professor and director of the Institute for Hydrology and Water Resources Planning at Karlsruhe University (today Karlsruhe Institute of Technology). Despite his pronounced talent for theoretical considerations, he always strived for practical usage of solutions, eagerly pushing the innovative goals from the scientific to the practical world. This was the background of his devoted commitment to disaster reduction that commenced in the late 1980s. He became one of the principal driving forces in the German and international scientific community to direct activities in research towards disaster reduction, thus supporting the International Decade for Disaster Reduction (IDNDR) and initiating efforts that led to ICFM. Until almost his last moments he remained involved and highly interested in the ICFM activities. The ICFM community honored him, as a founding father, with the “*Erich Plate Best Young Scientist Poster Award*” presented at each ICFM conference and financially supported by one of the ICFM partners – The Institute for Catastrophic Loss Reduction (Canada). Professor Plate will always remain part of the ICFM series and his knowledge and vision will continue to guide the ICFM in the future.

Prepared with assistance of Drs. Wolfgang Kron and Zbyszek Kundzewicz

ICFM 2020 lifetime awards - Xiaotao Cheng & MSc Jos van Alphen

In 2020, the Ad Hoc Committee established the ICFM Lifetime Achievement Award, to honor those outstanding members who have made significant and sustained contributions to the advancement of ICFM and flood management at the international scale. The Lifetime Achievement Award is the highest honour bestowed upon an individual by ICFM.

WHO MAY RECEIVE THE AWARD - The award may be given to an individual or split between two individuals who have spent a minimum of 10 years making consistent and regular contributions to the International Conference on Flood Management.

WHEN IS THE AWARD GIVEN - The ICFM Ad Hoc Committee felt that it was important to ensure not only that the award go to individuals whose achievements are outstanding, but also to ensure that the award remain a special award, not something done out of annual habit. Therefore, we suggest that the conference consider giving the award every three years (to coincide with the organization of ICFM conferences).

HOW ARE THE AWARDEE(S) NOMINATED – Members of the ICFM community can nominate candidates for the award at any time by sending nominations to the ICFM permanent secretariat. When the preparations for the ICFM conference start, the community will be reminded by receiving information together with the call for papers. These nominations should be prepared in accordance with the criteria listed below. In addition to the nomination a vitae must be submitted.

WHO SELECTS THE AWARDEE(S) - An awards committee of at least three individuals will be elected at the Ad Hoc Committee meeting the year before the award is given. This committee will review the nominations and vitae submitted for each nominee and will make the final decision.

WHAT ARE THE CRITERIA FOR THE AWARD - The award will be given based on how well the individual meets standards listed under these categories: (1) contribution to the sustainable flood management for increasing resilience; (2) promotion of the ICFM; (3) active participation at the ICFM conferences; and (4) taking an active role in public education.

The 2020 recipients of the ICFM Lifetime Award are **Prof. Xiaotao CHENG** and **MSc. Jos van ALPHEN**

Nomination of Prof. Xiaotao Cheng:



Prof. Xiaotao Cheng, the chief editor of the Chinese Journal of Hydraulic Engineering (Shui Li Xue Bao) and the former Deputy Chief Engineer from China Institute of Water Resources and Hydropower Research (IWHR), is a leading voice in flood management, both in China and worldwide. He has provided significant contributions to flood risk theory, flood simulation and forecast, emergency response, decision support systems, flood insurance, etc. During the past two decades, he has significantly contributed to the growth and prosperity of ICFM by taking an active role in organizing conferences, initiating management mechanisms, making strategic and critical decisions, and promoting ICFM's international profile. He played a central role in the organization of the 2nd ICFM conference in Beijing in 2002, where he proposed the establishment of a permanent committee (now called Ad Hoc Committee) to ensure the efficient operation of ICFM. At the 4th ICFM conference, he actively contributed to the change of the conference series name to reflect the switch from "Flood Defence" to "Flood Management". This was a milestone in the history of ICFM - from the 4th conference, the original name "International Symposium on Flood Defence" has been replaced by the current "International Conference on Flood Management." Prof. Cheng has widely published and presented his work and served as a senior advisor to multiple organizations in and out of China, including Thailand, Pakistan, Japan, among others.

Short bio of Prof. Xiaotao Cheng

Dr. Cheng Xiaotao is a professor and former director of the Research Department of Water Hazards and former vice chief engineer of the Institute of Water Resources and Hydropower Research (IWHR) where he has been a researcher from 1985 until 2015. He completed his Ph.D. at DPRI of Kyoto University in 2003. He is now a member of the expert team of the China Nation Disaster Reduction Committee, the Chief Editor of Journal of Hydraulic Engineering, the director of the Urban Water Management Committee of CHES and Vice Chairman of Flood Risk Management Committee of IAHR. His research interests lie in the area of flood control and flood risk management, ranging from strategic planning to emergency response.



Nomination of MSc. Jos van Alphen



Mr. Jos van Alphen, presently a co-leader of the Dutch National Sea Level Rise Impact Research Programme and a member of the Delta Programme Commissioner, has been committed to sustainable coastal protection, river management, as well as development of flood protection standards for over 30 years. He started his devotion to ICFM since 2002, when he joined the 1st Standing Committee and proposed to lead the team which hosted the 3rd ICFM conference. In 2005, he organized the 3rd International Symposium on Flood Defence (Nijmegen, The Netherlands) and became a member of the ICFM Ad Hoc Committee. In the past two decades, he has been playing an essential role in the development of ICFM. During his career, he cooperated with many international flood risk and delta management organizations in Bangladesh, China, Japan, USA, and EU countries.

In addition, he serves as a technical consultant to many research institutes and is involved in the coordination of several research programmes, including the European Floods Directive.

Short bio of MSc. Jos van Alphen

Jos van Alphen (1958) graduated at Utrecht University, The Netherlands, in Physical Geography in 1983. From 1984 - 2010 he was employed at different positions in the Ministry of Transport, Public Works and Water Management / Rijkswaterstaat and involved in the coastal zone and river management. Regarding flood risk management, he was involved in the implementation of the European Floods Directive. In 2005 he organized 3rd International Symposium on Flood Defence (Nijmegen, The Netherlands) and became a member of the ICFM Ad Hoc Committee. After supporting the Dutch Committee on Sustainable Coastal Protection ('2nd Delta Committee'), in 2010 he joined the Dutch Delta Programme Commissioner's Staff, e.g. on the development of new national flood protection standards. Presently he is co-leader of the Dutch National Sea Level Rise Impact Research Programme.



ICFM now

The ICFM is evolving with changing flood management landscape and COVID-19 pandemic. Since ICFM7 the ICFM Ad Hoc Committee implemented a new set of activities to keep the flood management community engaged and connected. The key changes and activities are presented here.

Activities

Update of the ICFM Ad Hoc Committee membership – The Ad Hoc Committee membership is voluntary and open for anyone interested in the work of ICFM. We welcome you with open arms. Here is the current list of the Ad Hoc Committee members:

Slobodan P. Simonovic, The University of Western Ontario, London, Canada – the chairperson

Subhankar Karmakar, Indian Institute of Technology Bombay, Mumbai, India – the vice-chairperson

Mishra Anil, United Nations Educational, Scientific and Cultural Organization, UNESCO, Paris, France Ali

Chavoshian, UNESCO Regional Centre on Urban Water Management, Tehran, Iran

Andre Schardong, ALTEN Engineering and Technology Consulting, Porto, Portugal Dan

Sandink, Institute for Catastrophic Loss Reduction (ICLR), Toronto, Canada

Nirupama Agrawal, York University, Toronto, Canada

Jing Peng, China Institute of Water Resources and Hydropower Research, Beijing, China

Johannes Cullmann, Water and Climate Dept., World Meteorological Organization Geneva, Switzerland Jos

van Alphen, Delta Commissioner, The Hague, The Netherlands

Marian Muste, IIHR—Hydroscience & Engineering, The University of Iowa, Iowa City, USA Nigel

G. Wright, De Montfort University, Leicester, UK

Paul Kovacs, Institute for Catastrophic Loss Reduction, Toronto, Canada

Giriraj Amarnath, International Water Management Institute (IWMI), Sri Lanka

Toshio Koike, International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Ibaraki-ken, Japan

Xiaotao Cheng, China Institute of Water Resources and Hydropower Research, Beijing, China

Permanent ICFM secretariat – China Institute of Water Resources and Hydropower Research in Beijing graciously offered to host the ICFM permanent secretariat. The work of ICFM has been tremendously enhanced with the support of the secretariat. The list of secretariat personnel is here:

Cheng Zhang, China Institute of Water Resources and Hydropower Research, Beijing, China, Director

Chongshan Guo, China Institute of Water Resources and Hydropower Research, Beijing, China

Wenyang Li, China Institute of Water Resources and Hydropower Research, Beijing, China

Hongbin Zhang, China Institute of Water Resources and Hydropower Research, Beijing, China

ICFM website – After the decision made at the ICFM7 and the assistance of the permanent secretariat, a new ICFM website has been launched www.icfm.world. The website offers a reach database of ICFM information. It provides links to basic information on ICFM history; list of the Ad Hoc Committee members; current flood-related news from all around the world; depository of all ICFM conferences with proceedings, programs, and declarations; recordings of all ICFM webinars with presentations available for download; and set of documents representing current views of major flood management issues.

ICFM and social media – The presence of ICFM on social media is maintained at two different locations: Twitter @ICFM_InternationalConferenceonFloodManagement or @IcfmI and WeChat : @国际洪水管理大会ICFM
Please follow us on social media and provide your contribution by posting your information.

ICFM webinars

Due to COVID-9 pandemic and uncertainty associated with the organization of ICFM8, the Ad Hoc Committee decided to initiate the ICFM series of webinars. With the assistance of the Permanent Secretariat in Beijing, we have successfully organized six ICFM webinars with audiences between 150 and 500 people. The webinars are very well accepted, and recordings of the webinars together with the presentations, are available through the ICFM website. Here is the list of past webinars with the names of webinar guests:

Webinar 1: Doubled crises - Flooding in a Time of Pandemic. Panellists: Zbigniew Kundzewicz, Polish Academy of Sciences, Poland; Cheng Xiaotao, IWHR, China; and Nigel G. Wright, Nottingham Trent University, UK. May 28, 2020.

Webinar 2: The Flood Challenge to Resilience. Panellists: Jun XIA, Chinese Academy of Sciences, Wuhan University, Wuhan, China; Toshio KOIKE - Professor, International Centre for Water Hazard and Risk Management, Tsukuba, Japan; Molly FINSTER - Argonne National Laboratory, US Department of Energy, Argonne, Illinois, USA; and Carol FREEMAN - Argonne National Laboratory, US Department of Energy, Argonne, Illinois, USA. August 27, 2020.

Webinar 3: Lowering Risk by Increasing Resilience. Panellists: Marian Muste; Gabriele Villarini; Witold F. Krajewski; and Larry Weber, IIHR—Hydroscience & Engineering, the University of Iowa. November 5, 2020.

Webinar 4: Managing Risks from Icejam Floods. Panellists: Tomasz Kolerski, IAHR Committee on Ice Research and Engineering, Poland; Guo Xinlei, China Institute of Water Resources and Hydropower Research (IWHR), China; and Karl- Erich Lindenschmidt, University of Saskatchewan, Canada. February 5, 2021.

Webinar 5: Flooding and the Value of Water. Panellists: András Szöllösi-Nagy, the National University of Public Service (NUPS), Budapest, Hungary; and Pradeep Mujumdar, Indian Institute of Science, Bangalore, India. March 22, 2021.

Webinar 6: Real-time Urban Flood Forecasting - Current Status and Future Challenges. Panellists: Subimal Ghosh, Indian Institute of Technology Bombay, Mumbai, India; Zongxue XU, Beijing Normal University; and Roxy Mathew Koll, Indian Institute of Tropical Meteorology, Pune, India. June 14, 2021.

ICFM9 announcement Tsukuba, Japan, February 22-24, 2023

We are very happy to announce that the ICFM Ad Hoc Committee received an offer from The International Centre for Water Hazard and Risk Management (ICHARM), Tsukuba, Japan for hosting ICFM9 in February of 2023. A preliminary host proposal:

Theme: River Basin Disaster Resilience and Sustainability by All - Integrated Flood Management in the Post COVID-19 Era

Objectives: More frequent, severe torrential rainfall events due to climate change have increased human losses and economic damage. The number of people vulnerable to devastating floods will continue to rise due to large-scale urbanization, population growth in flood-prone areas, deforestation, climate change and rising sea levels. In the current COVID-19 environment, immediate attention in the world often focuses on preventing further virus infection. However, the threats of floods remain as imminent now as before the pandemic. If we fail to learn lessons and improve our society to become more resilient to changes and disturbances, flood disasters will hit humanity even harder.

Starting with the adoption of "The Sendai Framework for Disaster Risk Reduction 2015-2030" at the third United Nations World Conference on DRR in March 2015, the international community agreed on the "Transforming Our World: the 2030 Agenda for Sustainable Development" in September 2015 and "The Paris Agreement on Climate Change" in December 2015. To support and implement those agreements, concerted, solid and strategic actions should be taken to enhance climate and disaster resilience and sustainability.

Flood disaster resilience and sustainable development are closely and structurally interlinked. For this reason, it is necessary to understand their issues in a comprehensive manner beyond disciplines, promote holistic, integrated and interdisciplinary approaches, and conduct planning, implementation and evaluation for resolution. Based on this conviction, the ICFM9 will comprehensively discuss a wide range of related issues from scientific, technological, social and economic perspectives.

The ICHARM is well positioned to serve as a local host of the ICFM9 in collaboration with several key organizations of Japan, including MLIT, JICA, JWA, JAXA and JMA. As the IFI Secretary, ICHARM will also coordinate the IFI partners, UNESCO, WMO, UNDRR, UNU, ICLR, IAHS and IAHR, towards a great success of the key ICFM event in 2023. Furthermore, ICHARM will encourage and coordinate participation from many countries in Asia, Africa and Latin America to liven up discussions to be held at the ICFM9.

Date and Place:

February 22 to 24, 2023.

Venue: Epochal Tsukuba International Congress Center, Tsukuba, Japan <https://www.epochal.or.jp/en/>. Study Tour: February 25, 2023

Tsukuba is a city located in Ibaraki Prefecture, Japan. The town is ideally located, approximately 50 kilometres from central Tokyo and about 40 kilometres from Narita International Airport. From the 1985 Expo, Tsukuba got the status as Japan's leading hi-tech research and development center. In the city center, Tsukuba Expo Center has interactive science displays and a planetarium. Tsukuba Space Center has a rocket engine and exhibits on space exploration. North, a funicular railway and cable car run to the twin peaks of Mount Tsukuba, known for its beautiful fall colours. At the foot of the mountain, Tsukubasan Shrine greets visitors since the 7th century.

UN High-Level Preconference Meeting:

February 21, 2023.

Venue: National Graduate Institute for Policy Studies (GRIPS) <https://www.grips.ac.jp/en/>.

A half-day symposium on "Enhancing Water-related Disaster Resilience and Sustainability(tbc)" will be organized by the High-level Experts and Leaders Panel on Water and Disasters (HELP) < <https://www.wateranddisaster.org/>> which assists the international community, governments and stakeholders in mobilizing political will and resources and promotes actions to raise awareness, ensure coordination and collaboration, establish common goals and targets, monitor progress, and take effective measures aimed at addressing the issues of water and disasters. Attendance to the symposium will be available for the ICFM9 participants.

CHAPTER 2

FLOODS AND THE COVID-19 PANDEMIC – A NEW DOUBLE HAZARD PROBLEM

This is the paper published by *WIREs Water* on the basis of the ICFM Webinar 1 discussion. Comments are welcome.

The full reference:

Simonovic SP, Kundzewicz ZW, Wright N. Floods and the COVID-19 pandemic—A new double hazard problem. *WIREs Water*. 2021;e1509. <https://doi.org/10.1002/wat2.1509>

Floods and the COVID-19 pandemic—A new double hazard problem

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Abstract

The coincidence of floods and coronavirus disease 2019 (COVID-19) is a genuine multihazard problem. Since the beginning of 2020, many regions around the World have been experiencing this double hazard of serious flooding and the pandemic. There have been 70 countries with flood events occurring after detection of the country's first COVID-19 case and hundreds of thousands of people have been evacuated. The main objective of this article is to assess challenges that arise from complex intersections between the threat multipliers and to provide guidance on how to address them effectively. We consider the limitations of our knowledge including “unknown unknowns.” During emergency evacuation, practicing social distancing can be very difficult. However, people are going to take action to respond to rising waters, even if it means breaking quarantine. This is an emergency manager's nightmare scenario: two potentially serious emergencies happening at once. During this unprecedented year (2020), we are experiencing one of the most challenging flood seasons we have seen in a while. Practical examples of issues and guides for managing floods and COVID-19 are presented. We feel that a new approach is needed in dealing with multiple hazards. Our main messages are: a resilience approach is needed whether in response to floods or a pandemic; preparation is vital, in addition to defense; the responsible actors must be prepared with actions plans and command structure, while the general population must be involved in the discussions so that they are aware of the risk and the reasons for the actions they must take.

This article is categorized under:

Engineering Water > Methods

KEYWORDS

COVID-19, floods, management, multihazard, natural disasters, resilience

1 | INTRODUCTION

Since the beginning of 2020, people around the World have been living with the consequences of the global coronavirus disease 2019 (COVID-19) pandemic. Most people's mobility is severely restricted. They are instructed to maintain social

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distancing and to wear face masks in public places. Many have had to adjust to online working. Personal hygiene (especially frequent hand washing) has taken a prominent place in everyday activities. Links between the COVID-19 pandemic and water security, water management and water use are already being investigated (Keulertz, Mulligan, & Allan, 2020; Neal, 2020; Staddon et al., 2020). However, at the same time, many regions around the World have been experiencing a double, integrated hazard—serious flooding and a pandemic. Papers on floods and COVID-19 are now being produced and published in academic journals. This article includes references to a sample of relevant publications available so far (also in the early-online mode). Some papers are dedicated specifically to floods and COVID-19, in the national context (for China—Guo et al., 2020; Japan—Ishiwatari, Koike, Hiroki, Koda, & Katsube, 2020; United States—Shen, Chenkai, Yang, Anagnostou, & Li, 2021). Han and He (2021) noted that urban flash floods that are on the rise in the warming climate pose risks of COVID-19 spread. Other references extend beyond floods, for example, covering compound climate risks (Phillips et al., 2020) as well as drought, fire and flood (McDonald, 2020).

Every few days, people are adversely impacted by floods somewhere in the world. This seemingly bold, global, statement is backed up by evidence gathered by the Flood Observatory at the University of Colorado (<http://floodobservatory.colorado.edu/Version3/MasterListrev.htm>, accessed September 26, 2020). The Observatory detects these impacts by monitoring the abundance of water, via remote sensing, in normally dry places all over the world. The authors' personal experience will point only to regions of the world where they live and practice. Broader global information is provided in the following section.

1.1 | Canada

The spring season of 2020 brought a series of floods in Canada. Days of heavy rain caused flooding in parts of western Canada. Some areas of British Columbia recorded more than 370 mm of rainfall from 30 January to 01 February. Many regional districts declared a local state of emergency. As a result of this rainfall, there has been severe localized flooding, landslides, and rockfall damaging potable water infrastructure.

Evacuations were ordered in Alberta, Canada, after snow melt and ice jams caused rivers to rise from around April 25, 2020. The region declared a state of emergency on 26 April due to high water levels of the Athabasca, Snye and Clearwater rivers. The ice cover broke up at many locations, forming ice jams downstream. The ice jams raised water levels along the Athabasca and Clearwater rivers between 4.5 and 6 m at some locations (like Fort McMurray). Since the jams could release at any time, potentially impacted residents had to be evacuated.

In July, around 40 homes have been evacuated in Manitoba, Canada, amid fears a dam on the Little Saskatchewan River will fail. The dam was facing unprecedented flows following heavy rains over the period of time (July 1–3, 2020). Provincial and consulting engineers had indicated there was potential for a structural failure and authorities called for evacuations in the area. This evacuation came after a weather system had brought significant precipitation in southwest and west Manitoba. Some areas received record-precipitation of more than 200 mm during this period (July 1–3, 2020).

Spring flood season in Ontario, Quebec, and Canadian East Coast ended without the major flooding seen in the previous couple of years. Water levels in all areas decreased and returned to normal range before end of the spring. Officials remarked that water flows this year looked nothing like 2018 and 2019, which saw record flooding that destroyed homes and closed roads and highways. The annual River Watch Program was in place from March 9 and provided information on the status of rivers and the potential for ice jams and other flood issues. After 10 weeks in operation, the River Watch Program for the 2020 season terminated.

1.2 | Poland

In Poland, the meteorological and hydrological situation in 2020 was subject to large spatial and temporal variations. After two dry years, 2018 and 2019, this year saw a wet and warm February, but the winter precipitation was mostly rain not snow, so did not help in augmenting soil moisture in spring via snowmelt. This was followed by a dry April, leading to large areas of the country being on the verge of severe drought, but from May to September. Despite the overall drought, there were many heavy rainfall events that led to local inundation. In particular, the latter part of June was very wet in the south of Poland, with rainfall of 152 mm over 24 hr in Jodlownik (Malopolskie Voivodship).

This heavy rain increased water levels significantly in the Stream Stradomka—by five meters in less than 1 day. A large part of the Commune of Lapanow (County of Limanowa) was inundated, with considerable material damage to infrastructure (roads, homes) as well as to agriculture and animals. There were also landslides. At several gauging

stations in the main rivers in Poland, the Vistula and the Odra, alarm stages were exceeded. On 21 June, the alarm stage was exceeded at 22 gauges in the Odra River Basin, while on 23 June, the alarm stage was exceeded at 11 gauges in the Vistula River Basin.

Although there were numerous flash floods caused by intense rainfall in the summer of 2020, the total flood damage in Poland in 2020 has been far lower than during the large summer deluges of 1997, 2001, and 2010. In contrast to these dramatic events, floods in 2020 did not cause fatalities. In 2020, inundations mostly affected the south of Poland (Podkarpackie, Malopolskie, Slaskie, and Dolnoslaskie voivodships), where the number of detected COVID-19 cases was consistently higher than in most other Polish provinces, so that there was a co-location of flood hazard and COVID-19 infection.

1.3 | United Kingdom

In the spring of 2020, the UK was impacted by a series of storms, the most serious of which was Storm Dennis from 15 to 19 February. On 16 February, severe flooding was reported across England. In the East Midlands, the River Soar flooded the town of Loughborough. Rail services were impacted by flooding between Derby and Long Eaton, affecting services between London, Derby, and Sheffield. Across the City of Nottingham, bus services of several companies were affected. Between Cambridge and Potters Bar, commuter trains to London were impacted by a tree on the line. Numerous outdoor events were canceled due to heavy rainfall and waterlogging.

In the West Midlands, a major incident was declared when river levels rose higher than the previous historic high of 2007 leading to damage to many properties and at least one death (<https://news.sky.com/story/storm-dennis-river-rye-reaches-highest-level-for-200-years-11936537>, accessed October 3, 2020).

In Wales, there were severe impacts with flooding at historically high levels. In the Rhondda (<https://www.bbc.com/news/uk-wales-51517529>, accessed October 3, 2020), more than 160 mm of rain was recorded in a 48 hr period. A major incident was declared by emergency services. Hundreds of homes were flooded across the region. In some areas, further damage was caused by flood water carrying cars and other debris. A further consequence was the occurrence of landslides causing further damage, which is indicative of the significant challenge to the UK transport infrastructure.

The City of Leeds had recently had new defenses implemented at a cost of £50 million with channel widening, raised defenses and movable weirs. These proved to be effective in lowering the level of the River Aire protecting over 3,500 vulnerable houses and businesses (<https://twitter.com/EnvAgencyYNE/status/1228965407199039489?s=20>, accessed October 3, 2020).

The UK Prime Minister convened emergency response meetings and subsequently announced tax relief for households and businesses. While flooding is often seen as being driven by physical factors it also has social and economic aspects. The severity of flooding depends on the unfavorable coincidence of specific temporal and spatial conditions with social and economic conditions. The COVID-19 pandemic can be described as a threat multiplier. Globally, changing conditions are considered to be flood threat multipliers too. We now have several threat multipliers that intersect with flood management challenges.

The main objective of this article is to assess the challenges that arise from complex intersections between the threat multipliers and provide guidance how effectively to address them. The following section of the manuscript discusses the multiple hazards and their nature. Section 3 presents the limitations of our knowledge, and Section 4 offers our view of flood management under the pandemic conditions. In Section 5, we offer some views of the future. The article ends with final concluding remarks and recommendations in Section 6.

2 | MULTHAZARD: COINCIDENCE OF INDEPENDENT EVENTS OR CAUSE-EFFECT CHAIN?

Flooding is a serious problem that could complicate the significant and wide-ranging measures countries have taken to fight the coronavirus pandemic (see flooding examples in the introduction). Significant flooding adds a whole additional layer of challenge to full-blown assault against the pandemic. For example, community sandbagging is more difficult when everyone is practicing social distancing and people are in self-isolation. During emergency evacuation, practicing social distancing can be very difficult, even impossible. The economic damage being caused by the virus has also destabilized people's jobs and financial welfare, limiting their ability to absorb unexpected costs from flooding. Public security officials also warned that the risk of contamination from the virus means that emergency shelters may not be available for people who

are forced out of their flooded homes. However, people are going to take action to respond to rising waters, even if it means breaking quarantine. This is an emergency manager's nightmare scenario: two potentially serious emergencies happening at once. 2020 has been one of the most challenging flood seasons seen in a while.

The coincidence of floods and COVID-19 is a real issue of the multihazard type, where the underlying hazards refer to independent events. However, in other cases, multiple hazards may not be independent. They may rather manifest a cause-effect chain, such as the disastrous Fukushima event on March 11, 2011, where a natural disaster (abundance of water due to a tsunami caused by a huge earthquake), caused a technological disaster (an unstoppable nuclear disaster at the Fukushima Daiichi nuclear plants).

Our world is filled with dynamic systems and epidemics are one such dynamic system. The more you look at the world around us, the more examples can be seen (populations, economies, climate, urbanization, and other examples). The system view is an effort to understand how dynamic systems operate (Simonovic, 2011). The goal behind system theory is to improve our decision-making processes to adapt to the dynamic attributes of complex systems. The systems view of epidemics is limited by our slow recognition of a change when it is happening and our slow response to that change.

On the other hand, a systems view of flooding states that flood losses are the result of interaction among three systems and their main subsystems: (a) the Earth's physical systems (e.g., the atmosphere, biosphere, cryosphere, hydrosphere, and lithosphere); (b) human systems (e.g., population, culture, technology, social order, economics, and politics); and (c) the constructed systems (e.g., buildings, flood defenses, roads and railways, bridges, public infrastructure, cultural heritage objects, cemeteries, and other).

Human systems include epidemics, and this is how a systems view must be used to integrate floods and pandemics. Potential solutions to integrated disaster management lie in (a) a definition of integrated disaster management as an iterative process of decision-making regarding prevention of, response to, and recovery from a disaster (in this case combined flooding and corona virus pandemic); and (b) a set of principles elaborated in Simonovic (2011, p. 73).

There have been 70 countries (Figure 1) with flood events occurring after detection of the country's first COVID-19 case and the number of such countries keeps growing. Table 1 illustrates the dates of emergence of the first COVID-19 case in a country that was subject to a flood afterwards, that is, during the duration of the pandemic. There were 22 such countries in Africa, 25 in Asia, 8 in Europe, 8 in North America, 2 in Oceania, and 6 in South America, adding up to 70, globally (Russian Federation is counted once in the global total, but it is counted at two continents—Europe and Asia). The number of displaced people in some of these floods during the pandemic was very high. For example, in South China 634 rivers flooded and nearly 64 million people were affected. The death toll reached 219 and over 54,000 properties were destroyed (as of August 30, 2020). Over a hundred thousand people in Uzbekistan and Kazakhstan were

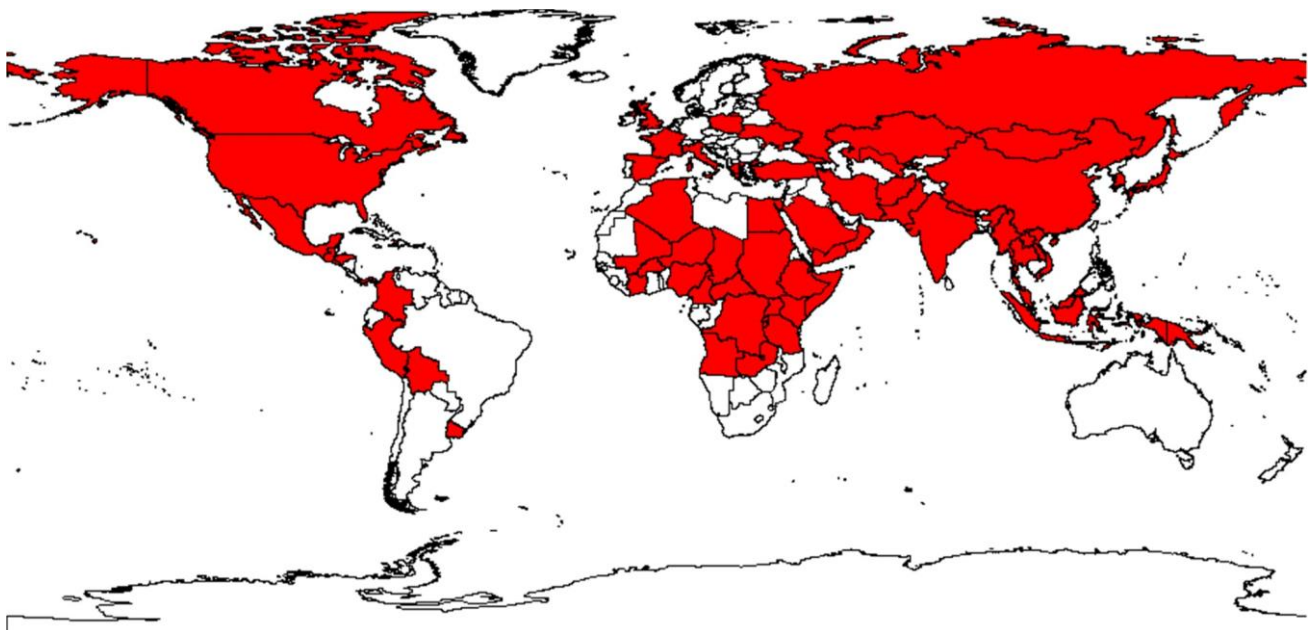


FIGURE 1 In 70 countries, flood events occurred during the pandemic, that is, after detection of the first COVID-19 case

TABLE 1 Dates of emergence of the first detected COVID-19 case in a country that was subject to a flood afterwards, that is, during the duration of the pandemic in 2020

Region	Country	Emergence of first COVID-19 case in 2020	Dates of flood events in 2020 after the first COVID-19 case
Africa	Algeria	25 February	16–18 May
	Angola	21 March	18–24 April
	Burkina Faso	9 March	19–26 April
	Burundi	31 March	19–26 April
	Cameroon	6 March	20 August
	Central African Republic	14 March	24–30 May
	Chad	19 March	20–26 April, 25 August
	Congo, D.R.	10 March	17 March–3 April, 16–20 May
	Djibouti	18 March	21–26 April
	Egypt	14 February	12–15 March
	Ethiopia	13 March	20–28 April, 8 August
	Ivory Coast	11 March	24–26 June
	Kenya	12 March	27 March–27 April, 25 August
	Mali	25 March	12 August
	Niger	19 March	8 August
	Nigeria	27 February	11 August
	Rwanda	14 March	19–26 April
	Somalia	16 March	20–28 April
	Sudan	13 March	3 August, 13 August
	Tanzania	16 March	24–27 April
Uganda	20 March	20 August	
Zambia	18 March	4 March–24 April	
Asia	Afghanistan	24 February	21 March–3 April, 26 August
	Bangladesh	7 March	19–20 May, 19 August
	China	A cluster of unexplained pneumonia cases was recorded in Wuhan in December 2019 that were caused by a new coronavirus, COVID-19	Multiple floods in June, July and August
	Georgia	26 February	1 August
	India	30 January	19–20 May and multiple floods in July, August and September
	Indonesia	2 March	24 February–10 March, 5–15 March, 31 March–3 April, 22–26 April, 22–30 May, 11–18 July
	Iran	19 February	24 February–10 March, 10–16 April
	Japan	3 January	29 June–5 July, 27–30 July
	Kazakhstan	13 March	1–11 May
	Laos	23 April	3 August
	Malaysia	25 January	20–25 June
	Mongolia	10 March	21–25 June
	Myanmar	23 March	15–30 July
Nepal	24 January	20 August	
Oman	24 February	27–31 May	

(Continues)

TABLE 1 (Continued)

Region	Country	Emergence of first COVID-19 case in 2020	Dates of flood events in 2020 after the first COVID-19 case
	Pakistan	26 February	6–17 March, 10 August, 26 August
	Russian Federation	31 January	24 April–11 May, 7–15 June, 17 July, 19–20 August, 20–24 September
	Saudi Arabia	2 March	6 August
	South Korea	20 January	29–30 July
	Sri Lanka	27 January	17–20 May
	Thailand	13 January	3 August, 24 August
	Turkey	11 March	23–25 June
	Uzbekistan	15 March	1–11 May
	Vietnam	23 January	22–26 April, 3 August
	Yemen	10 April	20–22 April, 4 August, 14 August
Europe	France	24 January	13 August
	Greece	26 February	9 August
	Italy	31 January	13 August
	Poland	4 March	21 June–5 July
	Russian Federation	31 January	20 June, 7–8 July
	Spain	31 January	1–2 April, 12 August
	Ukraine	3 March	22 June–5 July
	United Kingdom	31 January	16–17 February
North America	Canada	25 January	25–27 April, 13 August
	Guatemala	13 March	2–3 June
	Haiti	19 March	21–30 August
	Honduras	10 March	26 May–3 June
	Mexico	28 February	12 August
	Panama	9 March	25–29 July
	Trinidad and Tobago	12 March	9 August
	United States	20 January	22 March–3 April, 18–20 May, 22–30 August, 15–18 September
Oceania	New Caledonia	25 March	18–22 April
	Papua New Guinea	20 March	1–3 April
South America	Bolivia	10 March	2–10 March
	Colombia	6 March	14–16 March, 1–3 April, 5–18 July
	Ecuador	29 February	16–19 May
	Peru	6 March	28 March–2 April
	Salvador	18 March	2–3 June
	Uruguay	13 March	22–26 June

*Source: <http://floodobservatory.colorado.edu/Version3/MasterListrev.htm> and further, national, sources (last accessed September 24, 2020). https://en.wikipedia.org/wiki/COVID-19_pandemic_by_country_and_territory (last accessed September 24, 2020).

evacuated during a dam break flood. Some 81,000 people were evacuated in Somalia and Ethiopia and 78,000 in Democratic Republic of Congo during floods caused by heavy rainfall.

Many people affected by the flood were in close proximity during evacuation and in the emergency shelters, which may accelerate the spread of the pandemic and increase the difficulty of pandemic control.

Box 1 Flood in Uzbekistan and Kazakhstan

On March 13, 2020, the first four cases of COVID-19 in Kazakhstan were confirmed from people arriving from Germany and Italy. The first COVID-19 case in Uzbekistan was detected on March 15, 2020 (an Uzbek citizen returning from France). After the announcement of the case in Uzbekistan, Kazakh president Kassym-Jomart Tokayev announced a state of emergency in Kazakhstan, effective from 16 March to May 11, 2020 and closed the border with Uzbekistan.

Six weeks after the first COVID-19 occurrence in Uzbekistan, there was a major flood in both Uzbekistan and Kazakhstan, caused by a failure of Sardoba dam in Uzbekistan. The dam was completed in 2017 and had a storage capacity of 922 million cubic meters. The dam was built to irrigate agricultural lands in the Uzbek provinces of Sirdaryo and Jizzakh. Heavy rainfalls and high winds caused a dam wall to partially collapse, flooding large land areas in both neighboring countries. Hundreds of houses in both Uzbekistan and Kazakhstan were flooded.

In Uzbekistan, about 70,000 people from three districts in the Sirdaryo and Jizzakh regions (Sardoba, Mirzaabad, and Akaltyn districts) were evacuated. Two child fatalities were recorded. In Kazakhstan, more than 31,000 people from Maktaaral district in southern Turkestan province, which borders Uzbekistan, were evacuated.

See AGU Blogosphere at <https://blogs.agu.org/landslideblog/2020/05/04/sardoba-dam-failure/> (last accessed September 25, 2020).

Box 2 Flood on the Yangtze River (China)

Wuhan is a megacity on the Yangtze River with a population of over 10 million, where COVID-19 was first detected at the beginning of December in 2019 and where the epidemic occurred in the winter of 2019/2020. Nearly all people in Wuhan received nucleic acid tests to control the COVID-19 epidemic. After a 2-month lockdown, the city reported no new cases of the COVID-19 for the first time on March 18. Recovering from the virus in its months-long battle, the city had reported no new confirmed COVID-19 cases for five consecutive days as of March 22.

In the middle of the recovery from COVID-19, starting on June 2, 2020, authorities in China issued alerts for heavy rainfall in the region for 41 consecutive days. The average precipitation in areas along the Yangtze River has reached to 754 mm for the period June 1–July 28, 2020 (China Meteorological Data Service Center, <https://data.cma.cn/en/?r=site/index>, last accessed September 30, 2020), the highest level since 1961. As of August 13, at least 219 people had been killed, 0.82 million people needed emergency assistance, 4 million people were evacuated, and nearly 64 million people were affected by the flooding (presentation of Mr. Zhou Xuewen, on August 13, 2020, Vice Minister, Ministry of Emergency Management and Vice Minister, Ministry of Water Resources, People's Republic of China).

According to Wang, Huang, and Fan (2020), the 30-day cumulative precipitation with a 1,000-year return period was observed in Anhui, Guizhou and Sichuan Provinces. The highest observed 30-day cumulative precipitation in 2020 was 1,221 mm, in Anhui Province, while the highest one in 1998 was 1,028 mm, in Jiangxi Province.

Flooding destroyed nearly 0.4 million homes and damaged 5 million hectares of farmland. According to the Ministry of Emergency Management of China, it is estimated that direct economic losses exceed USD \$25 billion.

Professional emergency management teams and the People's liberation Army participated in the flood control. Three Gorges Project (TGP) also played a key role in controlling the flooding. Until August 21st, it intercepted floods of 30,000 m³/s on nine times, floods of 50,000 m³/s on five occasions and on August 20, 2020, the largest flood since the construction of 75,000 m³/s.

There have been major floods on Yangtze River in 1931, 1954, and 1998. Improved forecasting and combined green and gray infrastructure protection (including the Three Gorges Dam) has improved the situation: the 1931 flood with a volume (60 days) of 435.66 billion m³ recorded 145,000 fatalities and 330 dike breaches; the 1954 flood with a flood volume of 489.95 billion m³ recorded 33,000 fatalities and 63 dike breaches; the 1998 flood with a volume of 417.45 billion m³ recorded 3,650 fatalities in the Yangtze River Basin (Kundzewicz, Su, Wang, et al., 2019) and only one dike breach along the main stem of the Yangtze river. This year's flood has yet to have a volume confirmed, but recorded the smallest number of fatalities at 219 (Xia, 2020).

Boxes 1 and 2 present illustrative examples of 2020 floods in Uzbekistan/Kazakhstan and China (Yangtze River, Hubei Province) amidst the pandemic that was on the dynamic rise in the countries affected by flooding.

Some other locations around the world experienced even more complex situation where the pandemic and flooding were affected by additional hazards. Locusts, COVID-19 and deadly flooding posed a “triple threat” to millions of people across East Africa in the spring. The combined threats imperiled a region that was already home to about 20% of the world's population of food-insecure people, including millions in South Sudan and Somalia. Lockdowns imposed for the COVID-19 pandemic slowed efforts to combat the locusts, especially imports of the pesticides needed for aerial spraying that is seen as the only effective control. The spring floods in parts of East Africa killed nearly 300 people and displaced 500,000, slowing locust control work and increasing the risk of the virus' spread, according to the International Federation of Red Cross and Red Crescent Societies.

Internet search engines deliver hundreds of thousands of entries for “COVID” + “flood,” some of which do not pertain to abundance of water, as the term “flood” illustrates abundance in general (e.g., flood of papers, flood of patients, flood of COVID-19 liability claims, flooding the world with fraud). Nevertheless, there have been many entries in media sources of considerable relevance and interest that illustrate a broad range of issues, related to floods and COVID-19, such as the sample compiled in Table 2.

In many countries, pre-existing flood disaster management plans deal with the individual disaster scenarios. The problem is that these plans do not account for a pandemic happening at the same time. The year 2020 was “unprecedented.” It has been noted that during 2020 flooding emergency managers were less focused on the pandemic response than the immediate danger from flooding, trying to minimize immediate loss of life.

In spite of the huge challenges from overlapping disasters, there are some reasons for hope. The pandemic did not change the capability to remotely monitor the environment for catastrophic events and to warn the public in a timely manner. Also, the pandemic led to the activation of emergency operation centers before flooding started, shortening significantly the response to sudden events like floods. The coronavirus will be difficult to avoid for the foreseeable future. But as has been shown above, when an additional disaster such as flooding takes place, the more immediate threat to life was dealt with first.

3 | UNKNOWN UNKNOWNNS

Floods have struck a myriad of times since the very beginning of human civilization, hence this hazard is well known, even if short-term memory syndrome can be observed. There are ample national flood risk-reduction activities, such as investments, legislation, and research that are typically triggered by disastrous flood events. However, the interest of decision makers and the broad public and the willingness to pay decrease with time, even after just a few years. This observation is valid for any economic, political, and social system. Hence a daily prayer of a flood manager may extend beyond “give us this day our daily bread” to include “and give us a little flood from time to time,” as a reminder.

The European Union's Floods Directive was triggered by disastrous large-area floods in Europe in August 2002. This legal act sets out national obligations related to implementation of the Directive in all 27 EU Member States which enhance the lasting commitment to reducing flood risk, which is conceptualized as a combination of hazard, exposure, and vulnerability. The Directive guards against short-memory syndrome.

In China, severe floods hit the basins of several major rivers in 1998 and since then USD \$294 billion has been invested up to 2017 to enhance flood control systems, accounting for more than one third of the total investment in water engineering, Figure 2, as a consequence, the length of dikes was increased from 76,532 to 201,124 km, and reservoir capacity increased from 493 billion to 932 billion m³. This sustained investment in the flood control system breaks the previous cycle of short-memory syndrome. This is because of the legal guarantee of the Flood Control Law of PRC enacted in 1998 and rapid economic growth in the 21st century.

In the context of the double calamity, a pandemic and floods, it is worth considering the concept that became well known after being used by Mr. Donald Rumsfeld, the US Secretary of Defense, in his news briefing given on February 12, 2002 in reference to the lack of evidence linking the Iraqi government and its weapons of mass-destruction. Mr. Rumsfeld spoke of known unknowns (“we know there are some things we do not know”) and unknown unknowns (“we do not know we do not know”). Actually, these concepts are older than the famous use by Rumsfeld by more than two decades. As indicated by Vit Klemes (2002), “unkunk” (unknown unknown) was a label used by the US Air Force for unpredictable problems (Linstone, 1978). In his oral contribution to the Kovacs Colloquium delivered in 1996, a long time before use by Mr. Rumsfeld (see Klemes, 2002), Klemes extended the notion. In addition to kunks (known

unknowns) and unkunks (unknown unknowns), he devised a category of skunks: unkunks represented as skunks that is “knowns” that stink. In the modern parlance, perhaps they could be baptized “postknowns.” Klemes (2002, p. 29) issued the following recommendations: “Kunks should be treated with rigor. Unkunks should be treated with care. Skunks should be avoided.”

The COVID-19 pandemic affected different countries with different level of shock, seeming to be a real unknown unknown for many nations and governments. However, for some experts, nations and governments, COVID-19 was more of a known unknown, since a SARS CoV pandemic had happened before. The WHO had also warned of the likely significant impact of the pandemic. Likewise, the UK National Register of Risk had identified a pandemic as the most likely and largest risk. Nevertheless, there was acute lack of prior knowledge about the characteristics of the virus and the spatiotemporal spread of the epidemic. The jury is still out as to the optimal policy for COVID-19 management. Different countries demonstrated different attitudes from business-as-usual to (obligatory or recommended) social distancing, self-isolation, and lockdown, though at different stages of development of the pandemic. In many countries a state of emergency was introduced. Probably countries impacted by SARS (China, Canada, South Korea) were better prepared for COVID-19. This could demonstrate the value of hindcast and experience as pointed out above in terms of short-memory syndrome. There is also a speculative hypothesis that nations where tuberculosis vaccination was obligatory are less susceptible to COVID-19.

WHO provided “Critical preparedness, readiness and response actions for COVID-19” guidance (WHO-COVID-19-Community_Actions-2020.4-eng.pdf, last accessed December 22, 2020) that focused on control of COVID-19 by slowing down transmission of the virus and preventing associated illness and death. Four transmission scenarios are considered in supporting countries in selecting and tailoring their approach to the local context: (a) no cases; (b) sporadic cases (one or more cases imported or locally detected); (c) clusters of cases (clustered in time, geographic location, and/or common exposure); and (d) community transmission (larger outbreaks of local transmission, detected through an assessment of large numbers of cases not linked to transmission chains, large numbers of cases from sentinel lab surveillance, or multiple unrelated clusters in several areas of the country).

WHO guidelines recommend the following global strategies:

- Mobilization of all sectors and communities to ensure participation in the response and in preventing cases through hand hygiene, respiratory etiquette, and individual-level physical distancing.
- Controlling sporadic cases and clusters and preventing community transmission by rapid finding and isolating.
- Suppressing community transmission through context appropriate infection prevention and control (population-level physical distancing, and appropriate and proportionate restrictions on nonessential domestic and international travel).
- Reducing mortality by providing appropriate clinical care for COVID-19 patients and ensuring the continuity of essential health and social services.
- Development of vaccines and therapeutics.

In spite of differences between the countries, it is quite clear that all countries should increase their level of preparedness and response to identify, manage, and deal with new cases of COVID-19. Response to different public health scenarios is required recognizing that there is no one-size-fits-all approach to managing the pandemic.

4 | FLOOD AND COVID-19 MANAGEMENT

Both for flood and pandemic, we can state that such a calamity cannot be prevented completely, but certainly we can, and must, reduce the likelihood and the impact. As out pointed earlier, the pandemic amplifies the risk related to weather extremes, including floods. A flood may complicate pandemic responses, including health risk for the first responders and for the evacuees. This creates additional challenge to decision makers, stakeholders, and those affected and concerned. Shifting resources is needed, worldwide, to combat the pandemic and to buffer the economy.

It is necessary to review and, if necessary, modify the existing action plans, procedures and protocols, in an ad hoc way, to ensure they are appropriate for the pandemic. There are contrary conditions, as the epidemic requires social distancing and isolation, while flooding requires collaboration. In Bangladesh, despite humanitarian assistance and government organizations being prepared for flooding as well as a pandemic, in the densely crowded camps in Cox' Bazar,

TABLE 2 A sample of media messages, related to floods and COVID-19, illustrate a broad range of important issues

Message	Media source
Floods are not unusual in Assam, particularly during monsoons. However, in 2020, it is not just the threat of rising waters that is facing the people of the state. The looming threat of COVID-19 in the flood relief camps set up by the administration, threatens to push the already-vulnerable to higher risk. “When the waters threaten to take away your life, swallow your land, your animals, the focus is to just survive. Now there will be two things threatening us.” (June 3, 2020)	https://india.mongabay.com/2020/06/with-floods-and-covid-19-assam-faces-a-dual-threat/
The workers were brought in from Florida and Texas to Michigan after the May 19 flood. Approximately 50 tested positive while in Michigan. There were claims that the workers were forced to work without sufficient personal protective gear and lived in crowded hotel rooms. (July 25, 2020)	https://www.michiganradio.org/post/group-asks-greater-covid-19-protections-workers
Mr. Chandrababu Naidu, former Chief Minister of Andhra Pradesh and current leader of parliamentary opposition expressed concern that the troubles of the common people in the state were multiplying day by day under the inefficient rule of the government. He stated that the government's failures and wrongdoings were exposed during the coronavirus relief measures and also floods. No relief was provided to the victims. Mr. Naidu accused the ruling party of “betraying all sections of population.” (October 11, 2020)	https://www.thehansindia.com/andhra-pradesh/covid-flood-exposed-governments-inefficiency-tdp-650707
Two companies brought the workers from Florida to mid-Michigan after catastrophic floods in the spring of 2020. After a COVID-19 outbreak among workers who helped with re-building efforts in Midland and Bay counties, companies are facing a lawsuit. Allegedly, the companies failed to take proper workplace safety precautions, after luring the workers to Michigan with false claims about workplace safety. They improperly discharged workers who had been exposed. The lawsuit says the defendants then sent the workers home, spreading the risk of COVID-19 to their families and to other communities. According to the lawsuit, at least 17 workers contracted COVID-19 (two have been critically ill), and some spread it to their families. (October 14, 2020)	https://www.michiganradio.org/post/companies-sued-over-covid-19-outbreak-among-flood-recovery-workers
Hyderabad flood victims were shifted to 165 rescue and relief camps. Flood victims, who exhibited symptoms that could be related to COVID-19 were tested and some tests gave positive results. Those identified as COVID-19 positive were shifted to government hospitals for treatment. In addition to the health camps, functioning round the clock, also 42 mobile health centers were set up, to reach out to people in flood hit areas who did not require evacuation. Doctors, nurses and other health department staff, who have been working hard for controlling COVID-19, now stepped up to assist flood victims. (October 18, 2020)	https://www.deccanchronicle.com/nation/in-other-news/181020/hyderabad-flood-victims-test-positive-for-covid-in-relief-camps.html

which shelter some 900,000 Rohingya refugees (Ishiwatari et al., 2020), some families were “turned away at the door of a shelter, because they didn't have enough face masks for every family member.”

It is necessary to identify hotspots related to pre-existing exposure and vulnerability in informal urban/suburban settlements, where marginalized people live and where flood protection cannot be provided. Both floods and the pandemic “cluster around poorer, racially marginalized populations so much that some have referred to inequality as a comorbidity” (Kramarz, 2020). COVID-19 exacerbates the “typical” morbidity concerns related to floods (injuries, gastric problems, PTSD—Post-Traumatic Stress Disorder). Lockdown increases the impact of mental health challenges leading to long-term health implications and exacerbates the factors that lead to greater domestic violence.

Some practical examples of managing floods and COVID-19 can be already extracted from this year's flood season. The Province of Manitoba (Canada) for example provided a high water response activity guide for COVID-19 adaptation (<https://www.gov.mb.ca/emo/pdfs/adaptations-to-high-water-response-activity.pdf>, last accessed September 15, 2020). For sandbagging activities, which is a common measure for temporary diking in Manitoba, the guide

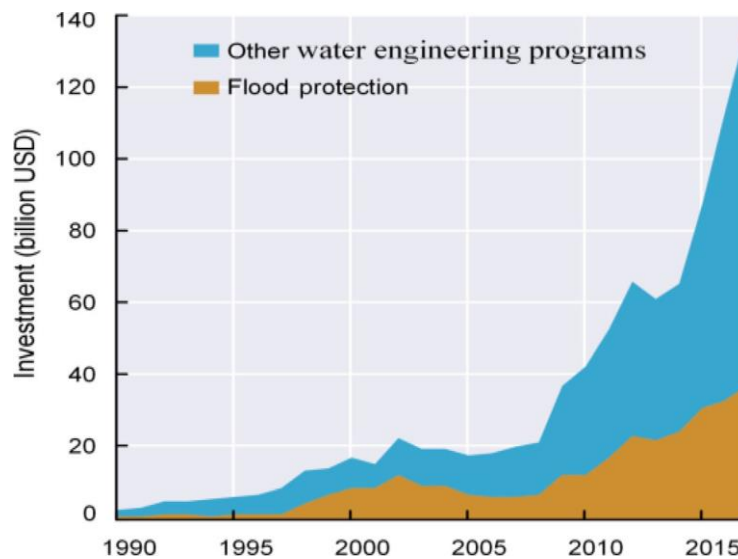


FIGURE 2 Investment in flood protection and other water engineering programs since 1990 in China (in 2015 USD)

Source: After Du, Cheng, and Huang (2019)

recommends: (a) for small dikes—the process using a 2-person team where individual workers will maintain separation by being at alternate locations in the process while ensuring a minimum 2 m spacing between them; (b) for large dikes—the process using a multiperson team (carousel) where one worker will take a sandbag from a stockpile and proceed to dike area along the circular path and place the sandbag at the dike. The workers will move to the right or left about 3–4 m following the circle and ultimately returning to stockpile while maintaining space between them. Workers will continue to move the line and sandbags along to complete the dike in a “carousel” fashion (Figure 3).

In Japan, the usual approach to housing people displaced by disasters in primary school gyms had 200–300 people crammed into an area with inadequate ventilation and limited access to toilets (Reynolds, 2020). Since each person is allotted space of about 1.6 m² for one straw “tatami” mat, this leaves little room for social distancing. Marking out spaces to keep households two meters (6 ft) apart means each shelter can accommodate fewer evacuees. Officials are trying to identify additional shelter sites, from government facilities to hotels and inns, with mixed success (Reynolds, 2020).

The Union of Concerned Scientists in the United States (<https://www.ucsusa.org/resources/maps-flooding-risk-and-covid-19>, last accessed September 16, 2020) provided maps of flooding risk and COVID-19 (Figure 4). These maps compare areas at risk of flooding with two different COVID-19 scenarios between April 13 and May 16. For example, in one scenario (Figure 4a), social contact within each county decreases by an additional 20% each week until the number of cases in that county starts to decrease. In the second scenario (Figure 4b), social contact decreases by 40% every week until cases decrease. The modest reduction in social contact in the first scenario results in more than 600,000 cases of COVID-19 that also carry a risk of moderate or major flooding. The second scenario results in roughly 170,000 cases of COVID-19 in areas also at risk of flooding—a reduction of more than two thirds.

5 | PROSPECTS FOR THE FUTURE

Flood hazard is clearly nonstationary. It varies with the climate as well as land-use and land-cover changes. However, projections for the future, even if largely uncertain, indicate increasing flood hazard and risk in many areas. Willner, Levermann, Zhao, and Frieler (2018) postulate that considerable adaptation efforts are required in many countries to preserve future high-end river flood risk at present levels.

There is evidence of regional predisposition (in a probabilistic, rather than a deterministic sense) to abundance of water, related to the climate variability, described by indices of the oscillation in the ocean–atmosphere system. Kundzewicz, Szwed, and Pinskiwar (2019) published a comprehensive literature review indicating the links between the climate variability indices, such as ENSO, PDO, NAO, and AMO and characteristics of abundance of water (intense

precipitation, high river flow, flood damages). Apparently, globally, the oscillation pattern that has strongest links with floods is ENSO (*El Niño*—Southern Oscillation). During the warm ENSO phase (*El Niño*), there is predisposition to floods in such regions as South America, California and Arizona, parts of Asia and central east Africa, while during the cold ENSO phase (*La Niña*), there is predisposition to floods in Australia and many regions in Africa.

The number of flood disasters has been increasing very rapidly, more than threefold, since 1980 (ICHARM, 2020). What is also striking is that more than three-quarters of the economic losses are reported from high or upper-middle-income countries, whereas more than 80% of the human losses have occurred in lower-middle or low-income countries. Disasters inhibit growth while growth amplifies disaster damage. To solve these problems, it is essential for nations to strengthen disaster resilience and achieve sustainable development. Multihazard conditions as demonstrated by flooding and virus pandemic create and amplify disasters that require a different approach—a paradigm change. There are practical links between integrated disaster management and sustainable development leading to reduction of disaster losses and re-enforcing resilience as a new development paradigm. There is a need for change in disaster management approaches, moving from disaster vulnerability to disaster resilience; the latter being viewed as a more proactive and positive approach. Hazards may be combined and increasing and at the same time they erode resilience. In the past, standard disaster management considered arrangements for prevention, mitigation, preparedness and recovery, as well as response. However, today more than ever we need a substantial progress in establishing the role of resilience in sustainable development. Multiple examples of flooding in 2020, during the pandemic, reveal links between attributes of resilience and the capacity of complex systems to absorb disturbance while still being able to maintain a certain level of functioning. Diversification of flood management strategies can pave the way toward more flood resilience (Hegger et al., 2016; Priest et al., 2016). Unfortunately, we manage neither by keeping destructive waters away from people at all times (via structural defenses—levees, bypass channels, storage reservoirs) nor keeping people and wealth away from destructive waters (via flood-risk prevention—including relocation and zoning, i.e., prohibiting or discouraging development in risky areas). Hence, it is necessary to embark on a diversified portfolio of flood-risk-management approaches, including flood-risk mitigation, preparation, and recovery, to maximize the net effect of a combination of strategies (Kundzewicz, Hegger, Matczak, & Driessen, 2018). There is a need to focus more on action-based resilience planning. Disasters do not impact everyone in the same way. It is clear that the problems associated with sustainable human wellbeing call for a paradigm shift.

Resilience—in the context of this discussion—is defined as: “the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous events in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions” (Agrawal, Elliott, & Simonovic, 2020; Simonovic, 2016, 2020; Simonovic & Arunkumar, 2016; Simonovic & Peck, 2013).

Ansell and Boin (2019) use Pragmatism (practical and commonsense) principles to deal with strategic crisis management arguing that crisis management is not rational when we have “unruly problems.” Real crisis management (preparation and response) is based on a few simple principles of Pragmatism: (a) constant calibration; (b) antidualism;

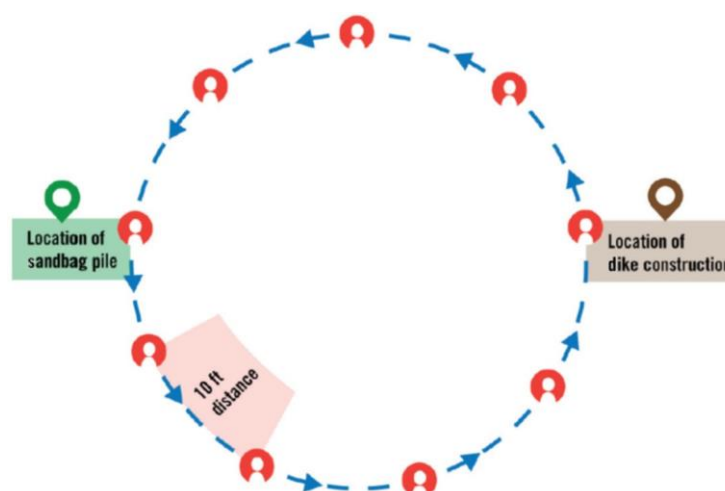


FIGURE 3 Large dike sandbagging using a multiperson team—carousel

Source: After <https://www.gov.mb.ca/emo/pdfs/adaptations-to-high-water-response-activity.pdf>, last accessed September 15, 2020

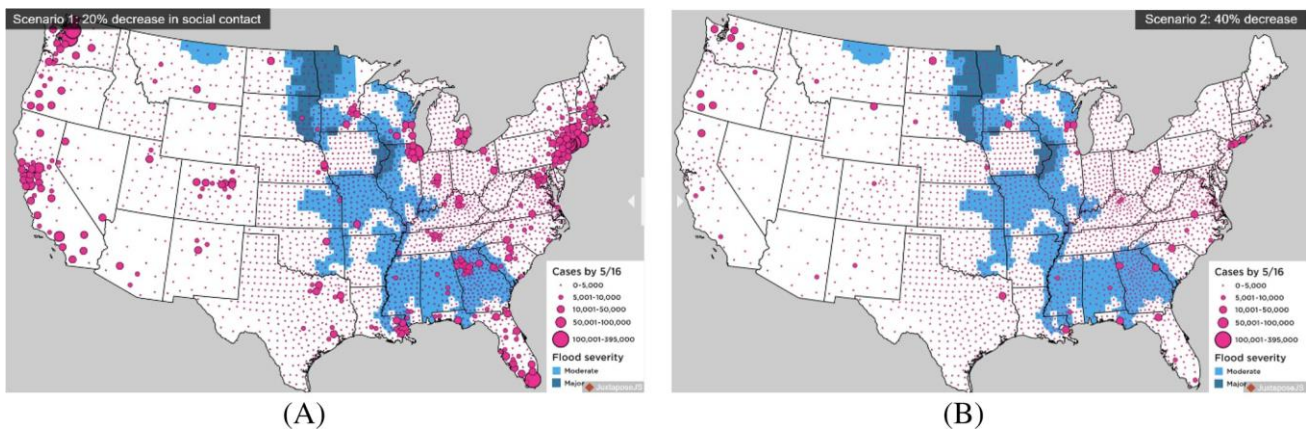


FIGURE 4 Maps of flooding risk and COVID-19 (a) social contact decrease by 20%; (b) social contact decrease by 40%
 Source: <https://www.ucsusa.org/resources/maps-flooding-risk-and-covid-19>, last accessed September 16, 2020

(c) experimentalism (adaptive decisions); and (d) bricolage (creating from multiple elements). The Pragmatist perspective offers an alternative approach that fits the resilience definition as used in this article: Treat the changing picture of the situation as a hypothesis and test it continuously against incoming information and avoid making irreversible decisions.

Some qualitative flood resilience work has been done by Wardekker et al. (2020) with a focus on the presentation of a practical tool that helps diagnose choices made in resilience-building, making them transparent and explicit. The Resilience Diagnostic Tool presented in this article aims to function specifically as a learning tool. The tool is process-based and qualitative: it uses guiding steps, frameworks, and questions to perform the assessment. Therefore, it does not require any software or detailed data sets, what may be one of the serious deficiencies of the tool. The Resilience Diagnostic Tool employs a generic three-step approach (commonly used by other qualitative and quantitative tools): (a) The first step reflects on choices in the goals of resilience-building by examining the local situation and goalsetting; (b) The second explores choices made: which aspects of resilience (resilience principles) are emphasized? This is done for both the current situation (baseline) and proposed plans, measures, or policies for resilience-building (interventions); and (c) The third reflects on consequences of these choices: whether the interventions match the goals and potential side-effects.

Following the definition of resilience presented above and experience obtained by its implementation in the context of flooding caused by climate change (Peck & Simonovic, 2013; Simonovic & Peck, 2013), we are recommending its easy expansion to the multiple hazard conditions of flooding under COVID-19. While traditional flood management focuses on the reduction of pre-hazard vulnerabilities, disaster resilience is achieved by introducing adaptation options that enable the community to adapt to the impacts of hazards and enhance the ability of the physical, social, economic sectors to function in the event of a disaster. These adaptation options help the system components to cope with, and recover from hazard impacts in order to return to a pre-disaster level of performance as rapidly as possible.

The quantitative measure of resilience is based, as previously stated, on two basic concepts: level of system performance and system adaptive capacity as illustrated in Figure 5.

Generic presentation of system performance used for the quantification of resilience is shown in Figure 5a. The area between the initial performance line P_0 and performance line $P(t)$ represents the loss of system performance, and the shaded area under the performance line $P(t)$ is used as the representation of the system resilience. By integrating the shaded area in Figure 5a and then normalizing its value, the system performance is converted into system resilience shown in Figure 5b. In Figure 5, there are three possible outcomes in resilience simulation: (a) resilience returns to pre-disturbance level (solid black line in Figure 5a,b); (b) resilience exceeds pre-disturbance level (dashed blue line in Figure 5a,b); or (c) resilience does not return to pre-disturbance level (dashed and dotted red line in Figure 5a,b). For example, proactive measures will result in the red curve and reactive measures may result in the blue curve. System adaptive capacity is defining the shape of the resilience curve which offers more insight into dynamic performance of the system under disturbance through the four values of robustness, redundancy, resourcefulness and rapidity, known as 4Rs (Bruneau et al., 2003; Cutter et al., 2008).

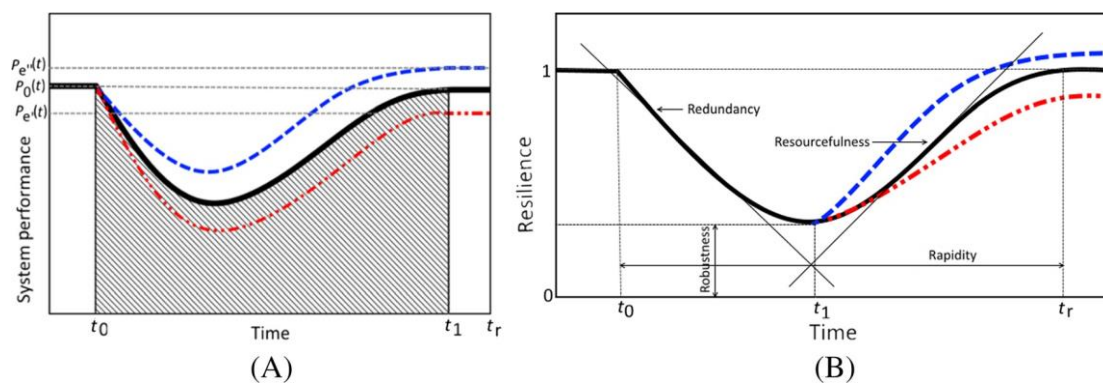


FIGURE 5 Graphical illustration of resilience: (a) system performance; (b) resilience. Black line shows full recovery to pre-hazard system performance. Red line shows partial recovery. Blue line shows improved system performance

The main characteristics of resilience (4Rs) are: (a) robustness, that is the strength or the ability of the system to resist hazard-induced stresses (e.g., flood protection measures); (b) redundancy, that is the ability of a system to provide uninterrupted services in the event of a disruption (e.g., a twinned pipeline); (c) resourcefulness, that is the utilization of materials (monetary, technological, informational, and human resources) to establish, prioritize and achieve goals (e.g., mobilization of disaster management funds); and (d) rapidity, that is the capacity to return the system to a pre-hazard level of functioning as quickly as possible. The slope of the declining section of the resilience curve in Figure 5b provides insight into system redundancy and slope of the rising section of the resilience curve offers the information about system resourcefulness. Robustness of the system and rapidity are clearly illustrated with the system performance level at time t_1 and difference in time between t_0 and t_r , respectively.

The implementation of quantitative resilience assessments is done by using system dynamics simulation. The quantification concept is easily expanded to assess the spatial distribution of resilience by implementing simulation process at various locations in space and then by connecting them creating a dynamic map that captures the temporal (simulation in time) and spatial (integration in space) quantitative characteristics of the resilience measure. Simulation modeling (for obtaining system performance and resilience in time) is integrated with GIS (Geographic Information System) processing to obtain resilience values in space. The same quantitative resilience concept has been successfully extended to multiple hazard situations in the infrastructure management (Kong, Simonovic, & Zhang, 2018).

Evidently, resilience is a proactive means of disaster management making it more desirable for implementation. It is dynamic. It offers quantitative measure to support decision-making in evaluation of various adaptation measures. It has been already tested in the single hazard case (Simonovic & Peck, 2013) of flood management. It has been also extended to multiple hazard case in infrastructure management (Kong et al., 2018) affected by hurricane and flooding. The methodology used by Kong et al. (2018) can be directly implemented in considering flood disasters under COVID-19.

Lessons for the future are:

- A resilience approach is needed whether in response to floods or a pandemic. This means accepting that the event will occur and ensuring that the resilience is enhanced and impacts are mitigated. It also means accepting that the socioeconomic system will not necessarily return to antecedent conditions, rather the system needs to adapt to a “new normal” (possible outcome shown in Figure 5 in blue and red).
- Preparation is vital, in addition to defense. The responsible actors must be prepared with actions plans and command structure, while the general population must be involved in the discussions so that they are aware of the resilience level and the reasons for the actions they must take to increase it.
- As well as understanding the engineering of defenses and how hydrology predicates events and their scale, it is vital to understand people's behavior. Only with this can resilience be communicated and only with this can the population be ready to respond to the events. Societies are diverse in many ways and within a population there are widely varying attitudes to risk, resilience and uncertainty. This means that flood management research must continue to include engineering and environmental science, but behavioral science and risk communication is also a vital component. The proposed quantitative resilience allows effective communication of risk and impacts of various



FIGURE 6 Generic presentation of the approach to multihazard management as it can be applied to flooding under the pandemic conditions

adaptation measures. It is worth noting that practice is often ahead of research in this regard, as pointed out by Latour (1999), "... it might be about time for social and natural scientists to forget what separates them and start looking jointly at those 'things' whose hybrid nature has, for many decades now, already unified in practice"

6 | CONCLUDING REMARKS

Globally changing conditions, including rapid population growth and migrations, climatic variability and change, and land-use change (especially rapid urbanization), are directly affecting the complexity and uncertainty of current and future disaster management problems. Hydrological extremes (floods and droughts) are projected to be more frequent and of higher magnitude in much of the globe. Both, the complexity and the uncertainty, are the result of dynamic interactions within three systems: (a) the physical environment; (b) the social environment; and (c) the constructed infrastructure environment. Within such a complex environment appearance of multiple hazards (at the same time or following each other) is becoming increasingly likely. Social, health and economic conditions under global change can generate various crisis situations, including those such as COVID-19. Figure 6 summarizes the main point of our discussion by providing a generic structure of multihazard management context based on resilience.

Future multihazard crises will be characterized by temporal and spatial dynamics. They will occur at the same moment in time, one immediately after another, or one after another with some time in between. In space, they may occur at fully overlapping boundaries, partially overlapping, or not overlapping at all. These characteristics of multiple hazards represent one of the main challenges in their management.

Current practice in managing multiple hazards is mostly reactive and focused on one hazard at a time. In this approach, priorities are established based on the risk to human life and the first attention is given to hazard with highest immediate potential impact. Risk, (a) being a static measure (independent of time), (b) exhibiting difficulties in

assessing the probability distribution of hazard, and (c) being unable to simultaneously consider physical, social, environmental, and economic consequences of hazardous situations, may not be the sufficient tool for addressing challenges of multihazard management (Simonovic, 2016). Many examples of the shortcomings of this approach warrant a focus on investigating other possible management options.

A new approach is needed in dealing with multiple hazards. It should include consideration of the whole region being affected, explicit incorporation of all costs and benefits, development of many alternative solutions, and the active (early) involvement of all stakeholders in the decision-making. Systems approaches based on simulation, optimization, and multiobjective analyses, in deterministic, stochastic, and fuzzy forms, have demonstrated in the last half of 20th century, a great success in supporting effective management of disasters (Simonovic, 2011) and has equal potential for managing multihazard events. To paraphrase Alexander (2020), the planning scenarios for viral pandemics combined with flooding are complex but fully capable of being formulated using a systems approach under uncertainty. Experience with COVID-19 has enabled us to update knowledge of the effects of previous pandemics on modern society at all scales. If uncertainties cannot be eliminated, or reduced, they can at least be clearly communicated in order to provide the firmest possible basis for decision-making.

An unprecedented situation of a compound impact of COVID-19 pandemic and a weather extreme (flood) to health and socioeconomy triggered considerable social and political disturbance throughout the World. Economies affected, unemployment, bankruptcies, major blow to markets and sectors (tourism, therein hotels and restaurants; transport and air transport in particular; sports and recreation; education; culture—theaters, concerts, cinemas; contact jobs—hairdressers, massage; spiritual life—churches, synagogues, mosques, and temples); for fear of infection or dramatic reduction of demand.

Where threats or hazards are known, emergency management plans should be based on scenarios of what is likely to happen. A scenario is a means of investigating a range of possible future outcomes and basic input into quantitative resilience assessment process (Simonovic, 2016). It enables us to foresee the requirements and investigate options to meet them, rather than relying on inefficient forms of ad hoc last-minute improvisation. As pointed above, the systems approach combined with dynamic resilience as a decision-making criterion can provide effective support for multihazard management.

A multihazard emergency management plan is only as good as its implementation (Alexander, 2020). In the event of a pandemic combined with flooding, the uncertainty in the behavior of the disease and the physical characteristics of the flood event means that plans must be flexible to start with and then adapted to circumstances as these evolve. This underlines the role of dynamic resilience as a support for planning and real time disaster management as a process rather than an end.

The proposed quantitative resilience application is implemented through (a) the development of a detailed simulation model of a system; (b) selection of various adaptation options; and (c) comparison of adaptation options using quantitative resilience as a decision-making criterion. The simulation model describes the region subject to change. The region is described using physical and socioeconomic elements and their interactions (e.g., area under inundation, population affected, health and other critical infrastructure, etc.). The changing conditions include flooding (with its timing, magnitude and spatial extent) and COVID-19 characteristics (e.g., number of people affected, infected, hospitalized, their location in the floodplain, etc.). The simulation process provides outputs in the form of system response to changing conditions. They are then used to calculate the resilience of the system (as discussed in Section 5) without any adaptation measures being considered—base case, and various adaptation measures being tested (e.g., addition of the hospital capacity, additional flood evacuation space, distribution of available resources between flood management and pandemic management, etc.). Calculated resilience for the base case can then be easily compared to other resilience values corresponding to the choice of adaptation measures. These values can serve the decision-making process and assist the response activities. The proposed measure and implementation procedure are tested in a single hazard context of municipal flooding (Irwin, Schardong, Simonovic, & Nirupama, 2016). The web-based decision-making tool is developed and available at <http://resilsim-uwo.ca> (last accessed November 1, 2020). Similar test has been conducted for a multihazard case of combined wind and water disaster (Schardong, Simonovic, & Tong, 2019). The web-based tool has been developed for this application and is available at <http://www.resilsimt-uwo.ca> (last accessed November 1, 2020).

The application of the proposed approach is possible in the planning context (before the disaster strikes) for solving various planning problems, selecting proactive measures that can affect system redundancy, increase system robustness, and enhance system resilience. However, the approach can be also used in real time disaster response where different reactive measures that can affect resourcefulness and rapidity can be tested through their impact on system resilience.

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AUTHOR CONTRIBUTIONS

Slobodan Simonovic: Conceptualization; methodology; resources; writing-original draft; writing-review and editing. Zbigniew Kundzewicz: Conceptualization; formal analysis; resources; writing-original draft; writing-review and editing. Nigel Wright: Conceptualization; methodology; writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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**CHAPTER 3: ICFM8
BOOK OF
ABSTRACTS**

**Science & Technology for
Flood Risk Management -
Citizen science for flood
management**

A comprehensive approach for flood-plain mapping through identification of hazard using publicly available data sets over Canada

Oral - Parallel Session

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Floods are the most costly and frequent natural disasters in Canada, causing over \$1 Billion in damage to homes, property, and infrastructure annually. Between 1900 and 2005, the country saw 241 incidences of flood disasters over various parts, which have resulted in socio-economic losses to a level that was never anticipated before. The situation is further expected to worsen in the near future with the impacts of concomitant climate change and land-use dynamics. Among various possible solutions in practice to minimize the losses, flood-plain mapping is identified as a promising step that can offer sustainable long-term benefits in terms of appropriate land-use planning and ensure a high degree of protection measures. Moreover, with the accessibility brought about by the availability of publicly available global data-sets by various agencies, it has become easier than before to utilize various meteorological, hydrological and topographic data-sets in flood-plain mapping assessment. The present study proposes a comprehensive framework of flood-plain mapping by determining flood hazards. To accomplish this goal, various publicly available data sets available with the HYDAT flow database and the recently released bare-earth SRTM DEM were utilized to derive flood inundation maps. The flood hazard was characterized in terms of depth and product of water depth and velocity; and later classified into low, medium and high flood hazard zones. The flood mapping was demonstrated for severe flood events that took place in Southern Alberta in 2005 and 2013; and Quebec in 2017. The flood maps provide important lessons to town-planners and stakeholders on precautionary measures to be considered while advocating guidelines on city planning and at the same time maintaining uniform standards. The maps can be further utilized with various land-use and climate change scenarios to identify potential zones at high flood risk; suggesting in panning out appropriate flood mitigation options

A Platform on Water Resilience and Disaster in Sri Lanka: Towards Strengthening Flood Risk Reduction under Climate Change for Sustainable Development

SS I.g

Dr. Mohamed Rasmay¹

1. ICHARM The International Centre for Water Hazard

There is an increasing need for strengthening flood risk reduction under climate change for sustainable development in Sri Lanka since water-related disasters have become more frequent, causing damage to lives and property. To this end, a platform on water resilience and disasters was formulated in Sri Lanka in August 2017, immediately after the historical floods (mainly in the southwestern and western parts of the country, the Kalu, Gin, and Nilvala River basins), by inviting all the national stakeholders responsible for the management of water-related disasters. The platform is facilitated by the International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM) and the International Flood Initiative (IFI) of WMO and implementing four target actions (i.e., flood early warning, adaptation planning for global climate change, economic effect of disasters, and contingency planning and mainstreaming) in three river basins of Kalu, Kelani and Malvathu. During these years, there have been remarkable achievements resulting from the platform activities such as: a) strengthening the functions of real-time data collection, integration, and analysis by facilitating data and information accessibility among the stakeholders; b) developing a prototype of an integrated flood information system in the Kalu River basin for providing information on flood disaster early warning and supporting rescue operations; c) conducting capacity building workshops and training to strengthen experts' capability of in-situ and satellite data collection and integration, flood modeling, and impact assessment of climate change on flood disasters; and d) networking through reporting at national and regional annual plenary meetings. The platform in Sri Lanka will continue enhancing its functions through multi-stakeholder collaboration to further strengthen the nation in resilience, sustainability, inclusive growth, and adaptation to climate change by following the IFI spiral-up implementation strategy while working in tandem with the International Decade for Action, "Water for Sustainable Development", 2018-2028.

Analysis of water balance and discharge distribution at river bifurcations using Bayesian rating curves

Oral - PS I.a Systems approach for flood management (monitoring, modelling)

Mr. Matthijs Gensen¹, Dr. Jord Warmink¹, Dr. Fredrik Huthoff¹, Prof. Suzanne Hulscher¹

¹. University of Twente

At river bifurcations, discharge is distributed over downstream branches, thereby also distributing flood risk. An accurate estimate of the discharge distribution is essential for flood risk management. In our research, we analyze the water balance and discharge distribution at two major bifurcations of the Rhine river in the Netherlands. The Dutch Rhine branches are highly engineered, and human intervention will continue in the future. For each of these branches, a 30-year record of discharge and water level measurements is available. Currently operational rating curves show non-closing water balances at the bifurcations, with errors of up to 10%. This indicates large uncertainties in these rating curves. In our study, we construct multi-stage rating curves using Bayesian inference and Markov chain Monte Carlo simulations. We explore two methods to increase rating curve accuracy. First, we will take explicitly into account the constraints of the river bifurcations, namely a closing water balance, in the construction of the Bayesian rating curves. Secondly, we will consider water levels along downstream branches as an indicator for discharge measurement inaccuracy. The results show that both methods are able to strongly reduce the water balance error, particularly at very high discharges. However, this comes at the expense of a wider uncertainty range in the rating curves. Still, the new rating curves may be more accurate due to the reduced water balance error. Using the rating curves, we quantify the 90% confidence interval of the discharge distribution at both bifurcations at around 10%, a value which is fairly independent of upstream discharge. At design conditions, this amount of uncertainty could result in uncertainties in water levels of up to 0.8m. We conclude that it is essential to regard the entire river system with its bifurcations for flood risk management and for future planning of human interventions in the system.

Application of TOPKAPI Model in Flood Forecasting of Small and Medium-sized Rivers in China

Oral - Parallel Session

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The lumped hydrological model and empirical model have the problems of low accuracy and short forecasting period in real-time flood forecasting of small and medium-sized rivers. The sharing of underlying surface data such as high resolution DEM, land use data, soil data and water system, and the popularization and application of Internet of Things, Big Data, Cloud Computing and Intelligent Calculation methods, make distributed hydrological model an effective method for real-time runoff simulating and predicting. TOPKAPI (TOPographic Kinematic APproximation and Integration) model is a distributed hydrological model with physical mechanism developed gradually in the early 20th century. It has great advantages in real-time flood forecasting in small and medium-sized watersheds. Based on the data required by TOPKAPI model, this paper simulates 24 representative flood processes from 2001 to 2012 at the outlet section of the upper reach of the Zhenjiang River in Guangdong Province, evaluates the application effect of the model in flood forecasting of small and medium-sized rivers, and according to the simulation results it points out that real-time flood forecasting should be closely combined with the dispatching of the small and medium reservoirs in the basin, and it needs to continuously revise and update the forecasting program. The application of TOPKAPI model can make a scientific and rapid analysis of flood control situation in the whole basin, and provide accurate information and maximum convenience for flood forecasting consultation and decision-making. Also, it can improve the efficiency of disaster prevention and mitigation work in small and medium-sized river basins, and has a major significance in enhancing the modernization level of flood forecasting.

Assessing flooding impact to riverine bridges

Oral - Parallel Session

**Dr. Maria Pregnolato ¹, Dr. Andrew Winter ², Dr. Andrew D. Sen ², Ms. Dakota Mascarenas ²,
Dr. Michael R. Motley ²**

1. University of Bristol, 2. University of Washington

Bridges are infrastructural assets built to span a physical obstacle (a body of water, road, rail), providing connections between two separated sides that can be detrimental to cross otherwise. They are critical elements in the wider transport systems, due to a high cost of construction and limited redundancy (i.e. no alternatives of crossing). Failure of a single bridge can have a significant effect on the overall transportation network, resulting in significant economic losses and even loss of life due to accessibility issues.

Flood events are common across the world and they are the most frequent cause of damage to infrastructure compared to any other natural hazard. High river flows and bank erosion are an actual threat for bridges located over waterways, especially during extreme flooding events. For example, in August 2019 floodwater forced a bridge in the North of the UK (Grinton, Yorkshire) to collapse, while roads around the area were inaccessible for several days.

This study proposes a methodology to assess flood impact to bridges and related infrastructure, focusing in the implications of network failures and associated risks. This study investigates fluid-induced hydrostatic uplift forces, quasi-steady hydrodynamic forces and associated dynamic impulse forces impacting riverine bridges during extreme events. The work encompasses the following objectives: (i) definition of the structural damage states; (ii) definition of the structural responses to the hydrodynamic actions; (iii) modelling of the responses in terms of damage states vs hazard intensity measure. The methodology is applied to a case study in a flood-prone area in the UK (Carlisle). This preliminary work is setting the basis for an accurate model for community-wide risks associated with riverine bridges subjected to hydrodynamic forces.

Assessment of Satellite Precipitation Product for Flood Prediction

Oral - Parallel Session

***Dr. Bongchul Seo*¹, *Prof. Witold Krajewski*¹, *Dr. Felipe Quintero*¹**

1. University of Iowa

Satellite-based precipitation estimation is mainly divided into two approaches (visible/infrared and microwave techniques) according to the sensors employed to measure the physical quantities that are translated into precipitation rate. Different approaches have their own pros and cons: (1) geostationary satellites using visible/infrared images provide higher temporal resolution data than polar orbiting satellites carrying microwave sensors (e.g., 30 minutes vs. 3 hours); and (2) observations from active microwave (e.g., reflectivity) have more reliable relation with precipitation rate than those from infrared channels (e.g., brightness temperature). As such, both infrared- and microwave-based precipitation estimates have been barely used for flood prediction (e.g., regional scale). This was because prediction models require a certain degree of accuracy and space-time resolution together for a precipitation input product, and none of the two products meets these requirements. By taking each advantage from both type products, NASA has developed a new satellite-based product called the Integrated Multi-satellitE Retrievals for GPM (IMERG) and has done IMERG retrospective processing to cover the TRMM era (e.g., back to June 2000). Precipitation estimates for IMERG are obtained through intercalibration, merging, and interpolation of precipitation estimates from satellite microwave estimates together with microwave-calibrated infrared satellite estimates, and precipitation estimates from rain gauge analysis products. The spatial and temporal resolutions of IMERG are 0.1° and 30 minutes, respectively. In this study, the authors evaluate the basic ingredients of the IMERG products (e.g., calibrated, uncalibrated, microwave-only, and infrared-only) using radar-based precipitation estimates and ground reference observations. This assessment is performed for the Iowa domain where abundant data resources (e.g., precipitation and streamflow) are available from the Iowa Flood Center (IFC). The authors then use the IMERG product to drive the IFC Hillslope-Link Model (HLM) for flood simulation and prediction and discuss the scale-dependent predictive capability of the product.

Keywords: Precipitation, Hydrology, Satellite, IMERG, Flood

Atmospheric Circulation Patterns Associated with Extreme United States Floods Identified via Machine Learning

SS I.e

***Dr. Katherine Schlef*¹, *Dr. Hamid Moradkhani*², *Dr. Upmanu Lall*³**

1. Western New England University, 2. University of Alabama, 3. Columbia University

The massive socioeconomic impacts engendered by extreme floods provides a clear motivation for improved understanding of flood drivers. This talk will present work from Schlef et al. (2019) in which self-organizing maps, a type of artificial neural network, were used to perform unsupervised clustering of climate reanalysis data to identify synoptic-scale atmospheric circulation patterns associated with extreme floods at unimpaired gage locations across the United States. Flood characteristics (e.g., frequency, spatial domain, event size, and seasonality) specific to each circulation pattern were assessed. Four primary categories of circulation patterns were identified: tropical moisture exports, tropical cyclones, atmospheric lows or troughs, and melting snow. The results show that large flood events are generally caused by tropical moisture exports (tropical cyclones) in the western and central (eastern) United States. Certain regions experience extreme floods regularly outside the normal flood season (e.g., the Sierra Nevada Mountains due to tropical moisture exports) while other regions can experience multiple extreme flood events within a single year (e.g., the Atlantic seaboard due to tropical cyclones and atmospheric lows or troughs). These results provide valuable insights for flood risk management. Furthermore, the results are available on an interactive website with detailed information for every flood of record. A recent extension of the work has applied the methodology to impaired gage locations.

Key words: extreme floods, machine learning, atmospheric circulation

Augmenting the operational capabilities of SonTek/YSI Side-Looker for quantification and prediction of streamflows

Oral - Parallel Session

Mr. Marian Muste¹, ***Prof. Dongsu Kim***², ***Ms. Janice Yasui***³, ***Ms. Xue Fan***³

1. Univ Iowa, 2. Associate Professor at Dankook University, 3. Son Tek/YSI

Recent advances in acoustic methods applied to river instrumentation are revolutionizing our capabilities to understand, describe and model river systems. These instruments can quickly and efficiently provide detailed multi-dimensional measurements that uniquely enable investigation of complex river processes that are related to critical riverine issues such as flooding, sediment transport, habitat availability and stream ecology. Most of the practical application of these instruments in riverine measurements are related with hydrologic measurements, with main goal to support the continuous estimation of streamflows in in real time. While the basic principles of operation for the instrument remain largely unchanged since their introduction in riverine measurements, currently there are attempts in the research communities to explore new capabilities of the acoustic technologies to provide additional information from the extensive datasets recorded by the instruments. The present paper explores the capabilities of the SonTek Side-Looker (pertaining to the family of Horizontal Acoustic Current Profilers) to measure in unsteady flows. Specifically, data from the gaging stations equipped with Side-Lookers (SL) are deployed is analyzed to demonstrate: a) the superiority of the index-velocity method over the conventional stage-discharge method to capture the dynamics of the unsteady flow, and, b) use of the of the index-velocity acquired by the SL to predict the time and magnitude of the flood crest during flood wave propagation. The exploratory investigations can potentially have a profound impact in the improvement of the accuracy and usefulness of streamflow data.

Best Practices and Lessons Learned Assessing, Communicating and Sharing Risk Information for Flood Risk Management

Oral - Parallel Session

Ms. Katelyn Noland ¹, Mr. Noah Vroman ¹, Mr. Christopher Baker ², Dr. Stacy Langsdale ²

1. U.S. Army, 2. US Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) Levee Safety Program uses the risk framework (risk assessments, risk management, and risk communication) to make risk informed decisions for levees in its portfolio. This portfolio includes not only USACE owned and operated levees, but also over 1,000 levees owned and operated non-federal sponsors. More than 10 million people work and live behind USACE program levees and as a result the efforts to assess, communicate, and manage levee risks is a shared among federal, state, and local government agencies, as well as communities and individuals. USACE has completed risk assessments on nearly every levee within its portfolio, shedding light on the risks associated with each system. This information is essential to risk-informed decision making and is predicated on understanding key risk drivers and potential consequences. Communicating those risks to all potential risk managers and providing access to risk information is key to risk management. USACE has been sharing risk assessment information with non-federal levee owners and communities as well as using that information to guide activities within the USACE Levee Safety Program. USACE recently published levee portfolio risk assessment data on the U.S. National Levee Database (NLD), which is a public facing interface responsive to questions such as whether there is a levee near me, the purpose of the levee including its role in managing flood risk in the community, the magnitude and characteristics of the flood risk associated with the levee, and what will get flooded if the levee overtops or breaches. This paper will discuss the successes, challenges, and lessons learned in providing access to levee related risk information and communicating that information so that it is relatable and actionable to risk managers, including USACE guidance, best practices, tools, and training to build capacity to execute this critical mission.

Bias Adjustments to the Global GEOGloWS ECMWF Streamflow Forecasts for Improved Local Decision-Making

Oral - PS I.a Systems approach for flood management (monitoring, modelling)

***Mr. Jorge Luis Sanchez-Lozano*¹, *Mr. Riley Hales*¹, *Mr. Giovanni Romero-Bustamante*¹, *Dr. Jim Nelson*¹, *Dr. Gustavious Williams*¹, *Dr. Daniel Ames*¹, *Dr. Norm Jones*¹**

1. Brigham Young University

The GEOGloWS ECMWF Streamflow Service is a global streamflow prediction system that provides access through web services to 15-day global streamflow forecast based on the ensemble predictions of the European Centre for Medium-Range Weather Forecasts (ECMWF) and a historical simulation based on ERA-5 Land data. One of the main concerns for decision-makers is the accuracy and uncertainty of hydrologic models, especially a global model. This uncertainty is due to the challenge of gathering and processing the needed local data to calibrate and validate these large-scale models and then assimilate for improvement. For global models, this is a challenge as the ability to perform validation over large domains is limited by both data and human resources. An important element of GEOGloWS forecasts is that they can be accessed as a data service through a web application or programmatically for improvement and development of derivative applications. In this presentation, we will describe the extension of a method to correct the bias in the GEOGloWS historical simulated streamflow which can then be extended to the forecast ensemble. We demonstrate an improvement in the bias-corrected in the historical simulation and in the forecasted values. Case studies will be presented where results have been found to be encouraging and suggest that the bias correction method can be used by local agencies around the world where historical observations are available to improve these global forecasts in order to provide decision-makers more actionable information.

Keywords: GEOGloWS, hydrology, observed data, simulated data, forecast data, ECMWF, Bias Correction.

Building more Resilient Roadways in the Missouri River Valley after the 2019 Flood

Oral - PS 1.c Flood infrastructure

Dr. Andrew McCoy¹

1. HDR

In March 2019, widespread flooding impacted the States of Iowa, Nebraska, and Missouri in the Missouri River basin due to rapid snowmelt and heavy rain, resulting in substantial flood conditions in western Iowa affecting towns and cities, transportation facilities including many Federal and State highways, railroads, and Federal aviation fields. Again in June 2019, due to significant rainfall, widespread flooding occurred along the Missouri River valley causing I-29 and several state highways to go out of service.

The various breaches along levee segments and levee-like embankments are being repaired along different timelines and expecting to take place over the next several years.

HDR has supported the Iowa DOT with development 120 mile 2D numerical model of the Missouri River (Mouth of the Boyer River to the Iowa-Missouri border) for operations support. Additionally several focus areas were identified for further study and the modeling facilitated an alternatives analysis for the design of more resilient transportation facilities for the future. The 2D model utilized Graphics Processing Units (GPU) to run models with close to 1 million wet cells within the allowable model run times.

This paper focuses on the 2D model development, calibration, validation, and demonstrates the usefulness of the model with two case studies.

Changes in the timing of flood events resulting from climate change

Oral - Parallel Session

Dr. Donald Burn ¹, ***Mr. Paul Whitfield*** ²

1. University of Waterloo, 2. University of Saskatchewan

Climate change is expected to impact the flood regime for many locations. The nature of changes in the timing of flood events that have occurred over the past 80 years are examined within Canada and adjacent areas in the United States. The timing of flood events is important for the operation of flood defenses and to better understand how changes in the hydrologic regime can affect the magnitude of flood events. We examine data from 46 long term streamflow gauging stations from a reference hydrologic network (RHN) for changes that have occurred, or are continuing to occur, in flood regimes from natural watersheds; 23 reference sites are from the Canadian Reference Hydrometric Basin Network (RHBN) and 23 sites are from the U.S. Geological Survey (USGS) Hydro-Climatic Data Network (HCDN). These RHNs were specifically developed to assist in the identification of the impacts of climate change; stations are considered to have good quality data and were screened to avoid the influences of regulation, diversions, or land use change. Peaks over Threshold (POT) event timing is used to investigate changes in the timing of flood events. Seasonality measures, using circular statistics, illustrate changes in the nature of the flood regime based on changes in the timing and regularity of flood threshold exceedences. Measures demonstrate flood regime shifts that include shifts from a nival regime to a mixed regime and from a mixed regime to a more pluvial-dominated regime. The flood regime at many of the subject watersheds demonstrates a decreased prevalence of nival flood occurrences, which has implications for design flood estimation and the operation of flood control infrastructure.

Communicating uncertainty and risk in flood forecasts: Improving the Use of Hydrologic Probabilistic Information in Decision-Making

Oral - Parallel Session

***Dr. Kathryn Semmens*¹, *Ms. Rachel Hogan Carr*¹, *Dr. Burrell Montz*², *Ms. Keri Maxfield*¹**

1. Nurture Nature Center, 2. East Carolina University

Abstract: Communicating forecasts and risk effectively requires understanding how intended audiences interpret and use forecast information whether presented deterministically or probabilistically. How do public and professional audiences use and understand probabilistic hydrologic forecasts and how can uncertainty be presented effectively?

To investigate these questions, Nurture Nature Center and East Carolina University have conducted three social science research studies looking at flood forecast products in Easton, PA, Lambertville, NJ, Ocean and Monmouth Counties, NJ, Jefferson County, WV, and Frederick County, MD, and recently completed a fourth study involving Eureka, CA, Gunnison and Durango, CO, and Owego, NY. The research team employs a mixed-methods approach utilizing scenario-based focus groups, surveys, and potential product revisions to assess understanding and impact of forecast formats and graphics on communicating risk.

After providing context from previous studies, we present details of our recent study of three forecast products to propose improvements to the display and communication of uncertainty and probabilistic information in hydrologic forecasts. Specifically, the Advanced Hydrologic Prediction System, the Hydrologic Ensemble Forecast System, and briefings for impact-based decision support services were presented to residential and professional audiences in three River Forecast Center service areas (Middle Atlantic, Colorado Basin, and California Nevada). An iterative process involving potential variations of the scenario products allowed the project team to assess how deterministic and probabilistic forecasts can best be understood to convey the complexity of risk and uncertainty in hydrologic forecasts.

Findings show significant differences in understanding and needs among the various stakeholders (professionals and public) and between different regions, but in general, additional uncertainty information was positively received. A series of user-tested prototype products developed in cooperation with the operational offices in each study area and detailed key findings and recommendations for probabilistic communication of risk will be presented.

Keywords: Uncertainty Probabilistic Forecast Flood Briefings

Contingency planning and flood early warning system of the Volta-Niger basins for capacity building under the “Water disaster platform to enhance climate resilience in Africa” (WADiRE-Africa) Project

SS I.g

***Dr. Maksym Gusyev*¹, *Prof. Miho Ohara*¹, *Dr. Mohamed Rasmy*¹, *Dr. Katsunori Tamakawa*¹, *Mr. Katsuhiko Onuma*², *Mr. Hiroyuki Ito*¹, *Prof. Toshio Koike*¹, *Prof. Masaki Yasukawa*³, *Prof. Eiji Ikoma*³, *Dr. Mohamed Hamatan*⁴, *Dr. Abdou Ali*⁴, *Mr. Salifou Dene*⁵, *Dr. Anil Mishra*⁶, *Dr. Abou Amani*⁶**

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As witnessed with the increasing hydro-climatic variability over time globally, West African countries are also faced with severe floods recurrence posing a major obstacle to the region’s efforts for poverty alleviation and achieving sustainable development. This necessitates increasing flood disaster resilience and enhancing regional and national capacity to predict, monitor, and provide appropriate preparedness within the region. To address these issues in eleven countries of the Volta and Niger River basins, ICHARM, AGRHYMET and UNESCO IHP in collaboration with Volta Basin Authority (VBA) and Niger Basin Authority (NBA) implemented 2-year project “Water disaster Platform to enhance climate resilience in Africa” (WADiRE-Africa) funded by the Government of Japan with the inception workshop held in Lomé, Togo on 17-18 June 2019. The WADiRE-Africa framework introduced contingency planning at two flood-prone municipalities and flood early warning systems (FEWS) prototype with ICHARM models on Data Integration and Analysis System (DIAS) developed at the University of Tokyo transferring outputs to AGRHYMET, VBA, NBA and eleven countries. The regional DIAS-FEWS prototype 1.0 is developed using real-time satellite rainfall, which is statistically bias-corrected with in-situ data, to simulate natural flood discharge and inundation depth providing access to FEWS prototype-generated real-time outputs. The DIAS-FEWS provides self-study pre-recorded English and French materials of the WADiRE-Africa e-Learning course “Flood Early Warning, Hazard Mapping and Contingency Planning in the Niger and Volta River basins” for training of experts (ToE) from VBA and NBA countries. Next, selected ToE leaders join one-week training of trainers (ToT) course to facilitate community flood risk reduction workshops in their countries. Despite COVID-19, the WADiRE-Africa project establishes the DIAS-FEWS platform providing a robust real-time operated infrastructure for disseminating natural flood information among eleven Volta-Niger basins countries and enhances flood awareness and contingency planning capacity with 288 ToE and 44 ToT participants increasing West Africa population disaster resilience.

Development and Applications of SRH-1D

Oral - Parallel Session

Dr. Jianchun “Victor” Huang¹, Dr. Blair Greimann²

1. Bureau of Reclamation, 2. Bureau

Sedimentation processes within rivers can be important to the long term viability of flood control systems. This paper presents the principles and methodologies of SRH-1D (Sedimentation and River Hydraulics – One Dimension). SRH-1D is a hydraulic and sediment transport numerical model developed to simulate flows in rivers and channels with or without movable boundaries. It is able to compute water surface profiles in single channels, dendritic, and looped networks. It has both steady and unsteady flow models, steady and unsteady sediment models. The active layer concept, which allows selective erosion, provides an appropriate framework to simulate bed armoring. Multiple bed layers are also possible. Non-cohesive sediment transport equations and cohesive sediment physical processes are applied to calculate the sediment deposition and erosion. SRH-1D model is used to predict the impact of sedimentation processes resulting from the effective removal of a small dam on the San Joaquin River on future flood elevations. Because sedimentation processes are difficult to predict and can have significant uncertainty associated with them, an uncertainty analysis of model results is used to inform the design of flood mitigations measures.

Development and evaluation of a risk communication system on water-related disaster management using virtual reality technologies

Oral - Parallel Session

Dr. Masatoshi DENDA¹, ***Dr. Daisuke KURIBAYASHI***², ***Prof. Miho Ohara***¹, ***Dr. Yoshimasa MOROOKA***¹,
Dr. Naoko NAGUMO¹, ***Mr. Masakazu FUJIKANE***¹

1. Public Works Research Institute ICHARM, 2. Reconstruction Agency

To achieve effective water-related disaster management, it is critical that each citizen keeps in mind that a flood disaster can occur to anybody and trains themselves to take appropriate evacuation actions when noticing signs of a disaster or receiving warnings. ICHARM has been studying practical disaster management measures to support citizens in attaining those goals and, as part of such effort, developed a virtual flood experience system using VR technology.

VR provides an opportunity for people to virtually experience water-related disasters before they actually occur. Since not many people experience a flood in reality, VR is very useful for them to see and feel what a flood would be like before they experience a real one.

In 2019, we conducted a questionnaire survey on VR at two outreach events held by ICHARM and the Public Works Research Institute (PWRI). At those events, the participants used VR and experienced a virtual flood situation, in which they tried to evacuate to the second floor. After collecting 226 answers (adults: 111, children: 115), we statistically analyzed them to see whether the VR experience had any effect on how people view a flood. We also compared adults and children in the effect of the VR experience.

The results found no difference in perception of a flood between adults and children. All age groups answered that being in a flood situation was very scary, even knowing that it was only virtual. Merely 40% were worried about a future flood before the virtual flood experience, but the figure went up to 80% after the VR experience. These results indicate that VR can be an effective tool to help people realize the destructive nature of floods and the importance of preparing for future events.

Keywords: Risk communication, Virtual reality (VR), Virtual flooding condition, questionnaire survey

Development of a Real-time Forecasting System for Flood Events

Oral - Parallel Session

Dr. Gokhan Kirkil¹

1. Kadir Has University

Climate change has a direct influence on the hydrological cycle and its elements. One effect is that extreme events are expected to occur more frequently at different times and locations on the Earth with increasing intensity. Given these facts, it is important to develop reliable forecasts of flooding streams and rivers prior to the occurrence of dangerous conditions. Real-time flood forecasting systems are becoming a critical tool for emergency preparedness and decision making where life and property are in jeopardy. With the aim of developing a fully coupled atmosphere-hydrology model system, the Weather Research and Forecasting (WRF) model is enhanced by integrating a new set of hydrologic physics parameterizations (WRF-Hydro) accounting for lateral water flow occurring at the land surface. The performance of the two-way coupled (atmosphere-hydrology-atmosphere) integrated modeling system (WRF-Hydro) is evaluated for the selected heavy rainfall events and associated flooding conditions over two basins in Eastern Black Sea and the Mediterranean regions.

Development of real-time flood forecasting system using particle filter combined with RRI model

Oral - Parallel Session

Dr. Daiki Kakinuma¹, ***Mr. Yosuke Nakamura***², ***Mr. Hiroyuki Ito***¹, ***Prof. Toshio Koike***³, ***Prof. Koji Ikeuchi***⁴

1. International Center for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM), 2. Mitsui Consultants Co., LTD., 3. International Center for Water Hazard and Risk Management, Public Works Research Institute, 4. The Univ. of Tokyo.

In recent years, water-related disasters due to torrential rainfall have become more frequent and severe. Torrential rainfall is expected to be even more frequent and intense due to global warming. The impact of such changes is likely to be greater in small mountainous river basins across Japan. In order to ensure a sufficient lead time for a safe evacuation, it is necessary to forecast river water levels in real-time utilizing a hydrological model. However, it is difficult to develop a flood forecasting model with highly accurate for such small rivers because most of the basins have poor hydrological data.

In this study, we conducted real-time flood forecasting using the hydrological models and data assimilation for the next six hours. We use a Particle Filter (PF), which is one of the data assimilation techniques that can be estimated state-space or parameters in the model by the filter theoretic-based on simulation. A system equation is the RRI model, which is a two-dimensional distributed hydrological model capable of simulating rainfall-runoff-inundation process simultaneously on a river-basin scale.

The state estimated by PF is the water depth on the slope. Observation equation is Gaussian-distribution according the observed water levels, the number of particle is 64. In this study, since we aim to improve the reproducibility of hydrological models, we simulated the forecasting water level under the condition forecasting rainfall is perfectly predictable for the next six hours. In order to verify the accuracy of flood forecasting, we compared RRI models with and without data assimilation. As a result, the forecasted water level by data assimilation was more accurate than the calculation results without data assimilation at all times from 1 hour to 6 hours ahead. In conclusion, we were able to suggest that flood forecasting accuracy can be improved by PF with the RRI model.

Development of the Japanese Arakawa River flood models for the extreme rainfall/flood events on October 2019

Oral - Parallel Session

***Dr. Kenichiro Kobayashi*¹, *Mr. Kazutoyo Toyomasu*², *Mr. Sho Tanaka*²**

1. Kobe University, 2. Graduate School of Engineering, Kobe University

For last years, a distributed rainfall-runoff/flood-inundation model has been developed. The model can simulate the floodplain flow by a 2D shallow water equation (leap frog method). The river flow is simulated with a 1D dynamic wave equation (FDS scheme). The mountain flow is simulated by a 2D depth integrated unsaturated flow model. The 2D floodplain flow model is coupled with the 1D river and 2D unsaturated flow models, thus the integrated model can simulate the basic flow processes in a catchment on some level with an Open MP parallelization. Likewise, solely the 2D shallow water model for flood inundation simulation has been parallelized with Open MP, MPI and a supercomputer which realized more than 100 times faster simulation compared to a 16 core workstation. On the other hand, the extreme rainfall/flood event occurred in large area of east Japan on 10-13 October 2019. This event caused one of the largest-ever impacts on east Japan including Tokyo metropolitan area. According to Japan Meteorological Agency, the total rainfall for 10-13 attained 1000 mm/3days at Hakone, Japan. 500mm/3days were observed at 17 observatories. Historically largest 3, 6, 12, 24 hour rainfalls were observed at many locations in East Japan. The number of death was more than 100 as of now. Dike breach occurred at 140 sites of 71 rivers. The number of house damaged was more than 78000. Thus, in the paper, we attempt to investigate the flood processes using the runoff model for a catchment and inundation model for the inundated area. The target is the Arakawa River catchment and Irumagawa River, the tributary flowing through Tokyo-Saitama metropolitan area. The rainfall-runoff and the inundation processes with the dike breaks occurred are investigated in details. The paper has meaning as a fast report of the event with well developed flood models.

Extreme versus minor events: Cumulative flood-induced mortality across countries in the past four decades

Oral - Parallel Session

***Dr. Bo Chen*¹, *Ms. Fan ya Shi*¹, *Ms. Ting ting Lin*¹, *Dr. Jing Zheng*²**

1. Beijing Normal University, 2. Guangdong Climate Center

More attention has been paid to the cost of extreme but infrequent floods than to the cost of minor but frequent events. To address this question, we looked back into the historical records of flood-induced losses. Using the flood-induced mortality data for the past four decades from the international disaster database EM-DAT, we defined the levels of flood loss according to the frequencies of flood-induced death, calculated the cumulative mortality and the marginal benefits of various levels of flood loss prevention. Our data analysis showed that for the world's top countries with large flood-induced mortality and with various levels of development: 1) in the past four decades, 70% of these countries have their cumulative death of minor floods exceeding half of that due to extreme floods; 2) for 80% of these countries, their marginal benefits tend to decrease with increasing levels of loss prevention and peak at loss prevention levels of 2-yr or 5-yr flood-induced mortality. These indicate that, in the long run, the cumulative death of minor floods is remarkable when compared to that of extreme events, and preventing loss of minor events can be efficient in reducing the total loss. For flood risk management under climate change, minor loss events deserve more consideration.

Flash Flood Early Warning Upgrade at Watershed Scale

SS I.f

***Dr. Changzhi Li*¹, *Prof. Dongya Sun*¹, *Dr. Xiaolei Zhang*¹, *Dr. Ronghua Liu*¹, *Mr. Xuezhe Tang*², *Mr. Hongxun Xue*³**

1. *China Institute of Water Resources and Hydropower Research*, **2.** *Henan Provincial Flood Control Section*, **3.** *Henan Institute of Water Resources Research*

A nationwide flash flood management project was accomplished and great achievements obtained from 2009 to 2016 in China, but forecasting and early warning systems are still at primary stage of development, many challenges still exist in aspects of social management and technical support. This study aims to discuss an effective approach for flash flood early warning upgrade at watershed scale by improving accuracy of flash flood early warning, extending leading time of flash flood, and enhancing emergency response capability at community level. Shewei River Watershed, a highlighted flash flood prone area with drainage area of 535 km² and locating in the north-east of Xixia County, China, was selected as the piloting catchment in this study. The key contents include: (1) piloting real-time flash flood early warning system at the entire Shewei River Watershed by developing point-to-point flash flood warning based on dual-mode communication and real-time flash flood early warning system based on county-level platform; (2) enhancing capacity for flash flood emergency response at community level; and (3) sharing knowledge on flash flood early warning.

Key Words: flash flood early warning, upgrade, watershed scale

FLOOD MUSEUM

SS I.f

Dr. emre akcali¹

1. General Directorate of State Hydraulic Works

The best way to prevent floods is “not to cause floods with human hands”. Based on this principle, the project of the first interactive “**Flood Museum**” of the world has been completed in order to raise awareness on the floods, by General Directorate of State Hydraulic Works of Turkey.

In the “Flood Museum” which take place in Trabzon Province, where the most floods occurred in Turkey, the main themes of “avoiding from floods”, “flood control” and “behavior at the time of the flooding” are handled. Under these themes 35 different sections (Interactive river flood physical model, Interactive urban flood physical model, Open check dam hydraulic model, Innovative and classic flood /sediment control structure types, Landslide - flood interaction physical model, debris barrier model, landslide and flood model of 1929 Trabzon province, Is your house in flood risk (touchscreen map), Flood Information Cinema, Flood Emergency Response Team Room, Virtual Reality Flood Room, Flood Technical Information Section, Historical Floods section, Flood Behavior section, Flood Early Warning simulator, mobile flood coordination center, etc.) take place.

The museum is free of charge to all national and international visitors of all age groups. In addition, for all technical personnel and academicians who involved in floods, have opportunity to see how to design flood and sediment control facilities correctly.

Thanks to the flood museum completed in 2020, local people and all other visitors are informed about floods and very important steps are taken to reduce flood damages. Official links for the museum are below.

<https://www.youtube.com/watch?v=k1CxShtfexw>

<http://taskinmuzesi.dsi.gov.tr/index.php/en/home-page/>

Key words: Flood Museum, Flood control, Flood awareness

FLOODPLAIN MAPPING OF UNGAUGED RIVER: A CASE STUDY ON SETI RIVER IN POKHARA, NEPAL

Oral - Parallel Session

Dr. Keshav Basnet ¹, Mr. Deepak Acharya ¹, Dr. Krishna Prasad Bhandari ¹, Mr. Biwas Basnet ¹, Dr. Suraj Lamichhane ¹

1. Tribhuvan University

Settlements and infrastructures along the Seti River in Pokhara, Nepal are in high risk of flood. Seti River being a snow feed river, is in risk of flash flood due to avalanches and rockfall in mountainous region. The river is flowing through narrow gorges in the central part of Pokhara Metropolitan City. Main goal of this study was to prepare floodplain maps along the ungauged Seti River in Pokhara using HEC-RAS for peak floods of 20, 50 and 100 year return periods. Catchment Area Ratio (CAR) method was applied to find the peak floods using 42 annual peak data of Mardi hydrological station as base station. Comparing with the frequency analysis of Seti River from Gumbel method in Tanahu station where Seti River drains off, specific discharge per km² of catchment area was found to be comparable with difference of less than 3%. Hence the flood forecasting for each sections of Seti River within Pokhara was performed using CAR method taking the base station of Mardi. Cowan's (1956) approach was applied to estimate Manning's roughness coefficient (n) from surveyed terrain data and flow records over the weir at Tulsighat. Comparison of thus estimated n compared with HEC-RAS modelled n using one point comparison yielded less than 4.5% difference. As such, Cowan's approach was used to estimate Manning's n for the reaches of Seti River which is ungauged. Finally, available 12.5 m resolution DEM, though insufficient for precise analysis, was used for terrain data in HEC-RAS for floodplain mapping. Inundation area within Pokhara found to be 2.76, 3.05 and 3.59 km² for 20, 50 and 100 year return periods respectively. Laltin Bazar, Gaighat and Ramghat areas identified to be under risk of floods. Floodplain maps of this study could be used for preparing flood hazard maps, planning infrastructures and flood management.

Hydraulic Flood Modelling Sensitivity Analysis of Culvert Blockage Factors and Blockage Timing

Oral - Parallel Session

Mr. Lee Williams¹, Prof. James Ball¹

¹. University of Technology Sydney

Estimation of floods remains a significant problem for managers of riverine systems. The occurrence of floods is the result of both climatic factors and catchment factors. One of the catchment factors that influences floods is the interaction between debris material and cross-drainage structures like culvert, bridges, etc. As the purpose of design flood estimation is the prediction of both flood magnitude and flood likelihood, there is a need to understand how blockage of cross-drainage structures influences the predicted flood levels and flows.

Presented herein are the outcomes from a hydraulic modelling study into the impact of cross-drainage structure blockage on both the predicted flood level and the predicted flood flow. The study presented is based on predictions obtained from TUFLOW; TUFLOW is a 2-D model of flows in rivers and floodplains developed in Australia. Factors considered in the study were the timing of blockage, the magnitude of blockage, the peak flow of the flood hydrograph, and the catchment storage upstream of the cross-drainage structure. These factors were modified in a manner designed to enable a sensitivity analysis of cross-drainage blockage on flood predictions when compared to flood predictions obtained with no blockage present in the cross-drainage structure.

Blockage results in a change to the flood profile and downstream discharge. This is dependent upon the relationship between the inflow magnitude and upstream storage volume. If the storage capacity is exceeded for the unblocked condition, the structure experiences overtopping. Therefore, any blockage will increase the upstream water level. A blockage will also reduce the time required to fill the storage capacity resulting in an increase in downstream discharge. The nature of this relationship is governed by the individuality of each structure. This study considers the results produced and highlights the need for further research.

Hydroclimatology of Extreme Floods in the Lower Mississippi River Basin

Oral - Parallel Session

Ms. Yibing Su¹, Dr. James Smith¹, Dr. Mary Lynn Baeck¹

1. Princeton University

Is extreme flooding getting worse? A question that demands more and more attention from the engineering community worldwide, but especially so among the Army Corps of Engineers. The urgency for the need to address the question is in part forced by the sequence of extreme flood events starting at 2008. The Bonnet Carre spillway, designed as the last line of defense for New Orleans, has been activated 5 times in the past 12 years as opposed to 8 times in the previous 78 years since completion. In this study, we assess the upper tail nature of flood extremes in the lower Mississippi river basin through hydrometeorological and hydroclimatological analyses of past extreme rainfall events in the region. A specific focus is paid on atmospheric water balance terms and their ability in dictating rainfall extremes. Using reconstructed atmospheric state variables from 1979 to present, provided by the North American Regional Reanalysis (NARR), we analyze the climatology and extreme value behavior of precipitable water (PW), integrated water vapor transport (IVT), and water vapor convergence over various durations of interest. In addition, the stochastic storm transposition (SST) approach and the NCEP Stage IV rainfall product allow us to identify catalogs of extreme rainfall events from the past 20 years in the lower Mississippi valley that have significant surface hydrological impact potential at the time scales of interest. The SST catalog events are subsequently assessed in the context of climatology to address questions such as: what anomalies dictated the extreme rainfall that lead to extreme flooding; how extreme were the anomalies; do the anomalies come from bounded distributions; are the extremes likely to increase over time. This series of analyses will provide insight on the upper tail of extreme flooding and inform methods for estimating possible future floods for high hazard structure design.

Improving Flood Management in Metro Manila

Oral - Parallel Session

Mr. Joop Stoutjesdijk¹

1. World Bank

The geographic location of the Philippines makes it prone to typhoons and extreme weather patterns brought about by climate change may worsen the situation. A Metro Manila Flood Management Master Plan (2012) proposes a set of priority structural and non-structural measures to provide sustainable flood management and safely control major flood events in Metro Manila. Major elements of the Master Plan are either under implementation or preparation, realizing that flood management improvements require a multi-sectoral approach of simultaneously improving or constructing infrastructure, improving solid waste management, and where needed relocating informal settler families living over waterways. The paper will describe the development of the program, how it will contribute to flood management, and how reducing the risk and impact of disasters is key to achieve the development goals of the Philippines. A US\$500 million Metro Manila Flood Management Project is under implementation that focuses on improving urban drainage through modernizing pumping stations and drainage channels, introducing efficient, high capacity pumps and modern dredging equipment, and improving solid waste management. The project also aims at increasing water retention capacity, including rooftop rainwater collection, green roofs, and temporary retention of drainage water in public areas such as parks and basketball courts. A second element of the Master Plan is under preparation. The objective is to improve flood management in the Pasig-Marikina River Basin through major grey and green structural measures (large dam, smaller control dams, and a retention basin), related smaller structural measures (catchment rehabilitation, sediment management, and flood forecasting and early warning systems), non-structural measures (inundation mapping, emergency response planning), and support to indigenous people living in the project area. The paper will discuss how the implementation of the proposed interventions can manage rainfall events up to a 100 year return period.

Incorporating Climate Change into Design Storms for Flood Risk Mapping and Infrastructure in Newfoundland and Labrador, Canada

Oral - Parallel Session

Ms. Abena Amponsah ¹, Dr. Joseph Daraio ¹, Dr. Amir Ali Khan ²

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Climate change is projected to bring warmer, wetter and more extreme events across Newfoundland and Labrador (NL). The Government of NL (GNL) has the most recent climate projections for intensity-duration-frequency (IDF) curves that have been used to updated flood risk maps accross the province. However, the the complexity of processes that determine the hydrologic responses of watersheds makes it difficult to predict changes without a high level of uncertainty. Additionally, it is likely that storm types that are used to develop design storms will shift as the climate changes, and it is not known if/how interactions between design storms and watershed properties will impact peak discharge. The objectives were to examine the effects of design storm and loss method on peak discharges under climate change. Peak discharge was simulated with 24 hour rainfall depths from current climate and two future time periods under two emission scenarios using HEC-HMS for hypothetical catchments across Newfoundland and Labrador. Bayesian regression methods were used to assess effects of interactions between design storm and loss methods on peak discharge. Results indicated that peak discharge increased in conjunction with increases in event rainfall intensity, which are impacted by return period and climate change. Under current climate conditions there is little change in peak discharge across a range of design storms depending on loss method. Climate change projections, which provide changes in IDF curves, seem to change this relationship in many locations to where peak discharges tend to increase when most rainfall occurs later in the event. The relationship between peak discharge, temporal distribution and loss method may change under a changing climate, and it is important to consider these interactions when assessing flood risk and for designing flood related infrastructure.

Cold regions, flood risk, modeling, uncertainty, stream flow

Incorporating Resiliency for Iowa DOT Infrastructure Due to the 2019 Missouri River Flood

Oral - Parallel Session

Mr. David Claman¹, Mrs. Tamara Nicholson¹

1. Iowa Department of Transportation

Abstract:

Record February snowfall in combination with a powerful “bomb cyclone” over frozen ground conditions in eastern Nebraska and western Iowa led to historic flooding within the Missouri River basin in March, 2019. The flooding resulted in severe damages to infrastructure due to 13 levee breaches along the Iowa side of the Missouri River flood plain. This presentation will describe recovery activities, challenges faced, and Iowa DOT’s approach to incorporating risk and resiliency features into recovery efforts to mitigate future extreme events. The Corps has indicated that temporary levee repairs to provide 25-year protection won’t be completed until Spring 2020 and permanent restoration taking years. This will still leave I-29 and many other critical roadways at risk for flooding and damages, emphasizing the need to incorporate resiliency features into repairs.

As part of the emergency response, Iowa DOT established a resiliency work group tasked with evaluating the benefits, costs and risks of including resiliency components in repair activities. Repair/Betterment concepts were analyzed utilizing 2D hydraulic modeling of the Missouri River and flood plain to determine impacts to our infrastructure from various flood event scenarios. Resiliency improvements are being evaluated within the context of the entire transportation system needs. Iowa DOT is developing a Project Prioritization tool, including a “Resiliency Index” to better prioritize investments. The Resiliency Index will be one factor that contributes to the score of a project and considers the functionality of the transportation network after extreme events.

Investigating the Rainfall Characteristics using Ground and CMIP-5 Climate Models Data under Changing Climate in the Davao River Basin, the Philippines

Oral - Parallel Session

***Dr. Mohamed Rasmay Abdul Wahid*¹, *Mr. Jiyong Bae*², *Dr. Katsunori Tamakawa*¹, *Prof. Toshio Koike*¹**

1. International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM), 2. Seoul National University

Global warming will accelerate the water cycle and thus may exacerbate water-related disasters at global, regional, and catchment scales. In this study, we investigated the effect of climate change on rainfall in the Davao River basin. The results from the data analysis using long-term observed rainfall records (i.e., 1951 to 2016) showed very clear upward trends in heavy rainfall intensity (> 50 mm/day) and frequency during the recent climate from 1981 to 2016 when compared to those during the past climate from 1951 to 1980. However, there was no significant change in the annual rainfall climatology during the two climatic periods. Further examination was performed on the Global Climate Model (GCM) outputs to find out whether the identified trends will persist in the future climate over the basin. The GCM-simulated regional climatic conditions from CMIP-5 experiments were analyzed using the Data Integration and Analysis System of the University of Tokyo (DIAS-UT), and six GCMs were selected based on their performance indices during the historical period (1981-2000) for further investigation. The selected GCMs were statistically bias-corrected using ground rainfall records. The projected mean and extreme rainfall conditions were investigated under the RCP8.5 scenario. The results from all the selected models showed that the intensity and frequency of extreme daily precipitation will also increase and thus make the basin more vulnerable to floods in the future climate (2081-2100). In addition, mean monthly precipitation will increase for all the months during the future climate. This research will further investigate the impacts on rainfall under other global warming scenarios (i.e., RCP 4.5 and RCP 6.0), as well as associated changes in river discharges and inundation in the future climate. These results can be used to support more effective management of water resources and water-related disasters in the basin under the changing climate.

Key parameters affecting the flood discharge capacity of wide-shallow urban river channel

Oral - PS 1.d Citizen science for flood management

***Dr. Jiazhen Li*¹, *Dr. Xinlei Guo*¹, *Mr. Deshen Gao*², *Dr. Tao Wang*¹, *Dr. Yongxin Guo*¹, *Mr. Hui Fu*¹,**

***Dr. JIAJIA PAN*¹**

1. China Institute of Water Resources and Hydropower Research, 2. Shandong Electric Power Engineering Consulting Institute Corporation limited

Urban river channel is an important element in city economy and ecology development. It has the functions such as transportation, flood control and drainage, landscape culture, urban ecology, rainwater utilization, et al. Undoubtedly, flood control and management is the primary and the most crucial one. There are many parameters affecting the flood discharge capacity of urban river, just like the roughness coefficient of the river bed and side slope, section morphometry parameters and certain water blocking structure. Taking the flood control and regulating engineering of a wide-shallow river as a case study, physical modelling experiment and numerical simulation were conducted. The results showed that the section morphometry was the most important influence factor and uniform shape across the chainage would be preferable when an urban river channel was designed. For a wide-shallow one, the roughness coefficient of side slope produced a difference less than ten centimeter when it ranges from 0.035 to 0.060. Due to the complexity character of piers, the existing prediction models for bridge backwater have been examined not as accurate as desired. The comparisons of water surface level and water surface velocity indicate that the numerical simulation has proven to be a flexible and inexpensive tool to obtain typical characteristics of urban river channel flood discharge and facilitate a better city planning.

Management of Stormwater in a Rural Iowa Community

Oral - Parallel Session

Dr. Benjamin Maas¹

1. Buena Vista University

The City of Storm Lake, a rural population of 11,000, has become a leader in Iowa for stormwater management due to the realization that past stormwater management practices were not working. This realization was the result of two large precipitation events that occurred in 2013 (10 inches) and 2014 (6 inches), causing flooding that resulted in millions of dollars in damages to infrastructure. Flooding, in the flat city landscape, occurred not by the flooding of a creek or lake, but rather water pooling due to insufficient stormwater infrastructure. These precipitation events highlighted the fact that something needed to be done to improve the city's stormwater management.

The first action taken was to partner with environmental consulting companies to create a 'Green Infrastructure Plan for Water' in 2015, identifying locations in the city that flooded at 2-, 10-, and 100-year 24-hour storm events. These efforts resulted in the identification of more than 20 locations that flooded at within the 2-year interval. Because the city identified key locations that would flood, they were able to use that information to acquire necessary grant funding to improve their stormwater management practices. Over the last four years, rain gardens, retention basin, permeable pavers, and constructed wetlands have been built, lowering the risk of flooding in these once vulnerable locations.

The purpose of this presentation is to highlight the success the City of Storm Lake has had building stormwater infrastructure, resulting in less frequent flooding. A second objective is to share the designs of some of the successful stormwater infrastructure. Work continues to improve upon older designs, public education, and vegetation of rain gardens. Future research projects will focus on determining the quantity of suspended sediment and ions coming into and leaving rain gardens and retention ponds.

Keywords: Rain gardens, rural design, pavers, wetlands, native vegetation

Numerical and Analytical Solution for Reservoir Routing and its Application

Oral - Parallel Session

Prof. Yu Guo¹

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Reservoir routing is a painstaking work for its much factors involved and high calculating difficulty. Due to its remarkable profits thus people put forward different solutions for different issues in practice. But traditional methods for reservoir routing is unnecessarily complicated, it requires the solution of a transcendental equation at each time step, the author thinks that reservoir routing is actually simply the numerical solution of a differential equation, any standard method can be used and all are simpler than the traditional methods. Therefore the paper presents general model of numerical routing solution for weir flow (or sluice flow), double discharge constructions and discharge weir with breast wall. Based on these the author further presents a numerical and analytical solution for reservoir routing under complex conditions, the method satisfies real time flood control of reservoir operation and one of the assets of the techniques is its rapidity and accuracy, then the author uses calculating example of Dahuofang Reservoir routing to illustrate the rationality and practicability of this numerical and analytical solution.

Numerical investigation and improvement of stormwater drain inlet flow for prevention of street floods due to intense rainfall

Oral - Parallel Session

Prof. Akihiko Nakayama¹, ***Dr. Kok Weng Tan***¹, ***Mr. Jing Kuan Tan***¹, ***Ms. Xin Yan Lye***¹

1. Universiti Tunku Abdul Rahman

In low-latitude areas surrounded by the sea in South East Asia, strong but relatively short-duration rainfalls cause frequent inundation of streets affecting the traffic. Though these inundations are not as serious as large-scale floods that submerge buildings and houses but they occur very frequently and even daily. Even in cities where the drain systems are built to take sufficient volume of water and the drain channel is rarely or never full. However, streets and parking lots are often inundated frequently. The inundations are usually caused by insufficient capacity of drain inlets.

Storm water drainage inlets are designed based on empirical estimate that a constant fraction of water coming towards the inlet goes through it. The flow through drainage inlets installed along streets and parking lots are complex and the volume flow through them are conventionally estimated by a gross factor, 'capture rate' and the verification of the actual drain system is depended on a model test or observation of real structure. If too much water floods the area above the inlet, the inlet is choked and the flow rate reduces significantly compared with the ventilated flows.

Among various hydraulic analysis methods, there is none at present that can handle the complex water flow through the drain inlets. One of the present authors has applied Smoothed Particle Hydrodynamics (SPH) methods to high-speed air-water mixture past spill ways and stepped channels. The present work extends the SPH method developed for open-channel flows to complex flow through stormwater drain inlets. Also the direct effects of falling rain are simulated. The developed method is applied to a flow through model inlet and flows with some modifications and with incidental clogging, so better design of drain inlet structures is obtained to reduce streets inundations.

Permanent Canal Closures and Pumps Project for Protecting the City of New Orleans

Oral - Parallel Session

Dr. FANGBIAO LIN¹, Dr. John Take¹

1. Stantec Consulting Services, Inc.

City of New Orleans, Louisiana, has a large area with elevations lower than Lake Pontchartrain and was subject to catastrophic damages from the Hurricane Katrina in 2005. The 17th Street, Orleans Avenue and London Avenue Outfall Canals are critical elements of the flood control system in New Orleans and serve as drainage conduits. As a part of the Hurricane and Storm Damage Risk Reduction System (HSDRRS), Permanent Canal Closures and Pumps (PCCP) at these three outfalls were designed and constructed to replace the Interim Closures and offer a sustainable and reliable solution. The PCCP project was constructed by PCCP Constructors JV and designed by Stantec from May 2013 to December 2017.

The PCCP at 17th Street has eleven storm surge gates, six 51 m³/s pumps and two 25.5 m³/s pumps with a total capacity of 357 m³/s; The PCCP at London Avenue has seven storm surge gates, four 51 m³/s pumps and two 25.5 m³/s pumps with a total capacity of 76.5 m³/s; and the PCCP at Orleans Avenue has three storm surge gates and three 25.5 m³/s pumps with a total capacity of 76.5 m³/s. These facilities were constructed and designed to withstand 200 mph winds at three second gusts and 155 mph sustained winds. Three onsite power generation plants were designed and constructed for reliable power supply during a storm event with onsite fuel storage capacity to run at full capacity for five days of continuous operation.

This presentation first describes the project rationale, project overview, and design and build (DB) process. Technical challenges of this large-scale project will then be discussed with a focus on hydraulics. The use of CFD modeling approach, complemented by physical modeling and other traditional 1D and 2D hydraulic modeling, enabled Stantec to develop satisfactory designs with confidence and successfully address hydraulic challenges.

Piloting Innovative Flash Flood Early Warning System in Xixia County, China

SS I.f

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***Dongya Sun*¹, *Mr. Yang Wang*⁴**

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Forecasting and early warning is considered the most effective measure to save lives and reduce the damage from flash floods. The centralized early warning technology could not reach all the communities in a reliable manner; the early warning information given to the public was too coarse to decrease uncertainties in making evacuation decision. In this paper, a piloting flash flood early warning system suitable for small river sub-basins to be a benchmark is provided under the national plan, which aims to pilot a localized end-to-end flash flood early warning system that will help to upgrade or complement the county-level flash flood warning system. Overall, this paper will demonstrate new approach, methodology, and technology to (i) increase warning accuracy and its effectiveness in evacuation and emergency response; (ii) extend the lead-time of warning to provide more time to local residents to save valuables and their own lives; (iii) support the local governments and communities through the establishment of decision support system in emergency response; and (iv) improve the warning information dissemination, and promote community-based flash flood early warning.

Platform on Water Resilience and Disasters toward Quality Growth

SS I.g

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There is no doubt that floods have become more intense and frequent in recent years around the world due to climate and societal changes. To cope with this critical issue, the International Flood Initiative, a joint initiative organized by such international organizations as UNESCO-IHP, WMO, ICLR, UNU, UNDRR, IAHS, and IAHR, has globally promoted the establishment of “Platforms on Water Resilience and Disasters” (hereinafter referred to as “Platform”) with the concept of “Resilient, Inclusive and Sustainable” in line with the Sendai Framework, the Paris Agreement, and SDGs. Platforms, under which all relevant stakeholders, including academia, take concerted actions for better water-related disaster resilience at national and regional levels, act to reduce the risks of water-related disasters based on scientific knowledge and evidences. Platforms’ thematically integrated approach, composed of data integration, early warning, climate change impact, economic assessment, and contingency planning, contributes to the creation of societal benefits such as effective investment, well-founded policymaking, and good local practices including capacity development programs.

Platforms have been formulated in the Philippines, Sri Lanka, Myanmar, and Indonesia by institutionally and thematically localizing the philosophy and plans of the Platform to their historical backgrounds and prospects on water-related disaster management. Integrated risk assessment with themes tailored to the circumstances of each country enables its Platform to implement effective prediction systems and produce valuable publications by taking the interdisciplinary approach bridging the knowledge of hydrology, meteorology, economics, and sociology. The Platforms thus are demonstrating the initiative to bring science and technology into society and assisting the countries in making considerable progress in the reduction of water-related disaster risks.

Rating curve determination of a flash flood by imaging techniques with STIV

Oral - Parallel Session

***Prof. Ichiro Fujita*¹, *Mr. Takuya Hamada*¹, *Mr. Tatsushi Shibano*¹, *Mr. Kojiro Tani*¹, *Ms. Saki Inoue*²**

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In the past decades, downtown areas of Kobe City have been developed significantly with crowded residential zones and runoff discharges tend to increase more than before with shorter flood concentration time. As an example, a flash flood with a water level rise of 1.72m in 20 min took place in the Myohoji River in 2018. In order to establish a proper river basin plan including inundation analysis, accurate information of discharge is required. However, as the river flows down the hilly steep slope area in a narrow channel with a mean width of about 15 m, the flow tends to become supercritical, which makes the conventional technique such as a propeller type current meter inapplicable. In order to overcome the difficulty, three monitoring cameras with time-controlled recording system were installed at main and tributary channels to capture video images of a rapidly increasing flow. The system is composed of a visual camera for daytime measurement and a near-infrared camera during the night. The system partially succeeded in capturing the flash flood during the passage of Typhoon No.18 on Sept.4, 2018. However, images with visual camera captured the whole process of the flash flood that lasted about one hour. The video images were analyzed by the improved space-time image velocimetry (STIV) technique that utilize the masked wavenumber-frequency spectrum for discarding wave-generated textures. The maximum velocity was more than 5m/s. As the side wall of the channel is made of concrete, the water level was identified by examining the color change in vertical direction. The water level rose more than three meters during the flood. With all of the above information, a smooth rating curve at the location of the Kamiyoichi Bridge was obtained. The data is being used as a measurement data for a runoff analysis of the Myohoji River basin.

RECONSTRUCTION OF THE 1374 RHINE RIVER FLOOD EVENT USING A 1D-2D HYDRAULIC MODELLING APPROACH

Oral - Parallel Session

***Mr. Hieu Ngo*¹, *Ms. Anouk Bomers*¹, *Dr. Denie Augustijn*¹, *Prof. Rosh Ranasinghe*², *Prof. Tatiana Filatova*³, *Prof. Suzanne Hulscher*¹**

1. University of Twente, 2. IHE, 3. Delft University of Technology

Reconstruction of the most severe historic flood events contributes to a better quantification of design discharges corresponding to large return periods. This has a great significance in constructing flood defences to protect the hinterland from future flooding. However, the reconstructed peak discharge values corresponding to these historic flood events often have a large uncertainty related to the accuracy of the historic topography and hydraulic river and floodplain roughness. The 1374 flood event is considered the largest flood of the last millennium in the Rhine river. This study sets up a 1D-2D coupled hydraulic model for a study area stretching from Andernach to Haus Burgel (Germany) to reconstruct the maximum discharge of the 1374 flood event. The historic topography of the main river and floodplains corresponding to the year 1374 was extracted from a high-resolution Paleo-DEM reconstructed for the Lower Rhine catchment for 800 AD (van der Meulen et al., 2020). The hydraulic roughness for land cover classes corresponding to the Paleo situation for 800 AD was also used as the input data for this model. We performed an uncertainty analysis with different river bed levels and roughness values to estimate the influence of these uncertainties on the reconstructed peak discharge. The upstream discharge wave was also varied. The simulated flood water levels were compared with the 1374 flood marks. Based on this comparison, the discharge magnitude was determined to be between 12,800-21,400 m³/s, with a best estimate between 14,000-18,300 m³/s. These best estimate values were used in a flood frequency analysis to determine the design discharges corresponding to different return periods (Bomers et al., 2019). A significant reduction of 2000 m³/s in the design discharge was found corresponding to a 100,000 year return period.

Key Words: historic flood event, flood mark, hydraulic model

Reducing Flood Risk Through Regulatory Engagement

Oral - Parallel Session

Mr. Mark Cohen¹, Ms. Cori Farrar¹, Ms. Emma Ross¹

1. US Army Corps of Engineers

Flood risk managers face unique regulatory challenges throughout the different regions in California. Facility improvement projects or routine maintenance of existing facilities may require several regulatory permitting processes with distinct federal or state agencies. Impacts to state and federally listed species, schedule restrictions, multiple applications, conflicting policy requirements and compounding compensatory mitigation obligations can render the process excessively onerous for flood risk managers. These challenges can often delay or preclude a flood risk management effort or needed maintenance. An improved and more responsive permitting process would allow for necessary flood risk management projects to be completed in a timelier manner. During the rainy season, predictable permitting timelines could alleviate flood risk in the region.

US Army Corps of Engineers, Los Angeles District, convened a Project Delivery Team (PDT) to develop a forward-thinking and collaborative approach to coordination and outreach to flood risk management agencies. The PDT communicated with agencies to identify and categorize gaps in the regulatory processes. Using that information, the team consolidated existing training materials and developed new modules to engage stakeholders on specific identified issues, including improving and maintaining infrastructure, emergency permitting, Section 404/408 coordination, mitigation and green infrastructure. In the initial socialization of this project, both applicants and agencies agreed that improved access to information would foster effective communications and address the challenges. Better information would support coordination with applicants and result in increased regulatory protection and compliance with the potential for increased efficiencies. During the final project phase, the team will set up a collaboration event with agencies and stakeholders to develop an action plan that reflects enhanced permitting processes that balance requirements of the regulatory process with risk awareness in long-term flood risk management or emergency response activities.

Keywords

Flood Risk Regulatory Emergency Collaboration

Removal of Saltmarsh-Impairing Tidal Flow Restrictions: Impacts on Upstream Flooding

Oral - Parallel Session

Mr. Bertrand Byrne ¹, Prof. Qizhong Guo ¹

¹. Rutgers University

Flow-restricted tidal creeks reduce tidal range and flow rate thereby disrupting established inundation and materials transport patterns critical to the sustainability of upstream saltmarshes. Although restoration of tidal flow by removing flow restrictions improves saltmarshes' viability, risk of upstream flooding may be potentially increased. Analysis of related flooding risk by mimicking real-world conditions where tidal cycles combine with stormwater runoff is necessary. This study investigated the flooding risks associated with removal of flow restrictions from tidal Marshes Creek on the community of Tremley Point in Linden, New Jersey, USA. A hydrologic/hydraulic model was developed and used to project water surface elevations (WSELs) under combinations of various design rainfall events with April 2015 spring tide before and after removal of flow restrictions. Spring tide after removal of flow restrictions would result in a higher peak WSEL of 0.25 m. Spring tide combined with rainfall of 10-yr, 25-yr, 50-yr, 100-yr return periods would result in peak WSELs 0.04 m higher, 0.02 m lower, 0.08 m lower, 0.12 m lower, respectively. These results show that compared to the existing restricted flow conditions, the removal of restrictions offers greater flooding risk for tide-only scenarios, while presenting less risk as the amount of rainfall runoff increases. However, for the particular community assessed, the small increase in WSEL under the tidal influence alone and under the combined influence with small rainfall would not flood the community. Taken together, fully unrestricting tidal flow on Marshes Creek will not increase the flooding risk to Tremley Point based on the assumptions used for this study. This type of study would help make the case for removal of tidal flow restrictions for saltmarsh and ecosystem restoration without exacerbating the upstream flooding problems.

Risk Analysis for Flash Flood Hazards in China

SS I.f

Prof. Qing Li ¹, Prof. Liang Guo ¹, Prof. Bingshun He ¹, Dr. Changzhi Li ¹, Prof. liu changjun ¹

1. China Institute of Water Resources and Hydropower Research

In recent years, flash flood hazards have become one of the major natural hazards in the world. The proportion of casualties and socio-economic losses caused by flash flood hazards in all kinds of natural hazards continues to rise every year, causing widespread concern among governments, world organizations and people living in hilly areas. Some countries have made flash flood prevention a national strategy.

The risk analysis of flash flood hazards is the foundation and premise of flash flood hazards prevention. In this paper, the risk analysis of flash flood hazards is the core contents. Based on the general theory of natural hazards system, the concept and expression of flash flood hazards risk are put forward. Based on the national investigation and evaluation data of flash flood hazards, the risk factors of flash flood are identified by correlation analysis, principal component analysis and factor analysis. Based on the analysis of deterministic coefficient model, the quantitative relationship of the risk factors of flash flood disaster is obtained, and the total factor risk index system of flash flood disaster is established. The small watershed in hilly area is taken as the basic unit, the risk of flash flood hazards in small watersheds is calculated by dividing 8 regions, and the fine risk analysis results of flash flood disaster in small watersheds are obtained. Further analysis of the spatial distribution characteristics of the national flash flood hazards risk will help for decision support and risk management.

Key words: flash flood hazards, risk analysis, deterministic coefficient model, risk management, China

Self-regulation of flood water levels for the uncertain impact of river interventions in a bifurcating river system

Oral - Parallel Session

Mr. Matthijs Gensen¹, Dr. Jord Warmink¹, Dr. Fredrik Huthoff¹, Prof. Suzanne Hulscher¹

1. University of Twente

The amount of discharge in a river section is a key uncertainty factor in flood risk analyses and is determined by upstream conditions as well as the distribution of discharge over river branches at river bifurcations. This study assesses the impact of river interventions in a bifurcating river system, considering the Dutch river Rhine system with its two bifurcation points. The river system is schematized in a 1D model, using the main channel roughness and floodplain roughness as stochastic variables. With this model we evaluated the uncertain impact of river interventions with varying locations and dimensions. Model results show self-regulation of downstream water levels and water level uncertainties through changes in the discharge distribution at bifurcation points. This is explained by a self-regulating mechanism in which the water level lowering impact of an river intervention induces an increase in discharge towards the branch in which the river intervention was implemented. This effectively reduces the impact of the intervention. Additionally, the self-regulating mechanism reduces the uncertainty of the impact of the river intervention. So, compared to a non-bifurcating river system, the impact of river interventions on flood water levels reduces, but involves less uncertainty. Furthermore, results show that the self-regulating mechanism has a larger influence in the smaller distributaries compared to the larger distributaries. Considering the results, it is essential to regard the entire river system, and specifically the influence on the distribution of discharge at bifurcation points, in the design and assessment of river interventions. We conclude that in a bifurcating river system, water levels and their uncertainties are controlled by a self-regulating mechanism. Water level uncertainties are smaller and therefore, flood risk estimates are more certain if considering this self-regulating mechanism in flood risk analyses.

Spatial Data-Based Hurricane Damage Models for Single Family Homes

Oral - Parallel Session

***Dr. Carol Massarra*¹, *Dr. Carol Friedland*², *Dr. Michael Leitner*², *Dr. Casey Dietrich*³**

1. East Carolina University, 2. Louisiana State University, 3. North Carolina State University

Hurricane are multi-hazards weather phenomenon (e.g., wind, rain, storm surge, coastal flooding, waves). The generated damage may be greater than the aggregation of damage caused by each hazard separately. Therefore, damage models must consider all associated hazards. The data-based damage modeling approach mainly focuses on non-spatial models, which ignore the existence of spatial autocorrelation between data points rather than evaluating the variation of observations based on geographical distribution, as spatial models do. This paper develops a hurricane multi-hazards spatial damage model to predict the probability of collapse using Geographic Weighted Logistic Models (GWLMs). GWLMs can be considered a spatially “local” form of the non-spatial logistic regression, in which the model is fit at each location. Instead of just one global regression equation for the entire dataset, this technique generates parameter estimates for each neighborhood within the spatial dataset. Physical damage and building attributes in coastal Mississippi following Hurricane Katrina (2005) and high-resolution numerical hindcast hazard intensities from the Simulating WAVes Nearshore and ADvanced CIRCulation (SWAN+ADCIRC) models are used as model input. Calculation of local relationships requires the choice of a spatial weighting factor, a value that determines how strongly values measured at nearby locations influence the regression equation calculation. In non-spatial model, the weighting factor is set to unity for all values in the dataset, and the neighborhood is extended to the entire geographic area, so values from all locations contribute equally to the regression equation. Spatial model quantifies the spatial variation and the relative importance of model variables at each location and helps understand the spatial distribution of the variables and their effects on building collapse. Results show spatial variation in the effect of each variable in the model, identify hazard variables that have the most variation across space, and indicate regions with highest damage from hurricane hazards.

Strengthening Resilience against Water-related Disasters by Formulating the Platform on Water Resilience and Disasters in the Philippines

SS I.g

Dr. Anthony Sales¹, **Mr. Jonathan Victorero**¹, **Mr. Socrates Paat**², **Mr. Michael Alpasan**³, **Dr. Patricia Ann Jaranilla-Sanchez**⁴, **Dr. Miyamoto Mamoru**⁵

1. Department of Science and Technology (DOST) Region XI, 2. Philippine Atmospheric, Geophysical and Astronomical Services Administration, 3. Department of Public Works and Highways, 4. School of Environmental Science and Management (SESAM), University of the Philippines Los Baños (UPLB), 5. Public Works Research Institute

The Philippines has been known as a country with high disaster risk due to its geographical location and geologic conditions. Located in the middle of the Pacific Typhoon Belt, the country is hit by an average of 20 typhoons every year and suffer considerably from increasingly frequent disasters. To cope with the challenge of water-related disaster risks, all stakeholders in the country cooperated and established the “Platform on Water Resilience and Disasters” (hereinafter called “Platform”) in 2017. In consideration of past efforts, current issues, and future prospects, the Platform focuses on and integrates five themes: data integration, early warning, climate change impact, economic assessment, and contingency planning. It leads integrated analysis consisting of data integration among hazard, damage, and socio-economic data by utilizing the Data Integration Analysis System (DIAS), rainfall and flood predictions by numerical models, and the assessment of climate change impact on economy and society in the pilot sites of the Pampanga and Davao River basins.

For creating societal benefits in policymaking and community of practice, the Platform also provides capacity development programs based on the results of integrated risk assessment, because it is important to understand disaster risks aggravated by climate and societal changes and strengthen the resilience of stakeholders and local communities against water-related disasters in order to keep the Platform “Resilient,” “Inclusive” and “Sustainable.” The outputs of integrated risk assessment allow for implementing well-founded capacity development programs to experience climate change, strengthen resilience beyond merely saving lives, and increase incentives for prior investment.

The Hazus Tsunami Module

SS I.e

Mr. Jesse Rozelle¹

1. FEMA

In 2017, FEMA released Hazus 4.0 that contained the new Hazus Tsunami Module that was the first new peril added to Hazus in 15 years. This was the culmination in a software release of the tsunami technical methodology development that FEMA completed in 2013 following the catastrophic Tohoku earthquake and tsunami. The effort was supported by both FEMA and the DHS S&T Flood Apex program.

Hazus Tsunami includes two types of hazard analysis based on the location of the source of the earthquake that caused the tsunami: distant source (tsunami only), where the earthquake occurs far enough from land or deep enough in the ocean such that coastal areas will only see impact from inundation, but not ground shaking; and near shore (combined tsunami & earthquake), where the earthquake is near enough to the landmass that coastal areas will experience impacts from both earthquake and tsunami.

Hazus Tsunami provides capabilities for both economic losses and casualties for all high-risk U.S. States and Territories. The casualty methodology incorporates both the FEMA 2013 methodology, as well as the USGS pedestrian evacuation methodology and tool. Casualties, including fatalities and injuries for both day and night and under and over age 65 population are provided based on 3 community preparedness levels. The results support the critical need for preparedness and mitigation in tsunami prone areas.

The Hazus Tsunami module was the first module to be developed without an internal hazard module. Rather for tsunami we rely on tsunami hazard data, inundation depth and velocity, provided by authoritative sources including NOAA and state tsunami programs. Several states including CA, HI and OR are starting to build out libraries of Hazus tsunami sources and the Hazus program will incorporate those in a Hazus Loss Library.

The Importance of Thresholds in Disaster Resilience Quantification

Oral - Parallel Session

***Ms. Angela Peck*¹, *Dr. Slobodan Simonovic*²**

1. Associated Engineering & Western University, 2. Civil and Environmental Engineering - Western University

Resilience is a significant concept in contemporary disaster management. A paradigm shift from disaster risk reduction to disaster resilience building strategies is required to provide holistic, integrated, and sustainable disaster management. Tools and techniques have recently been developed by academics and organizations which allow governments to assess, monitor, and review progress in achieving disaster resilience.

However one of the key concepts often overlooked is the concept of thresholds. Thresholds are important characteristics of system performance which contribute to disaster resilience. Thresholds define limits or acceptable operating space. Outside of this range, systems may function differently, or not at all. And when a system operates beyond critical thresholds, it can initiate or break critical feedback processes which cause the system to operate under a different regime or exhibit different – often undesirable – behaviour. These threshold-influenced behaviours can ultimately lead to critical compounding or cascading system failures. Shortcomings of most existing disaster resilience assessment and quantification tools include: (a) that they do not yet consider thresholds as significant contributors to the dynamic disaster resilience; and (b) they provide no means for their explicit inclusion in resilience quantification. It can be challenging to detect threshold-influenced behaviour amid typical variability in large and complex sets of data which is why sometimes thresholds are not apparent until they have already been crossed. This makes identifying thresholds particularly important for analyses considering extreme events.

The task of determining thresholds can seem daunting. However, discussing these issues at across various scales (governments and organizations) can help clarify and develop thresholds that will inform decision making and improve disaster management. Spending time in pursuit of identifying thresholds may well be worth the investment.

Key Words: disaster resilience, system performance, thresholds

The Observed Flood Extent: Using Multispectral Satellite Imagery to Map Historical Flood Events

SS I.e

Ms. Catherine Ipsan ¹, Mr. David Cunningham ¹

1. Maxar

New developments are being constructed on flood-prone agricultural or rural land where there has been little to no documentation of flooding. If these undocumented historical flood events had been recorded, it is likely that additional engineering/mitigation efforts or increased flood insurance premiums would have been implemented, potentially preventing hundreds of millions of dollars in claims and uninsured losses from subsequent flooding. This study, Observed Flood Extent (OFE), developed a water detection algorithm and used extensive cloud processing to analyze 35 years of open source multispectral satellite imagery. The result produced a historical flood extent layer for eight cities that consisted of up to 1500 observations of water per pixel. A subsequent economic analysis using National Flood Insurance Program's (NFIP) flood claims showed that almost \$300 million in flood claims could have potentially been avoided. Using satellite imagery for direct observations of flooding provides the flood community with empirical data of historical flooding that was previously unavailable. This data can be used as a direct input of modeling flood risk, can help prioritize flood studies for new construction on flood-prone land, and it can be used to help reduce non flood-proofed new construction.

THE USE OF NARX NEURAL NETWORKS TO PREDICT THE TIMING AND LOCATION OF DIKE BREACHES DURING RIVER FLOODS

Oral - Parallel Session

Ms. Anouk Bomers ¹, Prof. Suzanne Hulscher ¹

¹. University of Twente

Generally, two dimensional hydraulic models are used to simulate the consequences of river flood events. However, the computational times of these models are commonly in the order of hours to days making them inappropriate to be used as an early flood forecasting system. Therefore, we studied whether neural networks, having computational times of less than a second, can be used to predict the locations and timing of potential dike breaches. The Dutch bifurcating system of the Rhine river delta was used as a case study. Training data was created with a 1D-2D coupled hydraulic model, in which the main channel and floodplains were schematized by 1D profiles and the hinterland was discretized on a 2D. The dike breach locations were assumed to fail if the simulated water level reached the dike crest levels. In total, 80 potential flood events were simulated by varying the upstream peak discharge and shape of the discharge waves. It was found that only two out of the 28 dike breach locations failed during one or more of the 80 simulated flood events. The discharge that left the river system through the dike breach, flowing into the hinterland, (i.e. the outflow hydrograph) was used to train the neural networks. NARX neural networks were developed since this type of neural network is capable of predicting a time-varying output based on an input time series (Shen & Chang, 2013). For both dike breach locations, a NARX network was set up. It was found that the NARX networks always accurately predicted if the specific dike location failed. Furthermore, the timing of the dike breach and the outflow hydrographs were predicted accurately. Finally, the cumulative outflow flood volume was accurately predicted, only deviating 1.5%, which is highly relevant for the prediction of inundation extents in the hinterland.

Too Soon for a National Conversation on Improvements to Flood-Frequency Analysis to Address Stationarity Violations?

Oral - Parallel Session

Dr. Nancy A. Barth¹, Dr. Jory S. Hecht¹, Dr. Karen R. Ryberg¹

1. USGS

Abstract:In the 'Future Studies' section of the current U.S. Federal government guidelines for flood frequency analysis, known as Bulletin 17 C, the authors identify the need for additional studies related to "Guides for determining dynamic flood frequency curves that vary with time, incorporating climate indices, changing basin characteristics, and addressing potential nonstationary climate conditions." To that end, the U.S. Geological Survey, in cooperation with the Federal Highway Administration, has undertaken a multi-year national study to research methods for detecting and addressing potential nonstationarities in flood frequency distributions because of changes in climate, land use, land cover, and other potential drivers of change. A Monte Carlo simulation framework is being used to examine the suitability of several methods that have recently been proposed to adjust estimates of design flows under nonstationary conditions. The observed characteristics and changes in the annual peak streamflow series at 2,683 sites across the conterminous United States, are used to develop experiments which include broken records, monotonic trends, change points, and low outliers. The Monte Carlo simulations are intended to inform the development of a decision framework to help practitioners select the most promising methods for adjusting flood frequency estimates. This interagency multi-year national study leveraged the expertise of a multi-disciplinary team and addressed the needs of multiple stakeholders. We will share some preliminary thoughts regarding how our experimental results can inform design flood estimation and flood management in the United States. And to effectively use the results of this study, there is a need to include additional stakeholders to bridge the complex science to the practitioners, who will inevitably use these results to inform decisions for design flows.

Five key words: Flood-frequency, nonstationarity, interagency efforts, multi-disciplinary approach.

Uncertain accelerated sea level rise in the Netherlands; potential consequences and adaptive strategies regarding flood risk management

Oral - Parallel Session

Mr. Jos vanAlphen¹, ***Mrs. Marjolijn Haasnoot***², ***Mr. Ferdinand Diermanse***²

1. Staff Delta Program Commissioner, 2. Deltares

Recent observations and publications present signals that a collapse of the Antarctic ice-sheet later this century may induce an accelerated sea level rise. Under a high warming scenario this may result in a sea level in 2100 that is up to 2 m higher than present and many meters higher beyond 2100. The large uncertainties in the projections immensely increase the challenge for investment planning in coastal strategies in densely populated areas like the Netherlands.

In this paper we present the results of two inventories that were carried out within the framework of the Dutch Delta Program, with the aim to assess the impacts of sea level rise and potential adaptation strategies. These inventories show that it is not only the absolute magnitude of the future sea level rise that presents a challenge, but also the annual rate of rise. The latter determines the annual volume of sand required for beach nourishments to maintain the coastline. In addition it impacts the life time of constructions like barriers and pumping stations. When the rate of sea level rise increases up to several centimeters per year (compared to the present 2 mm/year along the Dutch coast), the intended life time of a structure may be reduced from a century to a few decades. This new challenge requires new technologies, strategies and governance.

The second inventory explored the different strategies that can be adopted to deal with accelerated sea level rise (Protect-open, protect-closed, advance, accommodate-retreat). It shows that strategic choices have to be made regarding the preservation of valuable inter-tidal areas, the permanent closure of estuaries, the pumping or periodic storage of high river discharges, the fresh water supply and agriculture in an increasingly saline coastal zone, and the maintenance of the coastline by beach nourishments.

Urban flooding and the value of data collection for flood warning and protection

Oral - Parallel Session

Mr. MILES CORCORAN¹, Mr. Derek Slocum¹

1. OTT Hydromet

As water managers and engineers, it's important to understand our watersheds, urban landscapes, and their response to extreme events like heavy precipitation and rising surface water levels. Of the numerous tools at our disposal, there are many benefits to a flood warning system, including knowing in time where flooding issues could occur, enabling reactive action, and protecting lives while minimizing damage.

In this presentation, I will discuss urban flooding and the value of data collection for flood warning and protection. Together, we'll examine what an ideal flood warning system might look like in your community and how data can help convince your community about the importance of being prepared for a flooding emergency.

We'll also explore readily available data from U.S. Federal Agencies—such as the U.S. Geological Survey and National Weather Services—and the increasing need for greater data density to augment spatial and temporal data sets feeding critical predictive models.

With this presentation, attendees will:

- Receive an overview of flooding in the U.S. and factors that contribute to flooding
- Understand the role of data collection in organizations like the USGS and NWS
- Learn the importance of flood warning systems and their components
- Explore how data can help convince your community about the importance of being prepared for a flooding emergency

Urban land use and precipitation intensity changes from 1950-2010 in northeastern Illinois and their effect on flood peak distributions

Oral - Parallel Session

Dr. Thomas Over ¹, ***Dr. David Soong*** ²

1. *Hydrologist, U. S. Geological Survey – Central Midwest Water Science Center, 2.* *Research Hydrologist, U. S. Geological Survey – Central Midwest Water Science Center*

During the decades from 1950-2010 during which most of the streamflow data are available, the population of Cook County, Illinois, which contains the city of Chicago, grew from 4.5 to 5.2 million, while that of the surrounding counties grew from 0.7 to 3.2 million. The population growth in the suburban counties indicates substantial land development and an associated increased risk of flooding. Also contributing to the likelihood of flooding in the region are a shallow regional water table, gentle slopes, and major precipitation events occurring with increasing frequency and intensity. As a result of these challenges, structural and non-structural flood control measures were put in place throughout the region, including stormwater detention ordinances, beginning with Cook County in 1972.

The U. S. Geological Survey has operated streamgages in the Chicago region beginning around 1950 at about 150 different locations, including an extensive small-watershed peak-only (“crest-stage”) streamgaging program in the 1960s and 1970s. The data obtained were first used to investigate the effect of increased imperviousness on flood peak distributions in a report published in 1979 and again in a set of three reports published between 2013 and 2016. The latter set of reports described the investigation of the effects of changes in imperviousness and in precipitation intensity. The latter set of reports also includes an analysis of the effect of stormwater detention, addresses effects of structural flood control measures, and provides annual peak discharges adjusted to fixed conditions, that is, those at the end of the study period. Having been adjusted to fixed conditions, the adjusted peak discharges are presumptively stationary.

In this presentation, the results of these studies will be reviewed. The focus will be on lessons learned in characterizing flood statistics in the context of changing urban land use and precipitation intensity trends.

“Act globally, think locally”: Changing flood risk in the Northern Great Plains (USA).

Oral - Parallel Session

***Dr. Paul Todhunter*¹, *Dr. Taufique Mahmood*²**

1. Department of Geography and GISc, University of North Dakota, 2. Harold Hamm School of Geology and Geological Engineering, University of North Dakota

Abstract: Global climate change mitigation advocates encourage stakeholders to “Think globally, act locally.” This paper argues that for changing flood risk we need to “Act globally, think locally.” A broad range of flood risk principles are reviewed and critically examined using examples from the Northern Great Plains environment. Changing flood risk is a complex, multi-faceted problem involving changes to flood hydrology, flood exposure, social vulnerability, flood resilience, and flood mitigation. North Dakota, located in the Prairie Pothole Region in the Northern Great Plains (USA), has experienced four major flood disasters covering a range of flood types over the past 40 years. These include the 1997 regional snowmelt flood catastrophe at Grand Forks, the post-1993 chronic terminal lake flood disaster at Devils Lake, post-1993 pervasive regional wetland flooding, and the 2011 Minot flood disaster caused by heavy regional precipitation and upstream dam releases. These disasters illustrate the ‘soft and hard facts’ of changing flood risk. Multiple methods are employed in assessing changing regional flood risk, including a physically-based cold region hydrology model to examine critical intermediate processes controlling snowmelt runoff, long-term hydroclimatology databases, remote sensing imagery, and detailed case studies. Results reveal changing flood risk principles that are labeled variously: surprises, radical surprises, wicked problems, non-knowledge, soft and hard facts, unexpected surprises, and probability vs. possibility thinking. The region demonstrates: a non-stationary long-term climate, snowmelt control by critical intermediate processes poorly resolved in global climate models and downscaling efforts, continued reliance upon structural flood mitigation, substantial residual flood risk, strong local adherence to property rights that impairs effective flood mitigation, low market penetration of flood insurance, increasing social vulnerability, and significant lack of knowledge. Flood risk is a global problem manifested at the local scale that demands local understanding and mitigation.

Changing flood risk, Northern Great Plains, flood disasters, cold regions

**Data and Information for
Flood Risk Management -
Big data and flood
management**

Assessing numerical model skill at simulating coastal flooding using field observations of deposited debris and photographic evidence

SS II.d

***Mr. Sean Ferguson*¹, *Mr. Mitchel Provan*¹, *Mr. Enda Murphy*¹, *Mr. Dominique Bérubé*², *Mr. Marc Desrosiers*², *Dr. André Robichaud*³, *Mr. Joseph Kim*⁴**

1. National Research Council Canada, 2. New Brunswick Department of Natural Resources and Energy Development, Geological Surveys Branch, 3. Université de Moncton - Campus de Shippagan, 4. University of Ottawa

Numerical simulation of coastal flood hazards at high temporal and spatial resolutions has become increasingly practicable owing to advancements in software, computing resources, and supporting datasets. Despite the growing range and availability of resources to support model development, there is often a scarcity of data to support critical assessment of the performance of community-scale coastal inundation models. Even where long-term tide gauge measurements are available at discrete locations in close proximity to the study area, the records provide little insight into the spatial distribution and limits of overland flooding, or the influence of topographic features and structures on flooding pathways. We present methods to support assessment of model performance using field observations in lieu of, or supplementary to, conventional water-level records. A high-resolution, numerical coastal flood hazard model was developed to simulate storm surge-driven flooding in the Acadian Peninsula region of New Brunswick, Canada. Owing to the remoteness of the community from tide gauge stations, model performance was assessed based on comparison with field measurements of deposited wrack and debris, as well as photographic and video evidence of coastal flooding, for two significant storm surge events in recent history. The simulated flood extents were plotted alongside georeferenced debris observations to evaluate model performance, and additional verification was conducted through comparison with photographic and video evidence. Our research findings illustrate the value of observational and qualitative data for characterizing coastal flood hazards, lending gravity to the importance of non-conventional data sources. Furthermore, the methods presented herein offer guidance to practitioners seeking to calibrate and validate coastal flood hazard models in data-scarce regions.

Keywords: coastal flooding, storm surge, numerical modelling, model performance, debris

Exploring the potential of using LSTM to predict outflow at catchment-scale urban drainage systems

Oral - PS II.a Big data and flood management

***Dr. Jiada Li*¹, *Dr. Zhongrun Xiang*², *Prof. Steven Burian*¹**

1. University of Utah, 2. University of Iowa

The frequency and magnitude of urban flooding events are increasing due to climate change and urbanization. Predicting urban flooding becomes important to reduce flood-induced environmental damage, economic and life loss. This study developed a sequence-to-sequence Long Short-term Memory (LSTM) neural network to predict the outflow of a drainage catchment located in Salt Lake City, Utah, USA. A total of 12,985 hydrological data, including precipitation, air temperature, snow depth, air humidity, soil temperature, and soil water content, were collected for sequence-to-sequence LSTM model training, validation, and testing. Compared with other widely-used machine learning models like random forest, support vector regression, gradient boosting regression, decision-tree bagging regression, ridge-L2, lasso-L1, and multi-layer perceptron regressor, the proposed sequence-to-sequence LSTM model presented more reliable outflow forecasting accuracy with higher Nash-Sutcliffe efficiency, correlation of coefficient, and lower rooted mean square efficiency. We also found that the snow depth and air temperature inputs can improve the prediction of outflow peaks significantly. This research is beneficial for developing efficient urban flooding warning systems in the downstream drainage catchment. Keywords: Urban flooding prediction, Deep learning, Long-short Term Memory, Drainage outflow, Urban drainage system

Investigating and Improving the USACE Operational Condition Assessment System

Oral - PS II.b Risk communication

Mr. Willie Brown¹, Dr. Jonathan Alt¹, Dr. Simon Goerger¹, Dr. Matthew Smith¹

1. US Army Engineer Research and Development Center

The U.S. Army Corps of Engineers (USACE) operates, maintains, and manages more than \$232 billion worth of the Nation's water resource infrastructure and relies on the Operational Condition Assessment (OCA) process to determine the condition of the assets and their components. The sheer number of components, all of equal OCA scheduling priority, creates challenges in ensuring that assessments are conducted in a timely manner and that data generated is of sufficient quality to inform resource allocation decisions. This research applied methods from systems design to determine the OCA system "as-is" state and create a stakeholder-informed vision of a "to-be" state that addresses current system challenges. In order to meet its objective of providing current assessments of asset condition, the OCA system must provide four high-level functions: provide access to asset data, conduct assessments, determine asset risk, and prioritize and schedule assessments. The development of capabilities to provide these functions will facilitate the achievement of the OCA system "to-be" vision: a consistent view of asset condition and risk across the enterprise. This presentation provides an overview of the aforementioned systems engineering process and the strategic roadmap to achieve the "to-be" state as well as emerging insights in the development of a methodology to determine asset risk to enable decision support for multiple USACE operating projects.

Keywords: systems analysis, asset condition assessment, prioritization, risk modeling, flood risk management

Potential of geometrically distorted laboratory scale models for validating computational models of urban flooding

SS II.d

Ms. Xuefang Li¹, ***Dr. Sébastien Erpicum***¹, ***Dr. Pierre Archambeau***¹, ***Prof. Emmanuel Mignot***², ***Prof. Nicolas Rivière***², ***Prof. Michel Pirotton***¹, ***Prof. Benjamin Dewals***¹

1. University of Liege, 2. National Institute of Applied Sciences of Lyon

The accuracy and applicability of computational models for assessing flood hazard remain hampered by a lack of suitable validation data. Indeed, existing field observations are often limited to watermarks and inundation extents, while only scarce information is available on the flow field and the discharge partition in-between streets in urbanized floodplain. Therefore, laboratory experiments are a valuable complement to field data to achieve robust validation of flood hazard models, since scale models enable measuring additional flow characteristics of relevance for assessing flood danger.

However, urban flooding is a multiscale process, involving horizontal length scales (of the order of 10^3 m) considerably larger than the vertical length scale (of the order of 0.1 to 1 m). Therefore, recent laboratory experiments of urban flooding have used geometrically distorted scale models, i.e. models in which the vertical scale factor (e.g. 1:10) differs from the horizontal one (e.g. 1:100). This enables limiting the model extent, while improving the relative accuracy of measurements and keeping the right flow regime.

A recent numerical study provided a first quantification of the bias induced by geometric distortion in laboratory scale models of urban flooding. It suggests that geometric distortion may lead to a bias of the order of up to 10 % in the flow depths and in the discharge partition in-between streets. This bias gets higher when the Froude number is larger. In some cases, increasing the scale model distortion leads to non-monotonous variations in the flow variables, hinting at a competition between decreasing frictional losses and increasing local head losses (recirculations...). In this communication, we present laboratory experiments which aim at validating the conclusions on the distortion-induced bias drawn from the computational study. The experiments use a laboratory facility representing a synthetic urban district, in which water depths and flow partition were measured.

Risk analysis and communication using semantic 3D city models

Oral - PS II.b Risk communication

Dr. Torsten Heyer ¹, Prof. Juergen Stamm ¹

1. Technische Universitaet Dresden, Institute for Hydraulic Engineering and Technical Hydromechanics

Along with the increasing digitalization, new possibilities evolve for interdisciplinary co-operation projects utilizing “digital twins” of the real world. In this regard, semantic, digital 3D city models are nowadays being used and created worldwide, but often for visualizing static urban environments (e.g. for architectural planning) only. This paper shows that such models have a much greater application potential as they allow for simulations of various physical processes with urban relevance, inundation processes due to river or pluvial floods in particular. On this background, the research project “Flood risk analysis using 3D city models (FloRiCiMo)” aimed for enhancing urban flood risk management by coupling 3D city models with appropriate hydronumeric solvers (2D for large areas, 3D for individual buildings). The development of a user-friendly, web-based workflow and the definition of relevant accuracy demands were only two of several project goals that could be achieved. By combining hydrodynamic simulation results (e.g. inundation depths and local flow velocities; also including a probabilistic classification of the simulated events) with the specific damage potential of urban areas, which can be attributed e.g. to buildings, infrastructure or even people, 3D city models offer vast opportunities for modern flood risk analysis. Furthermore, 3D city models are an excellent platform for risk communication, as results can be displayed user-tailored for experts and non-experts (e. g. photorealistic, VR and AR representations). The developed methods and achieved results of the FloRiCiMo project will be explained and demonstrated more detailed on the example of a pilot study that was conducted for the City of Dresden/Germany. The potential for further enhancement of the city models for flood risk analysis, e. g. by integrating underground structures, BIM and real time sensor data in the models will also be addressed in the paper.

digital city models, urban floods, risk analysis, risk communication

Risk-Informed Prioritization of Operational Condition Assessments

Oral - PS II.b Risk communication

Dr. Jonathan Alt¹, ***Mr. Willie Brown***¹, ***Dr. John Richards***¹, ***Mr. Eddie Gallarno***¹, ***Dr. Matthew Smith***¹

1. US Army Engineer Research and Development Center

The U.S. Army Corps of Engineers (USACE) operates, maintains, and manages more than \$232 billion worth of the Nation's water resource infrastructure. Using the Operational Condition Assessment (OCA) system, the USACE allocates limited resources to assess conditions and maintain assets in efforts to minimize risks associated with asset performance degradation. Currently, OCAs are conducted on each component every five years, regardless of the component's risk contribution. The analysis of risks associated with Flood Risk Management (FRM) assets, such as dams, includes considering how the asset contributes to its associated FRM watershed system, understanding the consequences of a degradation in the asset's performance, and calculating the likelihood that the asset will perform as expected given the current OCA condition ratings of critical components. This research develops a scalable methodology to model the probability of failure of gate systems that contribute to the performance of dams in their respective FRM systems combined with consequences derived from hydrological models of the watershed to develop a risk score for each gate. The resulting risk score serves as an input for a mixed integer optimization program that outputs the optimal set of components requiring OCA assessments in order to minimize risk at the watershed level. Proof-of-concept results for a case study watershed are provided. Keywords: systems analysis, asset condition assessment, prioritization, risk modeling, flood risk management

Validation in Flood Risk Modelling: state of art and research recommendations

SS II.d

Dr. Daniela Molinari¹

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Model validation is a key topic in flood risk analysis, as flood risk assessments are presently characterised by significant levels of uncertainty. Since large investments for flood risk reduction are made based on flood risk estimates and maps, decision makers must be aware of the limitations of accuracy of risk analysis outcomes. Despite most of attention is paid to flood hazard models, validation requires to consider the different components of the risk modelling chain, i.e. flood hazard and flood damage analysis as well as their role in risk estimates. By presenting the state of art on flood risk model validation, with a specific focus on flood damage models, this contribution aims at identifying policy and research recommendations, towards promoting more common practice of validation, and an improvement of flood risk model reliability. In this regard, the need of higher quality data to perform validation and of benchmark solutions to be followed in different contexts, along with a greater involvement of end-users in the application on flood risk model validation will be discussed.

**Flood Disaster
Prevention, Mitigation,
and Adaptation**

A Comprehensive Risk Assessment at Individual Building Levels for Future Flood Occurrence at the Coast of Louisiana, USA

Oral - PS III.b Changing flood risk

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Among many of the high-risk zones of coastal flooding, the coast of Louisiana is extremely vulnerable due to its exposure to storm surge - caused by hurricanes, shoreline erosions - caused by relative sea-level rise, tidal influences, and loss of river sedimentation, and land subsidence – caused by reduction of marshlands and underground resource extractions. In addition, increasing frequency and intensity of natural hazards under climate change scenarios can elevate the risk of flooding. There is a wide range of studies focused on flood risk assessment and mitigation strategies both for present and future, and a substantial number of works studied future flood risk considering only the climatic variables and sea-level rise. This study is a comprehensive approach that has considered coastal subsidence, sea-level rise and hurricane storm surge variability under climate change scenarios and hazard uncertainty - along with precipitation variability, river discharge, and tides to evaluate flood risk at the individual building levels at the coast of Louisiana in 2050. Result suggests that subsidence will contribute over 80% to increase the flood depth which will result in an almost double loss at the coast of Louisiana in 2050. On average, 100-year flood depth will increase by 1.2 feet at the individual building level in Grand Isle, Louisiana. Outcomes from this study will fill the gap in current studies to implement a more realistic risk assessment model and will direct the flood risk manager, property owners, and stakeholders to build a comprehensive framework to avoid flood risk in the future for one of the most vulnerable states in the USA.

Development of a flood damage model for urban drainage networks

SS. III.e

Mrs. Alice Gallazzi¹, **Dr. Daniela Molinari**¹, **Dr. Anna Rita Scorzini**², **Prof. Francesco Ballio**¹

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A thorough understanding and assessment of flood damage to network infrastructures is fundamental to assist both policy makers and managing authorities in mitigation and restoration actions against inundations and, consequently, in increasing the resilience of the territories at risk. This research work focuses on the estimation of potential impacts of floods on urban drainage systems, by proposing a general methodology that can be adapted to other typologies of networks. The method consists in the development of damage-dysfunction matrices, as proposed by Eleutério et al. (Nat. Hazards Earth Syst. Sci., 13, 983–998, 2013), for drainage systems, by adopting an expert-based approach. These matrices allow analysing physical, systemic and functional vulnerability of each component of the network under investigation and, therefore, identifying the potential transfer of dysfunctions between the different components. Regarding this last point, a hierarchy method of the network was developed in order to assign a systemic vulnerability degree to each component, hence helping the managing authority to prioritize recovery actions in case of emergency. Nonetheless, by identifying the number and types of users (i.e. residents, businesses, institutions) connected to each sewage pipe, the potential adverse consequences of sewerage's disruptions for society are investigated as well. As an example, the model has been implemented on the sewerage system in the municipality of Parma, Northern Italy, by using the Baganza River Flood in October 2014 as a case study in support of the work.

Keywords: flood damage modelling, networks, damage-dysfunction matrices

DWAT applicability for flash flood and seasonal streamflow simulation

SS. III.g

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The Dynamic Water Resources Assessment Tool (DWAT) is a new tool designed to help water resource managers and policy specialists identify current and future water management challenges, and compare those with current and past water resources availability. This will allow to improve understanding of the impacts of past and present water management practices on water resources, as well as the interactions between climate, water and landscape.

DWAT uses a distributed conceptual scheme for water cycle analysis and contains sub-algorithms, such as evapotranspiration, infiltration, watershed runoff, groundwater movement, and channel routing. Linking the system to a GIS tool allows the user to search for physical input parameters in an easier way.

DWAT has been developed by the Ministry of Environment of the Republic of Korea to help ensure the sustainable and effective management of water resources, and it is being peer-reviewed by a panel of WMO Commission for Hydrology experts, who are applying it to basins located in different geographical areas, each with different climatic characteristics.

DWAT has been operationally applied in Republic of Korea, Thailand, Bhutan, Jamaica, Russia, Argentina, and New Zealand in experimental basins with different sizes, hydrologic and climatological environments and data ranging over different temporal scales. In this presentation, the main scheme of DWAT and its application for flood forecasting will be introduced and discussed.

Keywords: Dynamic Water Resources Assessment Tool, flood forecasting tool

Flood modeling of urban environments using an integrated hydrosystems approach

Oral - PS III.d Cooperation in the management of large flood events

***Dr. Siddharth Saksena*¹, *Mr. Sayan Dey*², *Mr. Neel Salvi*², *Mr. Pin-Ching Li*², *Dr. Venkatesh Merwade*², *Mr. Peter Singhofen*³, *Ms. Lin Zeng*⁴, *Dr. Anu Ramaswami*⁵**

1. Virginia Tech, 2. Purdue University, 3. Streamline Technologies, 4. University of Minnesota, 5. Princeton University

As the flood intensity and magnitude is expected to rise from urbanization and climate change, there is a growing need to develop flood prediction and alert systems that can capture the compound nature of extreme events. Despite an immense potential, the application of integrated models towards flood prediction remains challenging without compromising on the spatiotemporal scale and resolution, computational efficiency, model structure and local-scale hydrodynamics. This talk will introduce an integrated modeling framework that is designed to address these challenges in flood prediction using the Interconnected Channel and Pond Routing model (ICPR) Linux Simulation Engine. The framework is developed using a two-step architecture: first, implementation of automated tools for integrating geospatial descriptors, and second, application of a computationally-efficient hybrid design for integrated flood modeling. The extent of improvement in flood prediction using this framework will be highlighted across several urban watersheds in the United States.

Key words: Flood modeling and mapping; urban flooding; integrated hydrologic and hydraulic modeling; stormwater modeling; extreme events

Flood Risk Mapping and WMO Community of Practice on End-to-End Early Warning Systems for Flood Forecasting

SS. III.g

Mr. Marcelo Uriburu Quirno¹

1. Comision Nacional de Actividades Espaciales

The World Meteorological Organization has been developing several initiatives to strengthen the Members' end-to-end flood early warning systems, and their disaster risk reduction capabilities, through freely available guidelines and tools.

As part of these, two endeavors are presented here: the drafting of a flood risk mapping manual and the establishment of a community of practice on end-to-end early warning systems for floods.

The flood risk mapping manual focuses on riverine floods, although other types of flooding are also addressed (e.g. urban, dam breaks, coastal - including large lakes - , groundwater table rise, ice jams).

The manual introduces practical solutions deemed achievable by the large community of stakeholders, particularly those of less developed countries, not surprisingly the most vulnerable to floods. The manual presents GIS tools, mapping techniques, and assessment methods for all the flood-risk components: hazard, vulnerability, exposure, coping and adaptive capacities, and resilience. Particular attention is given to the use of the expected annual damage for alternative preventative measures selection.

A community of practice (CoP - a group of people who share a concern or a passion for something they do) enables practitioners, across organizational and geographic boundaries, to take collective responsibility for managing the knowledge they need. WMO CoP will be a friendly space dedicated to all topics related to the end-to-end stages of flood early warning, where best practices, lessons learnt, case studies, stories, tools, and ways of addressing recurring problems will be shared, contributing to the improvement of the day-to-day activities of operational flood forecasting and warning.

Prominent activities promoted in our community are the development of assessment guidelines to help the National Hydrological Services to identify strengths, weaknesses and gaps in their flood-forecasting capacities, and the cataloging, description and assessment of flood-forecasting Interoperable Models and Platforms.

Flood risk mapping; End-to-end early warning systems

High-Resolution Probabilistic Flood Risk Mitigation Analysis Approach

SS. III.e

Mr. Omar Nofal¹, Prof. John van de Lindt¹

1. Colorado State University

Flood risk mitigation is crucial for vulnerable communities that get flooded frequently specifically with climate change and land-use policy. There are many qualitative flood risk mitigation studies in the literature with less quantitative research. Additionally, many current flood risk assessment approaches are based on deterministic stage-damage functions (e.g. HAZUS) making uncertainty propagation into infrastructure damage and resilience modeling difficult. In this paper, a probabilistic flood risk mitigation analysis model is developed using high-resolution hazard, exposure, and vulnerability models. Component-based multi-variate flood fragility functions are used to account for building damage which enables detailed mitigation analysis at both the component- and building-level. The impact of building-level flood mitigation measures on aggregated flood damage/losses at the community-level is calculated using a portfolio of fragility functions that can model the community flood vulnerability. The mitigation strategies included the impact of using flood barriers, decreasing flood duration using water pumps, and elevating water sensitive components within buildings in a community. The impact of applying other hazard control measures such as building a levee and using flood gates was also investigated. The analysis showed that using building-level flood barriers along with increasing the elevation of select water sensitive components can significantly reduce flood losses at the building- and aggregated community-level. Enhancing the levee system can also provide good control and significantly reduce flood losses. The outcomes from this research can help policymakers and urban planners make decisions based on high-resolution (building-level and finer) quantitative analysis.

Integrated Flood Management: a proactive approach to “build back better” (or not having the need to build back)

SS. III.g

Mr. Giacomo Teruggi¹

1. World Meteorological Organization

Knowing when and where a flood would strike is an essential component of reducing risk, but per se this is not sufficient: to ensure an effective response to flood events, informed decisions need to be taken, combining emergency response protocols and actions to a wide understanding by the people living in flood prone area of the risk they are exposed to. Moreover, a series of preventive actions and measures can be taken to reduce the vulnerability of assets and people located in flood prone areas. A proper framework, combining risk management to water management and land use management, is essential to build a society that is resilient to flood events. Integrated Flood Management is an approach that tackles the different aspects related to flood management, from the traditional technical and engineering solutions (forecasting, risk mapping, structural mitigation measures), to other disciplines covering socio-economic considerations, institutional frameworks and environmental issues. This provides a set of “boundary conditions” to make an end-to-end early warning system truly effective, minimizing loss of life and maximizing the net benefits derived from the use of floodplains.

Since 2001, the World Meteorological Organization and the Global Water Partnership have advanced the Associated Programme on Flood Management, promoting and formulating the basis of the Integrated Flood Management concept. Efforts have been made to produce a library of around 50 publications and tools available to practitioners willing to further explore the concept and its sub-components. The expertise on Integrated Flood Management is also available to the wider public through a HelpDesk on IFM, soon to host also the Community of Practice on end-to-end early warning systems for floods, through which users can access the expertise of more than 30 external institutions specialized in specific aspects of Integrated Flood Management.

Keywords: Integrated Flood Management; Flood resilience; multi-disciplinary approaches

Iowa Silver Jackets Interagency Team - Flood Support for Communities

SS. III.e

Mr. Jason Smith¹, Mr. Anton Stork², Mr. Jim Marwedel³

1. U.S. Army, 2. U.S. Army Corps of Engineers, Rock Island District, 3. Iowa Emergency Management and Homeland Security

This presentation will highlight how the Iowa Silver Jackets federal and state partners are supporting communities as they respond, recover, mitigate, and plan for flood disasters. This presentation will highlight the organizations role in the record setting 2019 flooding. This presentation will also highlight how the partnership has worked with various communities in developing products that assess and communicate flood risk so communities can take actions to lower the risk to their citizens. Assessment products vary from traditional mapping and modeling to levee breach analysis to economic modeling techniques. All of this work is geared toward reducing flood risk for the people of Iowa and also transferring the lessons learned from Iowa to the other Silver Jacket teams around the United States of America.

Interagency, Flood, Risk, Damage, Communication

MyDewetra.World: the integration of national and international data as the way forward for effective flood management

SS. III.g

Dr. angela corina¹

1. Italian Presidency of the Council of Ministers - Department of Civil Protection

Complex forms of decision-making need technological support for achieving flood risk reduction. In fact, the effectiveness of flood management depends greatly on the efficiency of managing relevant information.

Often countries face an overall poor capability to collect national data and to share it among different institutions. International services are often very useful to address this lack of data, offering a free and open access to a variety of models and data observations, which are fundamental for good decision-making process.

Ideally, decision-making processes should consider both national and international data through a holistic and integrated approach. However, this is not always possible as data is often delivered as fragmented and isolated information. This results in a difficulty on the overall risk scenarios analysis, with data often not being fully integrated in the decision making process.

myDewetra.World is an integrated real-time system for hydro-meteorological forecasting and monitoring, which has been designed to work as a single-access knowledge hub, bridging the gap between the collection of data at national level and the availability of free and open data at international level. It allows single States to prepare their own real time risk assessment while using both detailed data from administrative levels and data from international services. It is a web-based geographical information system (WebGIS) that improves the access and sharing of world-wide disaster risk information needed for flood management related actions. The system adopts a comprehensive framework of policies and guidelines, data sharing initiatives and spatial data infrastructures with the purpose of gathering the knowledge for real time risk assessment and monitoring for use by both hydro-meteorologists and decision makers.

myDewetra.World is in use by the Italian National Civil Protection Department and is freely available to other Members of the World Meteorological Organization.

NATIONAL-SCALE FLOOD MODELS – ONE MODEL FOR DIFFERENT PURPOSES?

SS. III.e

Mr. Martin Salaj¹, Mrs. Sarka Cerna¹

1. Aon Impact Forecasting

Abstract: Natural catastrophe models are needed by multiple players - (re)insurance industry, governmental organizations, municipalities, etc. All these parties are dealing with flood risk assessment, mapping and management, but aims of each player are different. Insurance companies need estimation of risk determined by n-years losses for portfolio of property for ensuring sufficient capital however it needs different detailed view for primary underwriting, where they seek insurance pricing for unique building. Similarly, municipalities have different requirements – e.g. they manage risk for people or evacuation during flood events or prepare strategic plans for flood protection measures. Different details of hazard are important for different purposes, and therefore different models are required. Is this approach still valid or new datasets and technologies make it possible to use one single model for multiple views, and therefore create the synergic effect?

New generation of National-scale flood models are built using all available data including LIDAR DTM's, detailed hydrology dataset and information about flood defences including storm systems. Hence, they contain detailed hazard information (depths, velocities, time of flooding). Such models can be utilised for all above mentioned purposes.

This article discusses four different ways how to utilise same data for (i) estimation of Probable Maximum Loss (PML), (ii) creation of AAL maps for primary underwriting, (iii) creation of risk maps for cars and people based on different functions of velocity and depths, and finally (iv) loss of lives estimation.

Examples and comparison of various approaches are delivered by Aon Impact Forecasting team on flood hazard simulations for Canada, which is essential component of Impact Forecasting Canada Flood Model (covers over 100,000 km of river network by fluvial component and 2,300,000 sq.km in its pluvial component).

Conclusions and recommendations for optimal method for different purposes are offered.

Insurance, flood risk maps, AAL maps, PML, national-scale

Numerical simulation of urban inundation using citizen-based data: a case study of monsoon 2019 in hanumante river basin, kathmandu valley

Oral - PS III.d Cooperation in the management of large flood events

***Dr. Rocky Talchabhadel*¹, *Mr. Rajaram Prajapati*², *Dr. Jeffrey Colin Davids*³**

1. Texas A&M AgriLife Research, 2. Smartphones For Water Nepal, 3. smartphones4water

Heavy precipitation and subsequent inundation are increasingly occurring at an alarming rate in Nepal. Since 2014, flooding due to pluvial, fluvial, or combination has increased in the Hanumante River basin, Kathmandu valley, Nepal. The Hanumante River is one of the major tributaries of the Bagmati River in the Kathmandu valley. The absence of hydrometeorological data in tributaries is one of the major challenges in flood management. Smartphones For Water Nepal (S4W-Nepal) initiated a citizen-science-based urban flood monitoring system in the selected study area during the 2019 monsoon. A network of six hydrologic and sixteen precipitation stations was established in the Hanumante River basin, where citizen scientists continuously recorded daily water level and precipitation measurements. Also, discharge measurements were conducted using an acoustic doppler velocimeter with the USGS mid-section method two times a month. This study first used hourly data of satellite-based precipitation of PERSIANN-CCS (4km) to capture sub-daily variation. Instead of using the absolute values of PERSIANN-CCS, we used the daily precipitation measured by citizen-scientists. We then used a kinematic wave flow model on hill slopes for simulating surface runoff. Finally, a two-dimensional shallow-water equation unsteady flow model was then used to simulate the inundation process. We used topographical data obtained from the Department of Survey, Government of Nepal. The hydrologic model was validated against the observed citizen-based water level measurements. The simulated surface runoffs from different hill slopes were then forced for an inundation analysis. The spatial extent of inundation for different events during the monsoon 2019 is in good agreement with the observed (we conducted visual inspections during extreme events). Since it was difficult to obtain observed inundation depths, our study still could not validate the inundation depths quantitatively. Our study, though preliminary, could complement future studies on urban inundation in Kathmandu valley.

The Progression of Urban Flood Risk in Southern Alberta Since the 2013 Flood

SS. III.e

***Mr. Seth Bryant*¹, *Mr. David Sol*², *Ms. Sandy Davis*³, *Dr. Evan Davies*¹**

1. University of Alberta, 2. IBI Group, 3. The City of Calgary

After a century of semi-restricted floodplain development, Southern Alberta was struck by the devastating 2013 flood. Aging infrastructure and limited property-level floodproofing likely contributed to the \$4-6 billion (CAD) loss and five deaths. Following this catastrophe, Alberta has seen a revival in flood management and a 10-fold increase in government mitigation spending, largely focused on structural protections. However, concurrent with these recent structural works, the urban population has increased by over 100,000 in the five years following the flood, leading to further densification of high-hazard areas. Building on the work of the Government of Alberta to develop an Alberta focused flood risk tool, this study develops a flexible and stochastic modelling framework to quantify risk in areas subject to both hazard and vulnerability dynamics. Within this new framework, a model is constructed to evaluate the progression of the direct-damage flood risk in a mature urban neighborhood in the period following the 2013 flood. Five years of remote-sensing data, property assessment records, and inundation simulations are used to construct the model. Results show that vulnerability trends (like densification) have increased flood risk by 5% (+/- 2%; in the five years following the 2013 flood); however, overall flood risk has been reduced by 45% (+/-5%) as a result of the recent structural mitigation projects. This demonstrates that the flood management revival in Southern Alberta has largely been successful at reducing flood risk; however, these gains are under threat from continued development and densification absent additional floodproofing regulations.

The “Flood Damage Models” repository

SS. III.e

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1. Department of Civil and Environmental Engineering - Politecnico di Milano, 2. Politecnico di Milano

Flood damage assessment is a quite recent topic in flood risk management; nevertheless, several tools are available for flood damage estimation which are characterised by different levels of robustness and reliability, and no model can be, at present, considered as a standard.

A key question concerns the coherence between the scales of analysis. Damage models are usually developed and validated to be applied at a specific scale and can be unreliable when implemented at different scales; similar problems may arise when models are used to estimate damage due to a different type of flood or a different vulnerability context compared to the original one. Another question concerns the ability of existing damage tools to cover the variety of exposed assets. Most models are focused on damage to specific items, and may supply a partial vision of the real expected damage. At last, problems may arise with respect to the specific inputs required by the model and available data.

The “flood damage models” repository is aimed at supporting flood damage modellers in the choice of the best available model(s) for a specific context and a specific problem at stake, by supplying (for each available model) key information that, if ignored, can lead to an improper use of models and then significant errors in flood damage assessment. With this objective in mind, the repository wants to be more than a review or a database of existing models, but rather an operative tool in the support of more reliable analysis.

The repository has been thought as a participatory effort by the research community. Once launched, all researchers working in the field of flood risk are encouraged to contribute in and share their experience, to reach the common goal of improving flood damage and risk estimates.

Keywords: flood damage models, repository

Urban and Rural Flood Vulnerability Assessment for Iowa

SS. III.e

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Flooding had a tremendous impact on urban and rural lands in the State of Iowa. During the last couple of decades, flooding caused tens of fatalities and cost billions of dollars in structural and agricultural losses. Recent studies show that flooding trends tend to increase across the state. Decision-makers are working on best practices to protect their communities against future flooding threats. At this point, a detailed vulnerability assessment is significant to take adequate mitigation measures for possible flood events. Understanding the urban and agricultural vulnerability is the key to better implementation of structural and non-structural flood mitigation efforts. An ideal vulnerability assessment must cover both urban and agricultural perspectives of the flooding impact to address multiple aspects of the flooding. In this study, a detailed urban and agricultural flood vulnerability analysis is presented. Agricultural land data which is created by the Department of Natural Resources is collected to execute agricultural flood vulnerability of the State of Iowa. Tax assessor data which includes the structural value of buildings and their geographic coordinates are collected to analyze urban flood vulnerability for major cities in Iowa. State-wide flood maps are obtained from the Iowa Flood Center. The results of the study are shared on the Iowa Flood Information System (IFIS) which is a real-time web-based flood information system. Vulnerability analysis outputs will be used for the investigation of structural flood mitigation analysis as a future study.

Urban flood model validated with records from affected population for dynamic resilience evaluation considering climate changes

Oral - PS III.d Cooperation in the management of large flood events

Dr. Maria Clara Fava ¹, Ms. Ana Carolina Sarmento Buarque ¹, Ms. Marina Macedo ¹, Prof. Eduardo Mario Mendonço ¹

¹. University of Sao Paulo

The urbanization process causes structural and environmental changes in urban catchments leading to an increase in surface runoff production and consequently the frequency of flooding events occurrence, a scenario aggravated by climate change. These events are complex and involve risk factors related to health, wellness and economy, which changes in time according to the individuals, environment and external factors. However, system resilience is commonly assessed as a static value, which does not consider the behaviour of the system over time, its adaptative capacity and recovery time. In addition, one often-encountered challenge to calibrate the flood models is the lack of consistent historical data, especially the overflow area. In this study, we propose to evaluate the resilience state of the Gregório Creek catchment, São Carlos, SP, Brazil, which suffers from recurrent flooding in a high-density area of commercial occupation. Hydrological modelling was performed using the Storm Water Management Model, and the current scenario was evaluated for design storm events with a return period of 5, 10, 50 and 100 years with duration of 30, 60 and 120 minutes. To overcome the lack of consistent water level data, the flood extent was calibrated using historical data such as photos, newspaper records, and population memory. Finally, an assessment of affected establishments' number due to flooding was performed from the analysis of the maximum water level reached. This measurement was used to evaluate system performance, and then the dynamic resilience curve was calculated. The same procedure was repeated for future scenarios, considering the effects of climate change. To this end, Intensity-Duration-Frequency curves updated by a regional climate model for the city of São Carlos were used for the future horizons of the years of 2050 and 2100. This analysis should assist decision-makers in choosing to implement flood mitigation measures aiming to increase system resilience.

WMO guidelines for the assessment of national needs and capabilities on end-to-end flood early warning systems

SS. III.g

Dr. Yuri Simonov¹

1. Hydrometeorological Centre of Russia

In line with the Sendai Framework, an end-to-end early warning system for floods is composed by many different elements, ranging from data collection, data management, hydrological modeling, operational issuance of forecasting products, dissemination of the forecasts and warnings and, on the final end, the support to decision making in favor of informed response actions. One of the activities promoted in the framework of the World Meteorological Organization Community of Practice on End-to-end early warning systems for floods has been the development of assessment guidelines to help the National Hydrological Services to identify strengths, weaknesses and gaps in their flood-forecasting capacities. The assessment guidelines examine the different steps of the aforementioned end-to-end early warning systems through a detailed analysis of the various elements, not forgetting about the institutional and legal framework in which the system is operating, nor the basic infrastructural needs, often neglected and given for granted at the level of international cooperation projects. The assessment guidelines have proved to be a crucial tool in the development and finalization of projects combining coastal inundation forecasting (such as the Coastal Inundation Forecasting Initiative), flash flood guidance (through the Flash Flood Guidance System) and riverine flooding in countries such as Fiji, the Dominican Republic, as well as combination of different flood types in countries of South-East Europe within the South-East European Multi-Hazard Early Warning Advisory System Project. Not only they allowed to identify underlying gaps in the end-to-end early warning systems, but they provide to countries a methodology for self-assessment allowing them to build sustainable early warning systems.

Keywords: flood forecasting, Assessment of national capabilities; End-to-end early warning systems, Coastal inundation; flash floods

World Meteorological Organization: from local to global - and back

SS. III.g

Dr. Jan Danhelka¹**1.** *Czech Hydrometeorological Institute*

The World Meteorological Organization (WMO) set up in its Strategy 8 long term ambitions related to hydrology. "No one is surprised by the flood" is the first of the list. Increasing the capacity of National Services in the provision of flood forecasting and warnings has traditionally been the focus of many activities and programmes of WMO, such as the Flood Forecasting Initiative, or the Flash Flood Guidance System, while at the same time promoting the integrated flood management approach through the Associated Programme for Flood Management. However, risk is always local and thus Early Warning System must comprise 4 components: risk knowledge, monitoring & forecasting, warning dissemination, and response capability. WMO supports an users' needs driven design and development of services at the national, regional and global level.

An example of flash flood indicator that was developed based on needs of local authorities and public in the Czech Republic will be presented. Its first component helps to prepare to flood by providing daily assessment of dangerous precipitation thresholds, while its second component evaluates the flash flood hazard in real time by generating alerts for local flood authorities. Flash flood indicator is currently being customized for the new crisis decision support system of Prague.

While the role of National Hydrological Services in supporting the local crisis management might be seen as obvious, the cascading role of regional and global products and services to be tailored for the need of National Hydrological Services is often neglected in design of those services. To elevate the role of operational hydrology and operations of National Hydrological Services, WMO adopted a coordination mechanism for hydrology under the changed structure of WMO. In this presentation we will present its set up and major challenges.

Keywords: flood forecasting, flood management, flash floods, World Meteorological Organization

Flood Preparedness, Response, and Recovery

Comparison of Flood Management in the Missouri and Mississippi River Basins

SS IV.f

Dr. Stephanie Bray ¹, Mr. Charles (Ray) Alexander ¹

1. US Army Corps of Engineers

The Missouri and Mississippi River basins are two large river basins in the United States. The Mississippi River basin drains 41% of the continental United States land area (370,000 square miles), including the Missouri River basin. Both basins are flood-prone and must be managed quite differently. The Missouri River Basin is difficult to manage as a complete system. There are 6 reservoirs on the upstream portion of the mainstem river, and several additional reservoirs on smaller tributaries. There are also a few, mostly non-federal, levee systems on tributaries. However, below the reservoirs, there is little possibility of managing floodwaters. Additionally, those reservoirs must be managed to balance the multiple purposes they serve (i.e., flood control, recreation, water supply, etc.). The reservoirs do serve to manage floodwaters and reduce risk; however, below the reservoirs, there are no systems in place to manage flood waters. The limited ability to manage this water was on display in the spring 2019 floods, which mostly occurred below the reservoirs. Meanwhile, the Mississippi River can be more fully managed as a system through the Mississippi Rivers and Tributaries (MR&T) System. The MR&T system includes floodways and spillways that have thresholds for operation which can divert water away from the mainstem river. This reduces the impacts of, flooding downstream. These floodways and spillways can be operated simultaneously to more closely manage the water levels on the mainstem Mississippi River. For the 2019 flood event, only one structure, the Bonnet Carre spillway, needed to be operated, though the thresholds for operation of both the New Madrid floodway and Morganza spillway were nearly met. The 2019 flood events were very significant hydrological events that demonstrated both the successes and challenges of managing the Missouri and Mississippi Rivers as we do.

Key words: Missouri, Mississippi, flood risk, system, flooding

Comparison of long-term streamflow forecasts driven by runoff from two different atmospheric climate projections and land surface models

SSIV.g

***Ms. Sara Lytle*¹, *Dr. Ahmad Tavakoly*¹, *Mr. Matthew Geheran*¹, *Dr. Shih-Chieh Kao*², *Dr. Jim Lewis*³,
*Ms. Elissa Yeates*¹**

***1. US Army Engineer Research and Development Center, 2. Oak Ridge National Laboratory, 3. US Army Corps of Engineers,
Mississippi Valley Division***

Under changing climate and non-stationary hydrologic conditions, including more intense and longer duration precipitation patterns, river flow regimes will change. The Mississippi River and Tributaries system, which comprises one-third of the continental United States, will need to be carefully managed under changing conditions in the coming decades to reduce flood risk. To assess these future flood frequencies and magnitudes, atmospheric climate and runoff projections from two separate datasets are used to drive a high-density simulated hydrologic routing model for the Mississippi River Basin (MRB). The Coupled Model Intercomparison Project Phase 5 Multi-Model Ensemble (CMIP5) and the Oak Ridge National Laboratory (ORNL) runoff datasets were produced using different subsets of the CMIP5 atmospheric forecasts, different emissions scenarios for future climate, and different downscaling approaches to produce rainfall runoff through a land surface model. The hydrologic routing model used for this analysis, Routing Application for Parallel computation of Discharge (RAPID), produces simulated hydrographs for a dense network of stream reaches in the MRB from 1980 through 2050 using these two different input runoff projections. The resulting flow rates are compared to evaluate differences in performance between the two input datasets. Future flow rates for key stream reaches in the MRB are compared for substantial differences in predicted flow regime changes. RAPID model results from both input datasets are also validated against gauge flow data for the available historical period. The resulting descriptions of future flow regimes in the MRB will have implications for flood risk and water supply management in coming decades.

Counting on the Contingencies: How Quickly Evolving IDSS Strategies Enhanced Services During the Record Mississippi River Flood of Spring 2019

SS IV.f

Mrs. Jessica Brooks¹

1. NOAA National Weather Service

A wet fall of 2018 primed the Upper Mississippi River watershed for flooding. Then a cold, snowy winter of 2018-2019 was followed by a very wet May, contributing to the longest period of continuous flooding in Mississippi River recorded history.

The National Weather Service (NWS) Quad Cities communicated with partners regarding the potential for near record or record flooding beginning in February, at least six weeks prior to the first crest. Interactions continued throughout the event to keep decision-makers informed of the risks they would encounter as the long duration event evolved. The discussions yielded discoveries that additional information was needed from what current NWS products and services provide, particularly concerning the potential for the river to reach higher levels than deterministic forecasts would indicate. To provide the decision-support required for our partners to prepare resources and take protective measures to reduce flood risk, the NWS Quad Cities developed new methods, including quasi-probabilistic forecasts leading up to each crest.

This flood produced extensive economic impacts and property damage due to both the magnitude and duration of the high water. Temporary flood protection barriers breached in the cities of Davenport and Burlington in Iowa, causing millions of dollars of damages. Also, the Lock and Dam system was closed to river traffic for months, creating an economic impact as the agriculture industry is typically transporting high volumes of materials and goods in the spring.

This event pushed the NWS Quad Cities staff to provide new levels of service by forecasting and messaging a challenging event involving saturated soils, deep frost, above normal snow, and heavy rainfall that persisted for almost five months and included three separate top 10 crests. These services provided the necessary information for partners to take action and minimize the eventual impacts.

probabilistic, forecasting, contingencies, decision-support, mitigation

Evaluating meteorological extremes under climate change uncertainty with stakeholders engagement in Vietnam: A case study of local scale flood assessment in the Hue, Ha Giang and Vinh Yen cities.

SSIV.g

***Dr. Maksym Gusyev*¹, *Dr. Katsunori Tamakawa*¹, *Dr. Tomoki Ushiyama*¹, *Dr. Yusuke Yamazaki*¹, *Mr. Hiroyuki Ito*¹, *Dr. Bhuwneshwar Prasad*², *Dr. Hiroyuki Miyazaki*³, *Prof. Ryosuke Shibasaki*³, *Prof. Toshio Koike*¹**

1. International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, Public Works Research Institute (PWRI), 2. The University of Tokyo/PASCO CORPORATION, 3. University of Tokyo

Climate variability quantification informs water management and policy decision-making for tailoring adaptation measures to mitigate an uncertain future and requires a synergy of best scientific practices and stakeholders' needs in vulnerable areas. In Vietnam, evaluation of meteorological and hydrological extremes is needed on country, river basin, and urban scales for proper land-use planning and sustainable management under climate change hazards uncertainty. For the nationwide assessment, we evaluated uncertainty of extreme daily rainfall and monthly temperature using a combined point-scale statistical downscaling, which uses in-situ bias-correction at Vietnam gauges with spatial interpolation of representative CMIP5 General Circulation Models (GCMs) outputs on Data Integration Analysis System (DIAS) for past (1979-2003) and representative concentration pathway (RCP)2.6 and RCP8.5 climates of near-future (2025-2049), future (2050-2074) and far-future (2075-2099), and spatial dynamically downscaled MRI-AGCM3.2S model outputs between past (1979-2003) and RCP8.5 future (2075-2099) climates. Selected historical flood events were simulated using the rainfall-runoff-inundation (RRI) model with in-situ Vietnam and satellite rainfall data to obtain reasonable match with available data of river discharge and flood inundation depth and extent collected during two field surveys in Hue, Ha Giang and Vinh Yen cities. Using the dynamically downscaled rainfall with the RRI model, five past and five future flood events were simulated to produce an aggregated flood hazard map and to select one past and one future rainfall for scaling of the past and future flood return periods. Identified changes of flood inundation extent and volume between past and future climates suggest that the Vinh Yen area remains flood prone while future extreme hazards are expected to have the most and least influence in Hue and Ha Giang areas, respectively. The resulting dynamical-statistical approach efficiently characterizes GCMs' uncertainty nationwide with flood hazard mapping on river basin and peri-urban scales for flood risk assessment under climate change in Asia.

Low gradient coastal land margin systems: Conceptualizing and understanding flood resilience in a changing climate

SS IV.g

Prof. Scott Hagen¹

1. LSU Center for Coastal Resiliency

Abstract: This presentation will begin with a contextual description of the relatively recent historical land loss of the Mississippi River Delta Plain (MRDP) and how the human and natural system is responding. Are the impacts of relative sea level rise (i.e., subsidence and eustatic sea level rise) in the MRDP the Sirens of our doom, or a basis for enhanced coastal and ecological engineering? Transdisciplinary research outcomes from recent synergistic studies throughout the northern Gulf of Mexico provide mixed results in evaluations of sustainability and resilience at the coastal land margin. A path forward may be achieved with a system of systems approach to bio-geophysical science and engineering with the integration of socioeconomic processes.

Keywords: Coastal land margin; climate change; compound flooding; storm surge; system of systems

Methodology for Measuring Adaptation Triggers in the Rockaways, NY

SSIV.g

***Ms. Suzana Rice*¹, *Mr. Maarten Kluijver*², *Dr. David Yang*¹, *Mr. Arun Heer*¹**

1. US Army Corps of Engineers, 2. Moffatt & Nichol

A new methodology was developed to trigger sea level change adaptations for project features in the East Rockaway to Rockaway Inlet and Jamaica Bay (the Rockaways), New York Study, specifically the Atlantic Ocean Shorefront Planning Reach. The low elevation project area has a high probability of flooding, and the communities are vulnerable to the effects of relative sea level change. Consequences of flooding are relatively high because of the density of development, and the critical infrastructure within the study area. The recommended plan for the area includes a composite seawall, beachfill and groins, with potential adaptation features. The design considered the USACE low, intermediate and high sea level change scenarios. The design accounts for 1ft of relative sea level rise based upon the middle of the current tidal epoch – year 1992. The trigger for future adaptations is when sea level rise exceeds the design sea level rise threshold, which is based on the low scenario. A methodology was needed to evaluate when the water level threshold has been met. Monthly and five month average mean sea level (MSL) observations were compared, a buffer was incorporated to account for the variance of the sea level, and multiple time period durations were tested. Based upon the analysis of variation of monthly mean sea level, the determined project adaptations will start when the five month average MSL observations exceed the threshold value plus a buffer for a sequential duration of six months or more.

Coastal projects, tangible trigger, adapting, water level monitoring, innovative design

Near real-time flood forecasting for coastal mega-cities in India: Major challenges and way forward

SS IV.h

Ms. Mousumi Ghosh ¹, Dr. Hiteshri Shastri ², Dr. Supantha Paul ³, Prof. Subimal Ghosh ⁴,

Prof. Subhankar Karmakar ⁵

1. *Interdisciplinary Program in Climate Studies, Indian Institute of Technology Bombay, Mumbai 400076, India, 2.* *Faculty of Technology and Engineering, Charotar University of Science and Technology, Anand 388421, India, 3.* *Department of Civil Engineering, TIT Narsingarh, Agartala 799009, India, 4.* *Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai-400076, India, 5.* *Environmental Science and Engineering Department, Indian Institute of Technology Bombay, Mumbai-400 076, India*

Floods account for the most extensive, catastrophic and frequent natural hazards in the context of Indian sub-continent. A substantial portion of the Indian population resides in the coastal cities, hence are immensely exposed to frequent flooding and runoff related complications. The erratic pattern and high spatio-temporal variability of rainfall, lack of adequate storm water drainage network, low permeable catchments pose a colossal challenge to the civic bodies for effective and efficient flood management. The accuracy in rainfall and flood forecasting is the need of the hour to develop a proficient flood forecasting and early warning system to reduce the overall vulnerability and risk. Under this context, the current study aims to develop a comprehensive 3-way coupled hydrodynamic flood modelling framework for near real time flood forecasting with rainfall obtained from statistical and physics-based approaches. A regional weather forecast model established with a quantile regression based statistical method is utilised to acquire rainfall forecasts at various quantile levels. Simultaneously, a physics-based numerical weather prediction model is implemented to forecast fine resolution rainfall under various urban canopy scenarios. The rainfall forecasts serve as input to the three-way flood model where the MIKE 11 (streamflow) with the storm water drainage network are coupled with the MIKE 21 (overland flow) to derive flood inundation and hazard maps. In addition, the tidal elevation are provided along the coastline in the model setup. The maps obtained through different rainfall forecast scenarios are compared with that of the observed rainfall. This stand-alone flood forecasting framework has been implemented for an Indian coastal mega-city and may be adapted in other flood prone cities. The study identifies major challenges associated with flood forecasting over data-scarce coastal mega-cities.

Review on Rapid Assessment Approach in Flood Damage Estimation for Malaysia: Case Study of 2007 Pahang River Flood Event

Oral - PS IV.c Impacts of life loss and damage estimation

Mr. Muhammad Kashfy Zainalfikry¹, Prof. Aminuddin Ab Ghani¹

1. River Engineering and Urban Drainage Research Centre, Universiti Sains Malaysia

Flood damage estimation is of great importance in flood management as it provides information for effective long-term flood risk reduction plan. Despite the essential role in risk management, the consideration of damage assessment in the decision-making process is relatively new in Malaysia. Therefore, this paper reviews two generalised flood damage assessment approaches proposed by Department of Irrigation and Drainage Malaysia (DID) based on their 2003 and 2012 national study. The methodologies were tested on a real event of 2007 Pahang River flood due to the availability of damage data of the event. The determination of affected properties and crops and information on flood hazards (inundation extent, water level and flood duration) required for the assessment were obtained from a calibrated hydrodynamic modelling of flood simulation in HEC-RAS and geospatial analysis. It is found that, the DID (2003) methodology is only suitable to provide first level damage estimation with its limited calculation work. The DID (2012) approach gave a better damage estimation and has the capacity to provide sufficient economic loss information for regional flood management study. A preliminary annual average damage (AAD) estimation is also presented in this paper using four-point damage-probability curve illustrating the average contribution of the study area in economic loss due to flood in a year. The methodology and findings can be applied in the field of flood risk management for decision support and regional policy development in Malaysia.

Key words: Flood damage assessment, flood damage factor, Pahang River, flood modelling, HEC-RAS

The Floods of 2019: A Kansas and Missouri Perspective

SS IV.f

***Mr. Matt Unruh*¹, *Mrs. Jennifer Hoggatt*²**

1. Kansas Water Office, 2. Missouri Department of Natural Resources

Our proposed presentation will be a case study of multiple flood effects felt during the floods of 2019. Nationally, many people viewed the flood of 2019 and will remember its impacts in images of flooded towns and farm fields along the Missouri River through Nebraska, Kansas, Iowa, and Missouri. However, what many times gets hidden from view are the impacts felt upstream as the USACE and others take every action possible to prevent further downstream flooding. Many locations in Kansas and Missouri experienced exceptional rainfall from spring through early summer 2019, with a number of Kansas and Missouri reservoirs reaching record capacities in an effort to retain floodwaters and in some instances having to make surcharge pool releases.

Representatives from the Kansas Water Office and the Missouri Water Resources Center will document progression of the flood events of 2019, highlight the magnitude of unprecedented flooding in particular areas, and present upstream and downstream perspectives of those impacted during the event.

Urbanization alters rainfall extremes over India

SS IV.h

***Dr. Jitendra Singh*¹, *Dr. Vittal H*², *Prof. Subhankar Karmakar*³, *Prof. Subimal Ghosh*⁴, *Prof. Dev Niyogi*⁵**

1. *Washington State University, Vancouver, WA, 2. Post-Doctoral, UFZ–Helmholtz Centre for Environmental Research, Leipzig, Germany, 3. Environmental Science and Engineering Department, Indian Institute of Technology Bombay, Mumbai-400 076, India, 4. Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai-400076, India, 5. Professor, Department of Earth, Atmospheric, and Planetary Sciences, Purdue University*

Abstract: Anthropogenic changes are likely to intensify rainfall extremes, posing a risk to human, environmental, and urban systems. Particularly, understanding the impact of urbanization on rainfall extremes is vital for sustainable urban policies. This study presents the unexplored impacts of changes arising in urban areas on summer monsoon rainfall extremes over entire India. Here we perform a nonstationary frequency analysis on Indian Summer Monsoon Rainfall (ISMR) extremes in a Generalized Additive Model for Location, Scale and Shape framework with a cluster of 74 models, considering nonstationarity in different possible combinations. An urbanization index is also developed to understand the extent of urbanization activities across the country. Interestingly, we observe significant nonstationarity in ISMR extremes in urbanizing/developing urban areas (transitioning from rural to urban), compared to wholly urbanized or rural areas. This presents a postulation that the extent of urbanization plays a significant role in introducing nonstationarity in ISMR extremes. Here, we show that urbanization, even though a local influence, is strongly related to the changes in rainfall extremes across the country, which further needs a scientific reevaluation by implementing physics-based modeling. The impact of these observational studies will be critical in correcting the bias of model projections of ISMR.

Extremes, Monsoon, Nonstationary, Urbanization

USACE Contributions to Managing the 2019 Missouri River Flood Event(s)

SS IV.f

***Dr. Stephanie Bray*¹, *Mr. Mark Roupas*²**

1. USACE, 2. US Army Corps of Engineers

The spring 2019 flooding in the Missouri River basin was the result of several events rather than having one distinct cause. A large snow event (i.e., bomb cyclone in March), large snowmelt from April through June, and rainfall ranging from 300-500 percent of average in May resulted in widespread and extended flooding throughout the basin. While there are six reservoirs on the mainstem Missouri River that can help manage floodwaters, the lower 600 miles of the Missouri River do not have any large-scale flood risk management systems in place. Between the releases necessary from the six reservoirs and the runoff from other, uncontrolled, tributaries, the lower Missouri River experienced heavy flooding. USACE had a significant role in managing the flood event, via management of flows out of the reservoirs, as well as a significant role in responding to and recovering from the flood event. There are numerous levees along the river downstream of the reservoirs. Those levees were not designed as, and do not operate as, a system. Some of the levees are in the Public Law 84-99 Rehabilitation Program while some are not. USACE assisted in floodfighting along the levees, and provided support to the local levee sponsors as various levees breached or overtopped as a result of the flood. After the flood event passed, USACE assisted in repairing those levees that participated in the Rehabilitation Program. Over 180 requests for assistance were received from local levee sponsors. Additionally, FEMA mission assigned USACE to provide assistance in the response and recovery. USACE will continue to play a major role in assisting the region in recovering from this event and becoming more resilient to future events.

Key Words: Missouri River, reservoirs, PL 84-99, levees, rehabilitation

“Above all else, show the data” : U.S. Geological Survey (USGS) Riverine Response to Flooding and Post-Flood Data Collection with Reference to the Midwest Floods of 2019

SS IV.f

Mr. Paul Rydlund Jr. PLS, CFM

1. USGS - CMWSC

The intense development of a low pressure system, combined with frozen ground and pre-existing snow accumulation, initiated flooding in March of 2019 in Nebraska and Iowa. Flooding continued into the summer months from subsequent heavy rainfall events that impacted a variety of watersheds and tributaries in Missouri, Arkansas, and Oklahoma. The magnitude and longevity of Midwest flooding along the main stem of the Missouri, Mississippi, and Arkansas Rivers were just a few of the open-channel systems emanating significant impacts and record-breaking peaks.

Aligning to the U.S. Geological Survey (USGS) mission of providing impartial scientific information for hazards mitigation and resource management, the USGS captures crucial information during flood response, which is subsequently used for recovery, future mitigation, and preparedness of future flood events. Through a pre-scripted mission assignment with the Federal Emergency Management Agency (FEMA) or other internal or external mechanisms, the USGS initiates identification and collection of high-water marks, surveys of levee breaches, targeted terrain surveys for the development of flood advisory maps, and periodic analyses contrasting base-flood elevations and regulated local freeboard. Working closely with state and county emergency management entities, along with FEMA, such data and products integrate into the disaster management cycle that ultimately supports and enhances floodplain management and future regulation.

This presentation will demonstrate the capacity and diversity of USGS flood response with reference to Midwest flooding in 2019, identifying the utility and benefit of data collection.

Flooding, Base-Flood-Elevation, High-Water-Mark, Surveying, FEMA

Flood Decision-making, Policy, and Governance

A Global Survey and Analysis of Flood Early Warning Systems

Oral - PS V.b Infrastructure and investments

***Dr. Edangodage Duminda Pradeep Perera*¹, *Prof. Ousmane Seidou*², *Ms. JETAL AGNIHOTRI*¹, *Dr. Vladimir Smakhtin*¹, *Prof. Paulin Coulibaly*³, *Dr. Hamid Mehmood*¹**

1. United Nations University Institute for Water, Environment and Health, (UNU-INWEH), 2. University of Ottawa, 3. McMaster University

There's a lack of information on availability and status of Flood Early Warning Systems (FEWS) around the world, their benefits and costs, challenges and trends associated with their development despite widespread recognition of the importance of FEWS for DRR. A comprehensive online survey with over 80 questions on various components of FEWS (risk knowledge, monitoring and forecasting, warning dissemination and communication, and response capabilities), investments, their operational effectiveness, benefits, and challenges, was conducted to bridge this information gap. The survey was distributed around the globe. Survey responses were received from 47 developing and six developed countries. They suggested that the advancement of the FEWS depends on available investments for system developments and continuous financing for their operations. Training the staff and maintaining the FEWS for long-term operations are challenging according to the responses. The primary reason for establishing FEWS, based on the survey, is to avoid property damage; minimizing casualties and agricultural losses appear to be secondary reasons. The range of the community benefited by FEWS varies, but 55% of FEWS operate in the range between 100,000 to 1 million of population. The study's recommendations to improve the global knowledge on status and implementation of FEWS in the context of Sendai Framework for DRR includes: i) coordinate global investments in FEWS development and standardize investment reporting; ii) establish an international hub to monitor the status of FEWS in collaboration with responsible national agencies. This will support the sharing of FEWS-related information for accelerated global progress in DRR; iii) develop a comprehensive, index-based ranking system for FEWS according to their effectiveness in flood disaster mitigation. This will provide clear standards and a roadmap for improving FEWS effectiveness; iv) strengthen the coordination between institutions responsible for flood forecasting and those accountable for communicating warnings and community preparedness and awareness.

A micro-scale flood risk assessment of a single residential building: A case study in Jefferson Parish, Louisiana, U.S.A.

Oral - PS V.c Insurance and building level protection

***Mr. Ehab Gnan*¹, *Dr. Carol Friedland*², *Dr. Arash Taghinezhad*¹, *Dr. Thanos Gentimis*³,
*Mrs. Jasmin McElwee*¹**

1. Bert S. Turner Department of Construction Management, Louisiana State University, Baton Rouge, LA 70803, **2.** Louisiana State University, **3.** Experimental Statistics, Louisiana State University, Baton Rouge, LA 70803

Many residential buildings in the U.S. are vulnerable to flood damage; however, communities and homeowners often perceive potential flood risk as below their threshold level of concern, where protection is deemed unnecessary. Robust flood risk assessment should result in actionable information for stakeholders that quantifies associated uncertainties. Therefore, the goal of this paper is to translate numerical flood modeling results to present value representation of lifecycle cost with the goal of enhancing individual and community resilience. This paper presents a comprehensive methodology that quantifies the lifecycle cost of flood hazards including insurance implications, flood mitigation costs, and future flood losses at the micro-level (i.e., single-residence building) scale. A synthetic flood record is generated using Monte Carlo Simulation and building and contents losses are estimated using US Army Corps depth-loss functions, which are aggregated over the simulation history to calculate the average annual loss (AAL). The findings demonstrate the present value cost of multiple first floor elevations (i.e., freeboard scenarios) at the time of construction considering flood insurance implications and model uncertainties. Application of the micro-level approach allows for a more localized, detailed, and comprehensive assessment of flood risk. The findings of this research highlight the benefit of assessing flood loss at the micro-level and the importance of acknowledging uncertainties in AAL assessments.

Keywords (5): Average Annual Loss (AAL); Flood Risk Assessment; Avoided Loss; Monte Carlo Simulation; Freeboard

A true risk-based approach to defining flood risk in Australia's riskiest floodplain

Oral - PS V.d Integrated flood risk management

Dr. Philip Haines¹, Ms. Carrie Dearnley¹

1. BMT

The Brisbane River drains one of the largest catchments in South-East Queensland, Australia, covering an area > 13,000km². The highly incised nature of the river downstream of Wivenhoe Dam results in relatively limited floodplain extents. Increases in catchment flows drives significant increases in flood levels throughout the river. For example, the 1 in 100,000 AEP flood level is about 20 metres higher than the 1 in 100 AEP flood level at Brisbane CBD, in the lower river reaches. Much of the city of Brisbane, Australia's third largest city, is located within and adjacent to the floodplain, making Brisbane River the highest risk floodplain in Australia.

A Strategic Floodplain Management Plan (SFMP) has recently been completed for the Brisbane River. The SFMP adopts an innovative definition of flood risk which is applied consistently across the whole floodplain, independent of local government jurisdictional boundaries. Risk was defined using an ISO 31000 compliant approach based on a likelihood x consequence framework. The risk framework was tailored for flood risk to consider 1) potential hydraulic risk, 2) exposure, and 3) vulnerability. Potential hydraulic risk described where the flood waters go (adopting a combination of event likelihood and flood hazard using a carefully defined risk matrix); exposure described what assets and development will be impacted; and vulnerability described the resilience of the affected community to flooding. Also considered was the risk of isolation during flooding, and the availability of safe and effective evacuation. This highly innovative approach allowed stakeholders to identify and prioritise flood risk areas so that bespoke risk mitigation approaches could be targeted within the SFMP.

This paper presents and rationalises the innovative approach taken to defining flood risk in the Brisbane River, Australia. The SFMP was developed in partnership with and delivered to the Queensland Reconstruction Authority, four councils and numerous stakeholders.

Application of Forecast Informed Reservoir Operations (FIRO) on US Army Corps of Engineers (USACE) Dams in California

Oral - PS V.a Governance and partnerships (shared vision & responsibility)

Mr. Cuong Ly¹, Mr. Joseph Forbis¹

1. US Army Corps of Engineers

The US Army Corps of Engineers (USACE) prescribes regulation on how reservoirs are to operate for flood control in water control manuals (WCMs). In some cases, WCMs and their reservoir operations procedures may not capture changed conditions in the watersheds or include the benefit of state-of-the-science weather and streamflow prediction. Given the technological advances and changed hydrologic conditions, it may be possible for forecast-informed reservoir operations (FIRO) to enhance flood risk reduction, improve water supply, and achieve additional ecosystem benefits.

A significant portion of the work during the preliminary viability assessment (PVA) for FIRO at one location - Coyote Valley Dam (Lake Mendocino) - focused on determining if improved water supply reliability could be achieved using FIRO without increasing the flood risk. Two parallel coordinated efforts were undertaken, using different reservoir model approaches and a range of hydrologic and meteorological conditions to evaluate multiple alternatives on how specific objectives are achieved. The analyses included performance metrics such as end of water year storage, frequency of uncontrolled spillway flow, discharge and stage frequency at Lake Mendocino and pertinent downstream locations, and expected flood damages.

The analyses completed for the PVA demonstrated forecast informed operation, as simulated in the studies, improved reliability of meeting water management objectives without adversely affecting flood risk management in the basin. Furthermore, FIRO concepts were implemented at Coyote Valley Dam for Water Years 2018 and 2019 using one of the reservoir operations alternatives from the PVA. The results of the implementation further demonstrated that FIRO could be used successfully. The initial success at Coyote Valley Dam led to the selections of two other reservoir systems (Prado Dam and Oroville/New Bullards Bar dams) with different hydrological and meteorological characteristics in California as additional pilot study locations to further validate FIRO concepts.

Can We Better Predict the Frequency and Severity of Floods Using Physics?

SS V.f

Mx. Daniel Wright¹

1. University of Wisconsin-Madison

Predicting the frequency and severity of floods has been a longstanding topic of hydrologic research and practice. Despite the fact that every flood is a unique combination of multiple physical processes (rainfall, snow, groundwater, and surface runoff, to name just a few), prediction of key metrics such as the 100-year flood has generally been seen as a statistics problem. This view limits the opportunities to use our evolving understanding of how actual floods work in order to improve predictions. This limitation has become particularly problematic in an era of rapid climate and watershed changes, both of which modify hydrologic processes in ways that can influence flood frequency and severity.

In this presentation, we argue that long-term flood prediction can benefit from deeper consideration of the physical processes that cause floods, as well as from decades of progress in the observation and computational simulation of these processes. Though this argument is not entirely new, it has received relatively little attention compared with more conventional approaches. We briefly describe the “process-based” approach that we use to generate estimates of flood frequency and severity. Crucially, this approach is flexible: it is straightforward to integrate recent advances in rainfall measurement, flood simulation, and climate modeling. We show that the approach can produce results with comparable or superior accuracy to more conventional statistics, and can provide insights into how changes in physical processes are leading to changing flood risks. We close by arguing that process-based and statistics-based approaches are not mutually exclusive—indeed, we foresee and are pushing for a gradual merging of the two over the coming decades.

Keywords: flood frequency, modeling, hydrometeorology, hydrology, extreme rainfall

Challenges of Compound Coastal Flood Modeling and Risk Assessment

SS V.f

***Prof. Hamed Moftakhari*¹, *Mr. David Pauta*², *Prof. Amir AghaKouchak*³, *Prof. Brett Sanders*⁴, *Dr. Hamid Moradkhani*¹**

1. University of Alabama, 2. The University of Alabama, 3. University of California, Irvine, 4. University of California

Large population around the globe living in a close proximity of freshwater-influenced coastal regions, while benefit from services that these systems provide, are increasingly threatened by compound coastal floods. These compound hazards, during which the coincidence/concurrence of two or more hazard drivers intensify the impacts expected from each of those drivers in isolation, are not easy to characterize. The complex interactions between atmospheric, oceanic, and hydroclimatic forcing over the coastal regions, besides nonstationarity in hydroclimate extremes, is of paramount importance for hazard prediction and infrastructure resilience. Common flood hazard assessment practices typically account for one driver at a time (e.g., either fluvial flooding only or ocean flooding only), whereas coastal systems are at risk for flooding from multiple drivers (e.g., extreme coastal high tide, storm surge, rainfall and river flow). Inappropriate characterization of risk associated with these compound hazards that does not take the nonlinear interactions into account may not provide reliable and actionable information on the coastal flood hazards to public and decision-makers, and thus yields ineffective communication of risk to threatened coastal communities. In this presentation the challenges we face for appropriate characterization of these compound coastal extremes will be discussed. Also, the opportunities to tackle the aforementioned challenges including recent advancements in linking statistical and hydrodynamic modeling platforms will be presented.

Keywords: Compound hazards, Coastal flooding, Risk Management

Creating Community Resilience through Flood Recovery

Oral - PS V.a Governance and partnerships (shared vision & responsibility)

Ms. Sandi Fowler¹, Ms. Jennifer Pratt¹

1. City of Cedar Rapids, Iowa

In June 2008, the city of Cedar Rapids, Iowa, population 133,000, experienced the largest natural disaster in Iowa history when the Cedar River reached a flood stage of 31.12', 19' above local flood stage. The result was \$5.4 billion in estimated total loss for the community. To recover, the City engaged in extensive planning, implemented floodplain protection, created neighborhood housing and business programs, and rebuilt government infrastructure, resulting in a better, stronger community.

Aggressive planning efforts were critical to the community's recovery, identifying opportunities to rebuild Cedar Rapids with resilience against future flooding and other disasters. These efforts included a strategy for a future flood control system to mitigate river flood threats, and a neighborhood plan to rebuild neighborhoods, business districts, and transportation systems. Using these tactics, nearly 1,400 properties were acquired, removing families from harm's way, building hundreds of units of new housing, and making way for community flood protection.

Following the devastating flood, new programs assisted in the recovery, retention, and attraction of businesses to the community. Disaster-affected businesses traditionally have suffered from long-term debt that hampers their successful recovery. Cedar Rapids implemented business recovery programs that provided grants rather than loans. The result was 82% of businesses affected remained in business three years post-flood, compared to the national average of 45%.

Many Cedar Rapids government facilities were also damaged or destroyed, resulting in the opportunity to rebuild major facilities with LEED designation and sustainable features. To further address risk to remaining properties, residents are encouraged to participate in the National Flood Insurance Program, with the Community Rating System, increasing the percent of structures within the flood plain that are insured from approximately 10% at the time of the 2008 flood, to 45%, and reducing costs for policy holders.

Developing decision tools for improving civil protection flood risk reduction strategies: the FLORIS project

Oral - PS V.d Integrated flood risk management

***Dr. Simon McCarthy*¹, *Dr. Christophe Viavattene*¹, *Prof. Giuseppe Aronica*², *Dr. Emina Hadzic*³, *Dr. Miranda Deda*⁴, *Mr. Halim Koxhai*⁵, *Dr. Giuseppina Brigandi*², *Dr. Brunella Bonaccorso*², *Dr. Laura Rossello*⁴, *Dr. Sally Priest*¹**

1. Middlesex University, Flood Hazard Research Centre, **2.** University of Messina, **3.** University of Sarajevo, **4.** CIMA Research Foundation, **5.** Prefekt I Quakut Berat

The two year FLORIS project aimed to co-develop with civil protection agencies an integrated flood risk information platform focused on critical area specific issues at risk of high frequency/low direct damage events that incur disruptions and so interventions. High frequency floods still involve and require precautionary mitigation actions on the part of civil protection and citizens before floodwaters inundate the land and directly impact assets. These emergency actions can benefit from enhanced civil protection protocols based on realistic scenario development.

With case locations in the city of Berat, Albania and in Sarajevo, Bosnia and Herzegovina working with the relevant local bodies opportunities to further develop the civil protection protocols have been identified. Co-development, including workshops, harnessed innovative modelling of cascade effects incorporating existing algorithms to develop procedures for flood risk reduction, taking into account resource management requirements. Enhanced protocols include associated physical, social and resource characteristics particular to the selected location. Combined with staff training and guidance manuals the information platforms take into account a range of relevant 'natural' hazards particular to the locations to incorporate the enhanced approaches. The centralisation of measures contribute to improved flood risk management actions under different and variable risk scenarios including climate and global change that are transferable to other regional and country contexts. The paper will explore the challenges, opportunities and outcomes of FLORIS project of co-development with civil protection agencies in this region.

Civil protection, decision making, protocol development, co-development, high frequency

Dutch Flood Protection Programme: Taking Innovations to the Next Level

Oral - PS V.a Governance and partnerships (shared vision & responsibility)

***Mrs. Ellen Tromp*¹, *Mr. Han Knoeff*¹, *Ms. Goaitske de Vries*²**

1. Deltares, Dutch Flood Protection Programme, 2. Dutch Flood Protection Programme

In the coming decades, the Dutch regional water authorities (RWAs) have to strengthen more than 1,100 km of flood defences to meet the newly derived safety standards. This immense operation is carried out under the wing of the Dutch Flood Protection Programme (DFPP) of the Netherlands. The work will be spread among nearly 300 projects located throughout the country, along the coast, lakes and major rivers. Achieving this goal is only possible, if we can develop a new perspective on Dutch dikes and on dike reinforcement. For this, the DFPP is strongly investing in knowledge development and innovations. Since the start in 2013, over 80 million Euros is invested in innovations, but the implementation of the gained knowledge is still lacking. Therefore, the DFPP recently developed a new way of working, aimed at stimulating the knowledge transfer and uptake of the innovations across the RWAs, and investing in more knowledge production to be able to carry out the full scope of the DFPP within the available time and budget. In this paper, we address how the DFPP stimulated innovations in the past years, and how she is currently changing her strategy based on her experience. We will also highlight innovations that were developed in the past years, which are now in their final stages of development, and even some reached the highest technology readiness level (TRL), and what effort we currently take to enhance the knowledge transfer and uptake of these innovations. Finally, we reflect on the societal challenges the RWAs will face while carrying out the dike strengthening projects, and how innovations can help them face these challenges.

Flood Risk Management, Innovations, Dikes, Flood Decision-making, Knowledge uptake

Engaging Vulnerable Citizens Through New Flood Insurance Tools at Poor-Gauged Basins Under Non-Stationary Conditions

Oral - PS V.c Insurance and building level protection

Prof. Eduardo Mario Mendiondo¹, ***Mr. Felipe Souza***¹, ***Ms. Ana Carolina Sarmiento Buarque***¹,
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Vulnerable communities are locally impacted by hydrological extremes, which are exacerbated at basins with poor-gauged monitoring under changing conditions of climate and land-use. Because engaging low-income citizens is a complex and transdisciplinary task, flood insurance examples are still insignificant for these targeted publics. This contribution aims to share lessons learnt and experiences gained with demonstrative pilots for engaging vulnerable citizens at poor-gauged basins under climate and land-use cover changes (C+LULC). The methodology implies addressing flood insurance in a more holistic framework of water security, ranging from multi-hazards' insurance to multi-risks' decision-making. Firstly, we use crowdsourcing and participatory inventory of vulnerability relations of flood damage (L\$) V return periods (Tr), societal survey on flood losses V capital assets (C\$), and cross-checks of the Willingness-To-Pay (WTP\$) with Tr and C\$. Under C+LULC scenarios, we propose a Willingness-To-Adapt (WtA) tool, to compare a behavioral transformation of citizens' engagement at poor-gauged basins, between stationary and non-stationary conditions of C+LULC. Secondly, we assess a WTP\$ from a Hydrologic Risk Transfer Model (HRTM), with a citizen-science framework of WtA using a framework of Disaster Risk Reduction and Resilience with the Socio-Hydrological Observatory for Water Security (DR³-SHOWS). Adapting to 2020/2100 IPCC's C+LULC impacts, we present a case study of how DR³-SHOWS friendly shares WtA for local community through hand-on, low-cost, decentralized and citizen practices. The Center for Education and Research on Disasters (CEPED/SP, www.usp.br/ceped), coordinate WtA-flood insurance and DR³-SHOWS' solutions through Civil Defense, linked to INCTMC2 (<https://www.cemaden.gov.br/inctmudancas-climaticas/>), CEPID/CeMEAI (www.cemeai.icmc.usp.br) and INCLINE (www.incline.iag.usp.br) to promote the outreach and education towards flood preparedness, lowering risks and enhancing resilience. Finally, new flood resilience thresholds with WTP\$ and DR³-SHOWS are then feasible, with WtA's results for changing society's coevolution, patterns, paradoxes and feedbacks, for 40,000 risk prone areas with 60 million people under landslides, flash-floods and inundations in Brazil.

Flood insurance as an adaptation measure for increasing water security in basins under change

Oral - PS V.c Insurance and building level protection

***Ms. Gabriela Gesualdo*¹, *Prof. Eduardo Mario Mendiondo*¹, *Mr. Felipe Souza*¹, *Dr. Diego Guzmán*²**

1. University of Sao Paulo, 2. Pontificia Bolivariana University

Extreme weather events are increasingly evident and widespread around the world due to climate change. These events are driven by rising temperatures and changes in precipitation patterns, which lead to changes in flood frequency, drought and water availability. To reduce the future impacts of natural disasters, it is crucial to understand the spatiotemporal variability of social, economic and environmental vulnerabilities related to natural disasters. The negative impacts of rising flood losses challenge governments and the private sector to develop sustainable flood risk management strategies to reduce those losses. Particularly, developing countries are more vulnerable to climate risks due to their greater economic dependence on climate-sensitive economic activities, infrastructure, finance and other factors that undermine successful adaptation. In this context, a flood insurance fund is a valuable tool for unexpected losses reimbursement, long-term impacts prevention and encouraging risk mitigation. Although this approach is successful throughout the world and major organizations support insurance as an adaptation measure, Brazilian natural disasters insurance fund only provides support for rural landowners. Thus, we will evaluate the implementation of an index-based insurance fund integrated with water security parameters, as an instrument for adaptation to climate change. We will use the SWAT+, a hydro-sedimentological model, to assess the current conditions and future scenarios (up to 2100) of water security indices considering RCP 4.5 and RCP 8.5 from the International Panel on Climate Change (IPCC). Then, we will incorporate those parameters to the Hydrological Risk Transfer Model (MTRH) with a new risk-based adaptation metric denominated WtA (Willingness to Adapt) included assessing the population willingness to pay against potential damage scenarios. Our results will provide an optimized premium in current and future scenarios for supporting adaptation plans to climate change in Brazil. Furthermore, technical-scientific information addressing possible effects of climate change on the hydrometeorological variables and their spatiotemporal variability.

Flood Management Issues in Hilly Regions of Uttarakhand in India under Changing Climatic Condition

Oral - PS V.d Integrated flood risk management

Prof. Mitthan Lal¹, Mr. Sachchidanand Singh¹

¹. Indian Institute of Technology Roorkee

Floods are the natural hazards that produce the highest number of mortalities and properties damage in the state of Uttarakhand. Besides harsh climatic conditions and topography, the unplanned development, weak legal framework and governance issues were claimed as responsible for stimulating the disasters. Thus, there is a need for the study of a possible increase in flooding occurrences and its management. The study highlights the issues and challenges faced by the hilly regions of Uttarakhand state in India under changing climatic conditions. The region is famous pilgrimage centre and is known for the natural environment of the Himalayas, the Bhabar and the Terai. However, the region is widely affected by innumerable natural disasters like cloudbursts, flash floods, landslides, glacier lake outburst floods, etc. which could be due to both anthropogenic causes like urbanization, deforestation, and natural causes such as extreme precipitation, diverse topography and climate change. Furthermore, the lack of active building regulations and state hydro-power laws, along with excessive development on the riverside has raised the severity of the catastrophe. Also, there is a need to assess the effectiveness of the early warning systems in eliciting the response from the targeted populations. In the present study, an attempt has been made to identify the factors that trigger these disasters and also to suggest effective flood management strategies to safeguard from the aftermath of these disasters. The study strongly suggests for collaborative governance of local, state and central policymakers and effective information system for better flood management in the hilly regions.

Flood Management: Practices in China

Oral - PS V.d Integrated flood risk management

Dr. Qian Yu ¹, Dr. Cheng ZHANG ¹, Mrs. Chongshan Guo ¹

1. China Institute of Water Resources and Hydropower Research

Flood is one of the major natural disasters in China. Subject to the special geographical and climate conditions, about two thirds of the national territory and over 90% of the population are under the risk of flood disasters to different extent. In recent years, with continuous investments in flood control and disaster reduction infrastructures, China has kept enhancing its capability in the field, achieving great reduction of flood inundation area and casualties. The average number of deaths caused by floods per year has decreased to 495 since 2011, compared with 1614 from 2000 to 2010. However, with socio-economic development and in the context of climate change, flood disasters show some new features, making economic losses stay high. In this regard, the Chinese government put forward the strategic concept of “transformation from flood control to flood management” in 2003. Following this philosophy, a series of practices and projects have been put forward, e.g., flash flood disaster prevention, flood mapping, informatization in flood control and drought relief, etc., achieving remarkable success. With rapid urbanization and due to unbalanced regional development, some areas of China are still short of well-established flood control and disaster reduction systems. In the new period, the Chinese government is supposed to put more efforts on water management based on the general principle of “identifying areas for improvement of water projects and strengthening supervision and management of water industry”, and stick to balanced structural and non-structural measures, to carry out flood control improvement projects, unsafe reservoirs reinforcement projects, small and middle-sized river treatment and flash flood disaster prevention projects, and to speed up applications of modern information technology to upgrade intelligent monitoring and early-warning capabilities, so as to raise the level of flood disaster management in all respects.

Flood Resiliency in the Chesapeake Bay: A Regional System of Approaches

Oral - PS V.d Integrated flood risk management

***Mrs. Amy Guise*¹**

1. U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers, Baltimore District, serves a large geographic area, encompassing the Chesapeake Bay Basin and the Susquehanna and Potomac River watersheds. This area spans 49,000 square miles and 7,000 miles of coastline in 6 states and the District of Columbia.

From large scale dams and levee systems, to wetland restoration and shoreline protection, down to technical assistance provided to local communities, the Corps carries out one of its central mission areas to manage flood risk through regional resiliency and innovative partnerships. The Chesapeake Bay watershed is a “living classroom” for the evolution and integration of flood risk management measures to improve resiliency and adapt to changing conditions.

Specific examples across the watershed include managing a system of 15 large infrastructure projects, developing master plans for shared vision and multi-purpose decision-making, and providing technical assistance through partnerships and innovative financing (including with private entities) to support local communities. The successes and lessons learned from comprehensive planning with other agencies will be highlighted through the North Atlantic Coast Comprehensive Study, which was a post-Hurricane Sandy study to reduce coastal flood risk by utilizing a vulnerability framework, and the Chesapeake Bay Comprehensive Plan, which resulted in a single, integrated roadmap to inform and guide decision-makers at all levels of governmental and non-governmental agencies within the Chesapeake Bay Watershed.

Strong collaboration to reduce flood risk takes time and commitment, which is proving (more and more) to be a critical element when the goal is to create a sustainable and resilient network of programs, funding options, implementation approaches and stakeholders.

Key words: resilience, system, regional, collaboration, partnerships

Improving compound flood assessment along the Texas coast: Implications for water supply infrastructure

SS V.f

Mx. Michelle Hummel¹, Mx. Nahal Maymandi¹, Dr. Yu Zhang¹

1. University of Texas at Arlington

Coastal communities along the Texas coast are home to dense human populations and extensive energy, water, and transportation infrastructure. Located at the confluence of terrestrial and coastal processes, these communities are impacted by watershed flooding driven by precipitation and river discharge as well as marine flooding due to tides and storm surge. When these processes interact spatially or temporally, their combined effects often lead to more severe flooding. Sea-level rise, changing precipitation patterns, and more intense winter and tropical storms will place additional stress on coastal communities in the future. Although watershed and marine flooding have been studied extensively as separate threats, knowledge of their relative contributions to compound flooding is still limited. Thus, there is a strong need to understand how watershed and coastal processes interact to drive compound flood events in the coastal zone and how these interactions might change in the future.

This project will use an integrated hydrologic and hydrodynamic modeling approach to study coupled watershed and coastal processes and their relative contributions to compound flood hazards along the Texas coast, with the goal of producing improved flood maps that account for the interaction between coastal and riverine flood drivers. The integrated model will be validated using historical hindcasts and will then be used to assess future flood hazards and impacts, with a primary focus on the resilience of water supply infrastructure near Beaumont, Texas. The results of this project will advance current understanding of the physical processes governing flood hazards in the coastal zone and inform flood mitigation and adaptation planning to protect coastal populations and critical infrastructure.

Keywords: compound flooding, coastal hazards, critical infrastructure

Improving Water Management Outcomes Through Forecast-Informed Reservoir Operations: Agency Perspectives from the Research and Development Effort to Inform Policy

Oral - PS V.a Governance and partnerships (shared vision & responsibility)

Dr. Cary Talbot¹, Mr. Sean Smith¹, Dr. Chandra Pathak¹

1. US Army Corps of Engineers

In May 2016, the US Army Corps of Engineers (USACE) updated Engineer Regulation 1110-2- 240 which governs water control management throughout the agency. Included in the update is language that allows forecast information to be used for planning future operations which represents a significant change from the decades-long policy of operating solely based on “water on the ground.” Since 2014, a multi-agency research and development effort called Forecast-Informed Reservoir Operations (FIRO) has been exploring how advances in weather prediction and observations can inform operations and policy decisions at Federal, State and Local water management agencies with the collaborative engagement and support of researchers, engineers, and operators. The FIRO process has consisted of first selecting a pilot reservoir and then forming a multi-discipline steering committee comprised of representatives from agencies and stakeholders key to the operational decisions at each pilot reservoir. Through a process of conducting viability assessments at the pilot reservoirs, the FIRO teams have demonstrated the potential for significant and simultaneous improvements in water supply, flood risk management and ecological benefits using current forecast skill. FIRO also includes concerted efforts to improve forecast skill, particularly for atmospheric river events in the Western US, with the promise of increased benefit to water operations. Lessons learned from the formation of FIRO steering committees, development of respective research and development work plans for testing FIRO at pilot reservoirs, execution of those work plans, and the interfacing of the FIRO effort with the participating agencies’ water management roles and stakeholders will be presented. Products resulting from research to improve forecast skill and understanding of the impacts of atmospheric rivers will also be presented.

Investment in Flood Protection Infrastructure: Estimating Demand and Filling Investment Gap

Oral - PS V.b Infrastructure and investments

Dr. Mikio Ishiwatari¹

1. University of Tokyo

Investment in infrastructure for flood protection is crucial for mitigating the damage caused by floods. The Sendai Framework for Disaster Risk Reduction emphasizes investment as a priority action for decreasing disaster risks and losses. While the demand of investment in flood protection are needed to formulate investment policies and plans, they are rarely available. The methodology for estimation has not been established. This study proposes methodologies for estimating demand for flood protection infrastructure.

Asian countries, in particular developing countries, are prone to flood disasters. Over the 10-year period from 2006 to 2015, economic losses of natural disasters in the Asia and Pacific region averaged USD73 billion yearly, which accounts for 56percent of the global total. Asia countries are forced to invest large budget in flood protection. It was found that total investment in the Asian region is 15-20 times larger than ones of USA and Europe. Even in developing Asia, six countries invest more in flood protection in terms of share-of-GDP than the average of USA and Europe.

The demand in Asia until 2030 is estimated using regression analysis to apply panel data of possible socio-economic factors. Also, the study examines financial gap until 2030. The study recommends the approaches of filling the investment gap. Asian countries have been securing long-term commitment for investment in flood protection by incorporating flood protection into national development plans, formulating long-term sector plans, establishing budget lines, etc. Japanese experiences show that PPP is useful for securing investment in flood protection, but that government policies and actions are needed to establish to promote PPP.

Investment, Estimation, Flood, Public-private-partnership, Asia, Budget

Newly enforcement of the Outflow Regulation Law for flood reduction in Taiwan

Oral - PS V.c Insurance and building level protection

Prof. Song-Yue Yang¹, Prof. Shaohua Hsu¹

1. Feng Chia University

Urbanization has led to an increase in impervious ground, resulting in a decrease in infiltration and an increase in surface runoff, shortening the concentration time, and increasing the risk of flooding in rivers. In addition, global climate change has caused an increase in heavy rainfall, which will expose cities to huge flood risks. Therefore, Taiwanese government set out to promote the Water Act amendment of the chapter 7-1 "Runoff distribution and outflow control". The act was promulgated on June 20, 2018 by Presidential Decree. "Outflow Control" is to reduce the risk of flood in adjacent land or downstream rivers associated with land development. The review of the Outflow Control Plan (OCP) was adopted, requiring land developers to set up flood reduction facilities in the development zone to reduce the increased surface runoff. When the area of the developed land exceeds two hectares, the land developer must provide an OCP approved by professional engineers, and submit it to the hydraulic authority for review. The construction can only be carried out after the review is approved. The construction, usage, management, and maintenance of the detention basin and low impact development facilities should be executed in accordance with the OCP, and the hydraulic authority can perform inspection at any time. After the completion of relevant flood mitigation facilities, the developer should make a record of the maintenance regularly and send it to the hydraulic authority for reference. In the Water Act, the inspection power of hydraulic authority and penalties for related violations are set to ensure the implementation of OCP. This article introduces the policy framework, characteristics, and related supporting measures.

Practical Guide to Enhance the Successful Development of Innovations within Flood Risk Management

Oral - PS V.d Integrated flood risk management

Mrs. Ellen Tromp¹, Mr. Han Knoeff¹

1. Deltares, Dutch Flood Protection Programme

The application of constructions to strengthen flood defences was once seen as an innovation. Nowadays, we apply this, wherever required or due to societal demands necessary. The participants involved in strengthening the flood defences have many ideas to optimize our current way-of-working within the dike reinforcement. Many efforts were undertaken in the past decades to further develop technical innovations. Still, most or even all innovations have not reached the highest Technology Readiness Level. In an attempt to help the innovator and the team involved to strengthen the flood defence, we have developed a practical guide to develop an innovation in a more 'structured' manner, knowing that one can take one step forward resulting in two steps back. In our framework we identified six critical success factors to successfully develop innovations. We framed them as traffic lights; is one of them on the red signal, the development of the innovation will stop. One of the barriers to applying innovations is the lack of assessment and design rules. In the practical guide, we have developed a framework that should be developed in the lower Technology Readiness Levels (TRLs) to stimulate its use. Attention is also given in the role of the members of the 'Triple Helix', governmental bodies, research institutes, contractors and engineering companies, but also to the other relevant stakeholders, as they should also be willing to implement innovations. In this paper we will show how this practical guide has helped several product innovations, such as the JLD Dike Stabilizer, relevant for the dike failure mechanism macrostability, but also the Coarse Sand Barrier, relevant for the dike failure mechanism of piping.

Keywords: innovations, learning, flood risk management, dikes, adaptive learning cycle

Probabilistic streamflow forecasting system for effective power generation dam operation in Japan

Oral - PS V.d Integrated flood risk management

***Dr. Tomoki Ushiyama*¹, *Dr. Cho Thanda Nyunt*², *Mr. Shigeru Nakamura*², *Dr. Asif Naseer*³, *Mr. Hiroyuki Ito*¹, *Prof. Toshio Koike*¹**

1. International Centre for Water Hazard and Risk Management, Public Works Research Institute, 2. Nippon Koei Co., LTD., 3. Water and Power Development Authority

Frequent severe rainfall occurrences increase flood risk in Japan. It makes more difficult to the operation of power generation dam, since it is required to minimize the flood risk in the downstream area simultaneously with maximizing the power generation amount. We developed a streamflow forecasting system combined with a dam operation model to support power generation dams. The streamflow forecasting part consists of a numerical weather prediction with a regional ensemble prediction system with an ensemble Kalman filter, and a hydrological modeling by a distributed hydrological model considering water and energy budget of the land surface. The numerical prediction model provides precipitation forecast for 48 hours in 33 ensemble members, and the hydrological model provides 39 hours streamflow forecasts every 6 to 12 hours also in 33 members. Our forecast experiments of 5 summers (2015 to 2019) showed that our precipitation forecasts of ensemble mean overperformed the deterministic forecasts by the Japan Meteorological Agency. We provided the ensemble streamflow forecasting into dam operation model during July to October 2018. The total amount of reservoir water used for power generation would increase 15 percent when the streamflow forecasts were considered, since the dam operator could generate additional power by pre releasing of dam water before coming the flood streamflow, resulted in reducing generation loss during flood period. This system could also keep the dam water level high enough in average to satisfy the future demand. We need further examination before the operational use.

Short-Duration, High-Intensity Rainfall Flooding in Canada: Impacts and Development of Mitigation Resources

Oral - PS V.c Insurance and building level protection

Mr. Dan Sandink¹

1. Institute for Catastrophic Loss Reduction

Flooding in urban areas associated with short-duration, high intensity (SDHI) rainfall events is one of the most significant drivers of disaster loss in Canada. For example, insured losses following the July 8, 2013 SDHI flood event in the Toronto area were ~\$1 billion (2018 CAD). Insurance catastrophe data has consistently indicated that the majority of losses during major urban flood events are attributed to flooding of residential buildings. From January 2016 to December 2018, approximately \$700 million in catastrophe losses were attributed to residential flooding from sewer backup.

Mechanisms that commonly result in flooding of buildings during SDHI rainfall events include overland flow of stormwater, seepage/infiltration of ground and surface water, and surcharging of buried sewer infrastructure resulting in backups. These flood mechanisms frequently affect households located out of formally defined river and coastal flood hazard areas. Until 2015, residential flood insurance was largely available only for sewer backup.

With recent flood events driving substantial losses and impacts, and garnering significant public and media attention, there has been growing interest in managing this risk, notably through newly funded national programs focussed on climate change adaptation. These programs have included development of new guidelines and standards focussed on managing underlying factors contributing to this risk.

The Institute for Catastrophic Loss Reduction (ICLR) was established in 1997 by the Canadian property and casualty (P&C) insurance industry to support natural hazard risk reduction by the public and private sectors. The presentation will provide a background on SDHI flooding in Canada, the role of the insurance industry and ICLR in managing this significant driver of flood loss, and new and upcoming national standards and guidelines focussed on managing of SDHI flood hazards at the residential property scale and management of in-flow/infiltration in sanitary sewer systems.

Key words: Urban flood; Canada; insurance; wastewater; stormwater

Strengthen resilience to rivers floods by the drag reduction technique

Oral - PS V.d Integrated flood risk management

Dr. wamid BOUCHENAFI¹, Mr. Arnaud LEFEVRE¹

1. SNF

Urban agglomerations face the overflowing rivers risk due to intense urbanization in flood-prone areas and the climate change effects. Despite the important protective measures deployed to reduce the fluvial flooding risk, additional efforts are still needed. This work aims to propose a new complementary non-structural protection measure, used to reduce the rivers flooding risk. The study is part of the NABRAPOL (NEBARSKA POLYMER) project, which aims to improve knowledge of the drag reduction effect by adding polymers in open-channel flows. The addition of polymers, even in limited concentrations, allow a high friction to decrease with the typical Manning coefficient reduced up to 45%. An application case on a real watercourse is presented in this article. Two measurement campaigns are carried out on a river along 30 km. Experimental devices are deployed, and non-intrusive hydraulic measuring instruments are installed at the study field. Surface velocities are evaluated by the Large-Scale Particle Image Velocimetry (LSPIV) technique, and water depth are measured using ultrasonic radar sensors over the river. Measurement results show that the addition of 20 ppm of polymers in the flows results in a marked drag reduction by decreasing the water depth to 18% of its initial depth. The drag reduction technique by addition of small concentrations of polymers can be considered as a new and effective method to reinforce the measures already deployed in the flood risk management strategy since it allows the water depth to be decreased thus avoid overflowing rivers in the extreme flooding event .

The Acquisition, Relocation and Resettlement of Flood-Prone Communities: An Applied Research, Teaching and Community Engagement Agenda

SS V.f

Dr. Gavin Smith¹

1. North Carolina

The maximum number of words is 300 (excluding the abstract title and authors). No figures or tables are allowed at the time of abstract submission

This presentation will discuss a series of interdisciplinary applied research, teaching and engagement-related projects that are focused on the acquisition, relocation and resettlement of flood-prone communities. Emphasis will be placed on four projects, including: 1) the cross-cultural comparison of the acquisition of hazard-prone housing in the United States, Australia and New Zealand, 2) a national survey of states, territories and tribes that seeks to understand the role they play in building local capacity to implement the emerging Building Resilient Infrastructure and Communities Program, 3) the writing of a textbook focused on the acquisition, relocation and resettlement of hazard prone communities in the United States and abroad, and 4) the creation of a graduate-level certificate program titled Disaster Resilient Policy, Engineering and Design. All projects are interconnected and serve as part of a larger effort to build on existing strengths found at North Carolina State University, to include applying the role of a land grant university to this vexing problem.

Keywords(maximum five words that best describe the content of your paper) Applied Research, Hazard Mitigation, Adaptation, Relocation, Resettlement

The flood control risk assessment in the main channel of large-scale water transfer project: a case study of the Middle Route of the South-to-North Water Transfer Project of China

Oral - PS V.d Integrated flood risk management

***Dr. Gang Wang*¹, *Dr. minglei Ren*¹, *Ms. Xiaodi Fu*¹, *Dr. xiaoming Jiang*¹, *Dr. Liping Zhao*¹, *Dr. Tianling Qin*¹**

1. China Institute of Water Resources and Hydropower Research

There is increasing recognition of the importance of inter-basin water transfer projects in promoting regional economic and social sustainable development in water-scarce regions. In order to ensure the sustainable and smooth operation of that kinds of projects, flood control is one of the key issues that should be focused on by decision-makers and engineering managers in both the planning & design and operation management stages. Based on the systematic analysis of flood factors, this paper aims to establish a scientific evaluation method to assess the flood control risk of the main channel of the project. The flood control risks are divided into four types: rainfall-runoff, confluence and flow capacity, the characteristics of the channel itself, and eco-social layout along both sides of the channel. On this basis, the specific risk factors are identified for each type of risk element, and the flood control risk evaluation index system for water transfer project is constructed. According to the framework of analytic hierarchy process (AHP), quantitative assessment of comprehensive flood control risk of the project can be carried out. Taking the Middle Route of South-to-North Water Transfer Project of China as an example, the integrated flood control risks of 39 units were evaluated, and 6 units with higher risk level were identified. The assessment results can be used for flood management of the project. The evaluation method is also expected to provide reference for the strategic planning and flood management practice of other similar water transfer projects in the world .

flood control risk identification; evaluation indicator system; risk assessment; flood management; water transfer project

The History and Progress of Flood Insurance in China

Oral - PS V.d Integrated flood risk management

Prof. KUN YANG¹

1. China Institute of Water Resources and Hydropower Research

China is one of the countries with the most frequent and serious flood disasters in the world. It is difficult to make up for the loss of flood disasters only by national financial disaster relief funds. As early as the 1980s, the Ministry of Water Resources, the Ministry of Finance, the Ministry of Civil Affairs and the People's Insurance Company of China jointly launched the "Huaihe River Flood Crop Insurance" in flood detention basin. Since then, laws such as the Flood Control Law and the Emergency Response Law have clearly encouraged the development of flood and catastrophe insurance. In the field of property insurance, more and more enterprises and individuals purchase insurance by themselves and will be compensated after suffering flood damage. In 2013, the Central Committee of the CPC clearly put forward the idea of "establishing catastrophe insurance system". Flood insurance has been carried out in Zhejiang, Fujian, Guangdong and Heilongjiang etc. provinces at different levels and ranges. In addition to flood and typhoon catastrophe insurance, innovative insurances products such as flood loss insurance for flood control projects (such as dykes) and submergence loss insurance for reservoir areas have also been developed. In 2016, the Ministry of Water Resources asked to research about insurance model. In 2017, the China Institute of Water Resources and Hydropower Research has established a long-term strategic partnership with China Reinsurance (Group) Co., Ltd. to jointly establish a "Flood Risk and Insurance Laboratory" to actively carry out related research, such as flood risk map, flood insurance, and flood risk management. With the continuous improvement of China's economic aggregate, flood control engineering system standards and related technologies, the insurance awareness of the government, enterprises and individuals, the flood insurance industry is facing rapid development opportunities.

Flood insurance, flood risk management, flood risk map, flood disaster, China

Flood resilience - Flood resilience in practice

Assessing the potential for Nature Based Solutions to contribute to flood risk reduction: evidence from recent studies

Oral - PS VI.b Nature-based solutions for flood management

***Dr. Ralph M J Schielen*¹, *Dr. Egon Baldal*², *Mrs. Debi Garft*³, *Prof. Chris Spray*⁴**

1. Ministry of Infrastructure and Water Management/Delft University of Technology, 2. Ministry of Infrastructure and Water Management, 3. Scottish Government, 4. University of Dundee

In this contribution, we present the outputs from the EU *North Sea Region Interreg Building with Nature* research program. The aim of the program is to generate science-based evidence to support the adoption of Nature Based Solutions (NBS) as an effective option for reduction of flood risk, alongside grey, grey-green and more traditional structural solutions. Four case studies in four countries (distinctive in scale and geographical conditions) are considered. Data from the case studies was used to assess their effectiveness for flood risk reduction and to characterize the added values of NBS with respect to increasing biodiversity and to decreasing operational and maintenance costs. In addition, a focus was included on stakeholder participation to make sure that the solutions are supported by the various key stakeholders. The case studies were also used to inform the development of a first concept of an assessment framework for NBS. Possible indicators for this framework include outputs and outcome, alongside efficiency and effectiveness. Using data from the case studies, the challenge is then to develop an objective method to score these indicators. One of the recommendations is that NBS should always be accompanied by a long term monitoring program, not only to assess the effects of NBS measures, but also to provide the evidence for adaptive management solutions in response to potential deviations from the assumptions that were made at the beginning of the project. A further recommendation is to explore innovative monitoring techniques such as Green Lidar to identify and track any changes in NBS performance. The next steps are to improve the assessment framework and couple this to the UN Sustainable Development Goals so as to broaden the context and to apply the framework to a continuum of NBS, varying from fluvial via estuarine to coastal measures.

Collaborative Approaches to Flood Risk Management in the United States

SS. VI.d

***Dr. Stephanie Bray*¹, *Ms. Jennifer Dunn*², *Ms. Elizabeth Bourget*², *Ms. Ellen Berggren*²**

1. USACE, 2. US Army Corps of Engineers

In the United States, no single Federal government agency is responsible for flood risk management. The United States Army Corps of Engineers (USACE) established the National Flood Risk Management Program (NFRMP) in May 2006 to integrate and synchronize USACE flood risk management programs and activities internally and with counterpart activities of other Federal agencies, state organizations, and regional and local agencies. At the State level, the NFRMP is implemented through the Silver Jackets Program. The philosophical approach to these programs is that no one agency has the ability to manage flood risk on their own; instead, multiple agencies at multiple levels of government, as well as multiple non-governmental partners, must coordinate and collaborate to develop and deliver effective flood risk management solutions for the nation. Shared responsibility and partnership efforts are key components of the NFRMP. Additionally, the NFRMP focuses on management of the full life-cycle of flood risk. This presentation will provide an update on the NFRMP, share lessons learned over the past decade in how to accomplish collaborative flood risk management, and highlight successes and challenges from the field. The presentation will also discuss broader interagency collaborative activities for flood risk management in which USACE participates, including the Federal Interagency Floodplain Management Task Force, the Mitigation Framework Leadership Group, and the National Silver Jackets Team.

Key Words: flood risk management, collaboration, coordination, Silver Jackets, interagency

Development and Application of a Disaster Resilience Quantification Framework for Climate Change Influenced Disasters – Metro Vancouver Case Study

Oral - PS VI.a Flood resilient communities

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1. Civil and Environmental Engineering - Western University, 2. Associated Engineering and Western University

Resilience is the ability of a complex system to respond and recover from disasters. It includes conditions that allow the system to absorb impacts and cope with an event which includes post-event adaptation processes that facilitate the ability of the system to re-organize, change, and learn in response to a threat. Presently, the most common approaches to urban disaster management are focused on disaster risk reduction, but there is growing momentum behind the concept and quantification of disaster resilience. The basis for developing a Disaster Resilience Simulation Tool (DRST) relies on the definition of a city as a sustainable network of physical (constructed and natural) systems and human communities (social and institutional) that possess the capacity to survive, cope, recover, learn, and transform from disturbances by: (i) increasing the system's adaptive capacity through innovative design and management; (ii) reducing failure probabilities; and (iii) reducing recovery time. To address some of the shortcomings in existing resilience models, a mathematical framework was developed to combine physical, economic, engineering, health, and social impacts and capacities for a more holistic, integrated form of disaster resilience. The framework and implementation methodology is based on three key tasks: setting the resilience landscape; characterizing dynamic resilience; and disaster resilience assessment (implementation).

A Disaster Resilience Simulation Tool was developed which combines system dynamics simulation and spatial analysis to implement the methodology and better understand the behaviour of complex city systems subject to climate change influenced disasters. The tool is applied to a case study in Metro Vancouver, British Columbia, Canada. Adaptation scenarios were developed to test the resilience model, observe the effects on model behavior, and identify areas where adaptation policy may be most effectively implemented.

Key Words: disaster management, flooding, resilience quantification

Evaluation of Community Resilience for Evidence-based Flood Contingency Planning

Oral - PS VI.a Flood resilient communities

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Preparing a flood contingency plan before disasters is essential to enhance the capacity of both governmental officers and local residents to achieve prompt response to disasters. Evidence-based flood contingency planning is a combination of disaster response planning and scientific approaches such as flood simulation and the quantitative assessment of risk and local resilience, aiming to provide more realistic disaster response scenarios. This paper proposes an effective method to develop a community-level flood contingency plan by quantitatively assessing community resilience to flood disasters. It also reports a case study of Calumpit Municipality in the Pampanga River basin in Luzon Islands in the Philippines, one of the most data-limited, flood-prone areas in Asia.

The proposed method consists of six steps: understanding current situations, identifying risk, analyzing resilience, developing response strategies, developing a contingency plan, and sharing the developed contingency plan. At the step of identifying risk, flood simulation using the Rainfall-Runoff-Inundation model is conducted to identify potential inundation areas with different flood-return periods and flood propagation scenarios. Population and property at risk of the exposure to the assumed flood are identified quantitatively. For analyzing resilience, this paper introduces the "Flood Diagnosis Chart," which can quantify the flood resilience of a community using several criteria such as robustness, quick recovery, and preparedness for prompt emergency response. By counting the score for each criterion, communities with high or low flood resilience can be identified. The scores are also used to conduct cluster analysis, through which communities with similar characteristics can be classified into several groups.

The method was applied to 29 communities (Barangays) in Calumpit Municipality in the Pampanga River basin in the Philippines. The case study revealed that the proposed method is effective to support communities at risk in developing a pre-disaster flood contingency plan.

Hurricane Matthew Disaster Recovery and Resilience Initiative: An Innovative Approach to Apply University-Based Research, Teaching and Engagement Techniques to Post-Disaster Floodplain Management Challenges

SS VI.c

Dr. Gavin Smith¹

1. North Carolina

The translation of what university scholars know about floodplain management as it relates to hazard mitigation and disaster recovery remains difficult to achieve. Key challenges include the inability of academic teams to address local needs rather than their own personal research agenda, the lack of university administrative support to engage in such efforts over long time periods and difficulties associated with embedding students in these types of endeavors. This presentation describes a case in which all three issues were addressed through the Hurricane Matthew Disaster Recovery and Resilience Initiative. This program, developed at the request of the Governor of North Carolina and the Director of the North Carolina Division of Emergency Management, lasted approximately two years. The team was tasked with assisting six hard-hit low capacity communities address issues that were not being met by federal, state or non-profit organizations. A team comprised of 9 faculty from the University of North Carolina at Chapel Hill and North Carolina State University, more than 15 graduate students and 2 practitioners assisted the communities address unmet needs. These included: 1) developing open space strategies to help define what to do with land purchased following the acquisition of flood-prone properties, 2) creating replacement housing prototypes, 3) identifying land suitable for housing development outside the floodplain but within town boundaries, 3) conducting flood retrofit studies of historic downtowns located in the floodplain, 4) developing disaster recovery plans and 5) conducting a 5-day design workshop to inform the relocation of parts of Princeville, the oldest African Community in America to a 52-acre site purchased by the State of North Carolina.

Keywords: Universities, Community Engagement, Resilient Design, Hazard Mitigation, Disaster Recovery

Improved Prediction of Atmospheric Rivers That Drive Flood Damages in the Western United States

SS VI.c

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Atmospheric rivers (ARs) are extratropical storms that produce extreme precipitation on the west coasts of the world's major landmasses. ARs have been shown to be an important source of variations in precipitation and streamflow in the western U.S. and globally. There is a growing awareness that ARs are responsible for a wide range of environmental, social, and economic impacts, affecting the frequency and severity of extreme floods, and influencing drought duration and intensity. ARs have been identified as the primary source of hydrologic flooding in the western U.S., yet their costs remain largely unquantified.

A systematic analysis of 40 years of data from the U.S. National Flood Insurance Program (NFIP) establishes that ARs are the primary drivers of flood damages in the western United States. The NFIP claims and payments are combined with a catalog of ARs classified according to a recently developed AR scale, which varies from category 1 to 5. The data reveal that flood damages increase exponentially with AR intensity and duration: each increase in AR category corresponds to a roughly tenfold increase in damages. AR1 and AR2 storms are mostly beneficial, replenishing the water supply while causing median flood damages of less than a million dollars; AR4 and AR5 storms cause median damages in the tens and hundreds of millions of dollars, respectively.

In addition to the AR intensity scale, a research effort to improve forecast skill of AR landfall and duration has produced an informative set of AR forecast tools that are used by agency decision makers at local, regional and national scales within the U.S. and globally. Discussion of these tools along with examples of their use by water resources and emergency management officials will be presented.

Key words: Atmospheric rivers, flood damages, economic analysis

Improving Resiliency: Evolution and Examples

Oral - PS VI.a Flood resilient communities

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1. USACE

Reducing flood risk and improving resiliency is a complex venture, requiring sound science, technical expertise, social engagement, effective partnerships, political sensitivity, and broadly-based conceptualization. Many aspects are involved in anticipating, preparing for, adapting to changing conditions, and ensuring that appropriate systems are able to withstand, respond to, and recover rapidly and wisely from disruptions. When confronted with unprecedented storm events and existing systems that evolved over time, imposing after-the-fact systems thinking introduces additional challenges.

The U.S. Army Corps of Engineers has been deliberately mainstreaming resilience thinking, inventorying resilience activities, and developing an enterprise strategy for how it addresses resilience. It considers project resilience within broader system and community resilience.

The Greater New Orleans Hurricane and Storm Damage Risk Reduction System in southeast Louisiana, now nearing completion, stems from vulnerabilities exposed by Hurricane Katrina in 2005. It was rebuilt as a system, incorporating resilience into the new approach. The approach required strengthening levees, floodwalls, gated structures, and pump stations to form a 133-mile perimeter system, while also improve 70 miles of interior risk reduction structures. Partnerships both informed technically advanced engineering solutions and facilitated the shared responsibility required. Implementation of this system offers insight into what can be achieved through an up-front re-engineering of a comprehensive system that incorporates resiliency.

After Hurricane Sandy in 2012, the North Atlantic Coast Comprehensive Study further built on resilience concepts, addressing significant coastal vulnerability and sustainability on a broader regional basis. The report helps local communities better understand their flood risk and offers a variety of coastal storm damage risk management strategies that communities can use to adapt to increased future flood risks. The experience gained is informing the ongoing South Atlantic Coastal Study, initiated in 2018 following Hurricanes Harvey, Irma, and Maria.

Influencing public and professional flood warning decision making: speaking the same language

Oral - PS VI.a Flood resilient communities

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Achieving the full benefits of flood warnings depends upon effective warning response. This research project focused upon the value of providing flood impact information within flood warnings and improving the capacity of the UK Environment Agency and Natural Resources Wales to provide such information. Flood warnings refers to the formal alerting system uniform across the whole of the UK. The Environment Agency funded project highlights the continuing tension between professional knowledge and language and recipient organisational and public requirements based on flood responsibilities and experience.

A review of existing literature and research revealed that, although internationally flood warning delivery has received much attention, little is known about impactful information inclusion. Employing a sequential qualitative methodology during 2017/18, new warning message content was developed. Stakeholders included members of the public at-risk of flooding (3 exploratory focus groups and 3 refinement workshops) and key UK professional emergency responder organisational staff (17 telephone interviews). Impactful content is valued by the at-risk public as a way of enhancing their decision making and response. Impactful content is most meaningful when developed and delivered at a local scale as different publics were revealed with differing content requirements. Locally specific information is key (local references and language). Other findings concern message structure, content, tone and uncertainty.

This paper provides insights in warning content bridging the gap between available scientific information and the information required by citizens to make decisions.

Flood warnings, warning content, public, professional, behaviour change

Integrated Benefit Evaluations of Green Infrastructure: A Case of Jinan

Oral - PS VI.a Flood resilient communities

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1. China Institute of Water Resources and Hydropower Research

Under the dual influences of climate change and human activities, urban waterlogging is increasingly serious these years in China. Green infrastructure (GI), a resilient approach, is being widely adopted worldwide because it can adapt to the changing climate. In addition to reducing polluted rainfall runoff, GI can positively impact the air quality, energy consumptions and other aspects, which is a great advantage compared to single-purpose grey infrastructure. However, the public still have doubts over the benefits of GI due to the frequent occurrences of pluvial floods in China. In this paper, we establish a set of integrated benefit evaluation indexes of GI within the urban context. The nineteen benefits can be divided into four major categories, i.e., disaster reduction benefits, environmental benefits, economic benefits and social benefits. We apply this benefit system to Daminghu District of Jinan, which is a Sponge City Construction pilot area. In view of the existing data, we select reduced inundation area, reduced influenced population, reduced affected GDP, reduced direct economic loss and improved living environment as the evaluation indexes. The first four indexes are quantitatively calculated by the flood simulation numerical model and flood risk analysis software (FRAS) and flood damage assessment software (FDAS) while the last one is qualitatively described. The results show that the inundation area is reduced by 11.02%, and the affected GDP and direct economic loss decreased by 9.6% and 15%, respectively, under the 5-year return period rainfall. With the increase of rainfall volumes, the corresponding effects decrease. Despite of the weak effects of disaster reduction, GI improves the living environment. In Yingxiongshan Road of the pilot area, the former impervious surface are replaced by rain gardens and bioretentions, which significantly improve the environment, and increase recreational opportunities.

Local Flood Resilience Contributions of Newly Emerging Civil Society Initiatives in England and the Netherlands

Oral - PS VI.a Flood resilient communities

Dr. Steven Forrest¹

1. University of Hull

The shift to flood resilience has seen a change in actor arrangements from primarily state-led flood risk management (FRM) towards 'governance' approaches in which non-state actors are playing a greater role, especially civil society initiatives. This paper focuses on the changing role and contributions of civil society initiatives (e.g. citizen initiatives and bottom-up flood groups) in local flood resilience. The paper explores the new authority-civil society relationships and interactions that are emerging as well as concerns over the socio-spatial distribution of capacities, vulnerabilities and inequalities.

England and the Netherlands are compared due to their rich flood histories, continued adoption of flood resilience approaches, and experience of greater citizen action in FRM. Comparing these two countries enables a greater exploration of the flood resilience contributions of civil society that can be more widely applicable. The paper specifically focuses on two areas that have been affected by recent flooding and are experiencing greater citizen influences in FRM: The Upper Calder Valley (England) and Arnhem (The Netherlands). Data in countries was collected through i) semi-structured interviews with civil society initiatives and authorities, ii) media and policy document analysis, and iii) official records.

This paper identifies the prominent role of civil society in the English FRM landscape as well as their less-developed role in the Netherlands. This paper critically discusses the changing role and responsibilities of the state and citizens including the challenges that arise from a more active citizenry in FRM. These insights support flood governance by illustrating the potential contributions of newly emerging civil society initiatives to local flood resilience, whilst also exploring challenges regarding issues of distribution and power. The paper has wider significance in its identification of the need for capacity building (including traditionally non-FRM capacities) to challenge and address inequalities as well as on 'shared responsibilities' in flood resilience.

Mitigating flood risk and increasing resilience by zone-expropriation project— A case study of Chunglu, Taoyuan County, Taiwan

Oral - PS VI.a Flood resilient communities

Prof. Hung-Pin Huang¹

1. National Taiwan University

For many industrial parks, factories and job opportunities, some settlements have rapidly developed into urban style in Taoyuan. With unplanned drainage system and increasing impervious area, the occurrence of flood has increased from 2012 to 2014, causing huge disasters than before. For example, cases of June 11 heavy rain in 2012, May 11 flood in 2013 and May 21 flood in 2014 all result in greater disasters than before. And, two meters inundation depth in Chunglu area was recorded.

In order to mitigate flood risk and increase resilience in Taoyuan, some measures of flood mitigation are necessary to be setup as soon as possible. Because facilities of flood mitigation need huge budget to buy large and complete block of private land, the zone-expropriation project would be the better way to achieve the win-win situation.

Chunglu zone-expropriation project was planned and designed for 487,600 people in 2021. Besides of well-designed and ecologic drainage system, three parks inside are also used as a detention pond and emergency refugee area during flood season. In this project, park is transferred to multifunctional park that is a recreational area during usual time and a detention pond in heavy rain event. In accordance with the experience of June11 flood and handbook of central government, the zone-expropriation project at Chunglu, Taoyuan, providing the capacity of flood mitigation between recurrence periods of 50 and 100 years, is a success demonstration of both urban planning and flood mitigation. In this project, the area of public facilities and permeable area are enhanced up to 41.88% and 60.47% of 121.07 hectares with a total detention volume of 79,300 m³ and the permeable water retention capacity of 104,926 m³ in one hour. This project was finished in 2014 and won the Gold Award of Public Works Commission.

Parametric prototype of a retention reservoir for resilient flood risk management in Sao Paulo City, Brazil

Oral - PS VI.b Nature-based solutions for flood management

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When green infrastructure (GI) is more suitable than grey traditional approaches? Which assessment can attest that green is the fairest solution? And in this case, how much green is needed, where, how and to whom? Admitting that possible answers may not be generalized and do not imply in an ambitious panacea, this work examines the big picture of the dialectic between green and grey through constrained specificity, considering a case study of a parametric prototype of a retention reservoir proposed for Sao Paulo City, in Brazil, as an adaptive flood risk management facility. This paper frames the concepts of adaptation and response as active, rather than reactive, attributes of an intelligent landscape with open and flexible ecosystem organisms and addresses the methodology of information modelling applied to landscape (Landscape information modelling - LIM) as a promising tool under exploration to provide and enhance nature-based solutions (NBS) in cities. The practical case study narrows and explores flood risk management techniques among available possibilities grappled to GI and NBS. Employing a Computer Aided Design (CAD) program, Rhinoceros, and a plugin for parametric modeling, Grasshopper, this work accomplished an algorithm matrix through intuitive visual syntax. This matrix can be applied to various scenarios and terrains and reconstructs a virtual 3D model based on the ontology and formal decomposition of an anastomosed river, with its meanders, banks and wetlands. The resulting model fulfilled the required capacity for retention. It was also submitted to a hydrological flow evaluation in Delft3D program and few areas of bed shear stress were detected only in minimum flow. Findings attested that the algorithm matrix is capable to model a new topography for a retention reservoir and accomplish requirements of variable volume and flow, which represent a more resilient approach to flood risk management with co-benefits of NBS to landscape.

Relocation programs: making resilient communities through involvement of diversified groups in Japan and the US

Oral - PS VI.a Flood resilient communities

***Dr. Mikio Ishiwatari*¹, *Prof. Nicholas Pinter*², *Prof. David Casagrande*³, *Mr. James Rees*²**

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Relocation from at-risk areas to safer places is effective in mitigating flood damages and attracting attention as an adaptation solution to climate change. However, managing relocation projects and consulting with local communities is challenging. This study aims at proposing the approaches of relocation programs by learning lessons from practices in the US and Japan. Researchers from two countries conducted a comparative study of policies, government programs, decision-making, and community participation.

About a dozen US towns have responded to flooding by moving themselves, entirely or almost entirely, off the floodplain over the past 150 years. In Japan, government organizations and communities are promoting relocation to higher ground from tsunami risk areas as a primary recovery program following the Great East Japan Earthquake and Tsunami in 2011.

It was found that the two countries face similar issues. Local governments are primarily responsible for implementing relocation programs, but often face difficulties in addressing diverse needs and perspectives into the programs. These governments often have limited capacity and experience dealing with large-scale programs, in particular in the recovery phase under severe time and personnel constraints. Rural populations in both countries have been declining and aging during recent decades. Responding to large elderly populations is a challenge, since elderly populations need special support. Case studies in Tohoku in Japan show that the local young generation and women's groups led in formulating the relocation and recovery programs. The women's groups facilitated consultations between local governments and communities and contributed to consensus building. Both countries face difficulties in coordinating multiple schemes of programs and a wide range of stakeholders and organizations concerned.

Relocation, flood, tsunami, Great East Japan Earthquake, community participation

The Coralville Flood Resilience Action Plan: A Community-Organizing Strategy for Resilience Planning

Oral - PS VI.a Flood resilient communities

Mx. Vanessa Fixmer-Oraiz¹, Mrs. Judy Joyce², Mr. John Boller³

1. Astig Planning LLC, 2. Impact 7G, 3. Coralville Food Pantry

Flooding in Iowa is becoming the “new normal”, where annual floods have brought into question the use of the “100 or 500-Year Flood” metrics often used to communicate the chance of a flood event. The water wheels are turning and well-intentioned watershed plans are being created across the state. Currently, a HUD-funded approach specifically identifies low-income areas as those that will receive funding to put best management practices in the ground. Is this top-down approach effective?

This paper outlines a community-scale Flood Resilience Action Plan (FRAP) for the town of Coralville, Iowa. These types of plans are being created as a part of the Iowa Watershed Approach grant the state of Iowa received from the U.S. Department of Housing and Urban Development. Each FRAP is uniquely tailored to a project-approved region based on several flood-related criteria. Thus far, two other communities in Iowa have created FRAPs: Vinton and Freeport.

The Coralville FRAP utilizes community-organizing strategies that move at the speed of trust, such as conducting house visits to talk with people, and empowering local actors to speak with their elected officials, this Flood Resilience Action Plan centers flood-vulnerable community member’s experiences and needs. Currently underway, this planning effort works with local decision-makers and under-represented communities to define what resilience means to them and how they can create their own vulnerability analyses. This paper narrates the the social-justice framework for the planning process, the successes, and mistakes encountered while creating a plan tailored to engaging flood-vulnerable people such that their specific flood resilience, and therefore community flood resilience, will increase over time. This community-organizing strategy for resilience planning is a tool that can be applied to flood-vulnerable regions throughout the Midwest.

The impact of semi-natural woodland on soil hydraulic properties and streamflow.

Oral - PS VI.b Nature-based solutions for flood management

Ms. Felicity Monger¹, Prof. Dominick Spracklen¹, Prof. Michael Kirkby¹

1. University of Leeds

The increased frequency of flood events in the UK has caused growing concern for the impact of more intensive farming approaches in the uplands. In recent years, the potential for using natural solutions as a method of flood mitigation, in particular tree planting, has become increasingly deliberated.

It is generally accepted that forests can influence rainfall-generated flooding through the mechanisms of interception, infiltration into the soils, and increasing available storage. However, historical research has focused on the impact of commercial forest plantations rather than naturally occurring woodlands. There is still low confidence in the impacts of land and soil management as a method of flood mitigation, predominately due to the limited empirical data. More data is needed to better inform decision makers on flood management and improve flood prediction models.

This study establishes a correlation catchment study in Haweswater, Cumbria, UK. Small catchments, less than 0.2km² in size, containing a small tributary were selected as examples of differing land use. Of the nine catchments, 3 are located in an area of semi-natural woodland, 3 are made up of common grazing land and the final 3 consist of lower grazing levels introduced by the land managers, the RSBP. At each catchment, a v-notch weir was installed to calculate flow. In addition, a number of soil characteristics were investigated; the soil moisture, saturated hydraulic conductivity, bulk density, porosity and organic matter.

Results have identified that there are significant differences between the different land uses, in both soil properties and the flow response to storm events.

The data collected in the field study is used to inform the parameters used in the Spatially Distributed Topmodel for flood prediction and in addition contribute to the evidence base for natural flood management.

The Study on Upgrading and Planning of a Flood-Resilient City— China's Experience

Oral - PS VI.a Flood resilient communities

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Located in the low-lying area at the confluence of the three rivers, Jintang County in China's Sichuan Province has been attacked by frequent floods in the past few years, which has caused lots of troubles to the production and life of local residents, and has also resulted in great social and economic losses. Based on the full survey of the historical flood damage, current building and lifeline engineering conditions, and existing risk management measures in Jintang County, this paper has given the upgrading extent according to the flood inundation map with the return period of 100 years, and also proposed the upgrading contents (e.g. the improvement of commercial/residential buildings and underground garages, flood storage construction, lifeline engineering protection and recovery) and upgrading schemes. In addition, a method that takes comprehensive consideration of multi-hazard defense including flood disaster has also been suggested in land-use planning during the future urban development. This study will improve Jintang County's ability to quickly recover from large flood events, and help local residents to establish an advanced concept and lifestyle to live and develop together with floods.

U.S. Geological Survey (USGS) Streamflow- and Precipitation-based Flood Warning and Mapping integrated with USGS “Water Alert” and “Water Watch” Tools for Selected Communities in Missouri.

Oral - PS VI.a Flood resilient communities

Mr. Paul Rydlund Jr. PLS, CFM'

1. USGS - CMWSC

The National Oceanic and Atmospheric Administration’s (NOAA) National Weather Service (NWS) provides stream forecasts and model precipitation to estimate potential flooding conditions at streamgaging stations. These forecasts take the form of plots of stages with time, including the time and magnitude of expected peaks. The forecasts, however, are restricted to the immediate vicinity of the streamgage stations for which the forecasts were generated and flood water elevations are not predicted for areas upstream or downstream of the gage. In addition, there are many small basins that respond rapidly and do not meet NWS time-to-peak requirements for the issuance of specific forecasts. Whether streamflow-based or precipitation-based, there is not a suitable method to translate the NWS- generated forecast into a visual product that residents can use to determine potentially hazardous conditions, including extent and depth of inundation along the stream reach.

This discussion will highlight how the U.S. Geological Survey (USGS) addresses the lack of precipitation, water level, and streamflow information in addition to the lack of any flood warning for municipalities throughout Missouri. More specific discussion will highlight the benefit of a USGS streamgage that serves as an NWS forecast point with corresponding information on the areas of inundation at various water levels that can be used in providing flood warning, flood prevention, rescue efforts, and flood cleanup. For small basins with rapid response, USGS precipitation gages are integrated and used to disseminate precipitation-based mapping. Also, the use of USGS “Water Alert” and “Water Watch” online warning tools, will be further highlighted.

Flood-Warning, Flood-Mapping, Resiliency, Streamgage, Flood-Insurance

POSTERS

A Web-Based Framework for the Investigation of Ethical Preferences for Flood Control

Poster - PS 1.d Citizen science for flood management

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In the not-too-distant future, sensor networks and control systems for hydrologic applications will become nearly ubiquitous in environs both urban and rural. These monitoring and control systems, used in conjunction with artificial intelligence algorithms which provide spontaneous recommendations or automatic responses for operations, could mark a fundamental shift in how we manage and operate our water infrastructure. The shift will allow for higher resolution decision making both in time and space. The expectation of this new management mode is that water resource challenges, such as flooding, could be mitigated to a degree unachievable with current infrastructure and operation. But, importantly, these new technologies would not categorically remove all possibility of damage associated with flooding. Likewise, it follows that greater discretization of control will allow the damage from flooding to be directed with greater precision. How these damages ought to be distributed – across populations and landscapes – is a question squarely within the moral domain and should be considered as these technologies are integrated into our decision-making process for water resources management. We propose an open and integrated web-based framework for the purpose of testing people's preferences to outcomes where damages are distributed unevenly. The results are intended for application within a praxis of incorporating human ethics and morality into machine assisted tasks in the environmental and water resource decision domains. We demonstrate this application by describing the workflow and results from preferences to flooding choices by a cohort of undergraduate engineering students.

Key words: Ethics, Artificial Intelligence, Decision Support, Flooding

Analysis of flash flood disaster characteristics in China from 2011 to 2019

Poster - PS IV.c Impacts of life loss and damage estimation

Dr. Tu Yong¹

1. China

Flash floods are one of the most serious flood and drought disasters, with huge loss of life and economic damage during these years. Several flash floods have occurred in Sichuan, Chongqing, Hunan, Yunnan and many other places in mountainous areas in Southwest China . An extensive compilation of the available data has been conducted across various hydro-climatological regions to analyze the spatio-temporal characteristics of flash floods in China. This inventory includes over 1209 documented events from 2010 to 2019 and is the first step toward establishing an atlas of extreme flash flood occurrences in China. This paper first presents the data compilation strategy, and introduces some typical flash flood events with great loss. The subsequent analysis indicates that the number of deaths caused by flash flood in China dropped from about annual 1079 in 2010~2010 to about annual 350 in 2011~2019 , a decrease of 68% in recent years. In 2018, the number of deaths caused by flash flood dropped to lowest 129, small and medium-sized flooding events occurred frequently affecting elderly and youth populations. Finally, this study also recommends measures could be implemented to mitigate high impacts of deadly flash floods.

Assessment of sea level rise along two Portuguese estuaries due to climate change

Poster - PS III.a Climate change and flooding

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Estuarine regions support different ecosystems and intense anthropic activities with economic importance that must be compatible with environmental values. These complex systems are among the most sensitive areas to environmental stressors like climate change. Sea level rise (SLR) and the increase in the frequency of extreme events can change future estuarine dynamics. Floods with high return periods are beginning to happen more often. Moreover, SLR could impact the tides propagation along the estuaries, also increasing the salt intrusion with harmful effects on the ecosystem's balance. In this work, numerical models of the Douro and the Minho estuaries (northern Portugal) were implemented, aiming to understand the climate change impacts in these estuaries. The models were set up using the Delft3D software and were calibrated with the data assimilator OpenDA, which automatically estimates the model parameters values to achieve a minimum error between observed and simulated hydrodynamic variables, being an invaluable help in the numerical modelling calibration and validation processes. The modelling scenarios considered 1000 years return period extreme flood level and extreme sea levels according to the RCP 4.5 and 8.5 scenarios. The results showed that the Minho estuary can be highly impacted by the SLR, while the Douro estuary remains almost unaffected. The difference between the scenarios with the highest and the lowest extreme water levels, near the mouth of the rivers, was 67 cm in the Minho estuary and 13 cm in the Douro estuary. This difference occurs because the Minho estuary is shallower and presents a wider mouth than the Douro estuary mouth, which is constricted by two breakwaters. Furthermore, the Douro's flood discharges are higher than the ones observed for the Minho estuary. It is concluded that numerical models are essential to study the estuarine complex dynamics, being essential tools to forecast the impacts of climate change.

Assimilation of High Spatial and Temporal Resolution Remotely-sensed Soil Moisture Data into Land Surface Models for Accurate Flood Forecasting: Using CYGNSS and SMAP/Sentinel-1A/B Soil Moisture Products

Poster - Erich Plate Best Young Scientist

Mx. Hyunglok Kim¹

1. University of Virginia

Prediction of regional-scale, water-related natural disasters such as droughts and floods can benefit from the highspatial-resolution soil moisture (SM) data of both satellite and modeled products. Specifically, flood events can be effectively predicted by accurately estimated antecedent SM data because the amount of antecedent SM controls the partitioning of outgoing energy flux into latent and sensible heat fluxes. However, despite the importance of predicting the antecedent SM information on a regional scale, our understanding of how to predict this information is limited. In particular, the coverage of current satellite-based soil moisture observation systems is not spatially or temporally continuous, leading to data gaps in the current data assimilation systems. This limitation hampers researchers' understanding of fundamental processes controlling the surface hydrologic cycle across both time and space domains.

In 2017, NASA launched eight microsattellites, called the Cyclone Global Navigation Satellite System (CYGNSS), to predict cyclone paths. Our previous research found that while CYGNSS satellites are predicting cyclone paths, they can simultaneously measure SM around 5 times per day. Since then, NASA's SMAP mission has been implemented in order to provide 3-km and 1-km SM data from a combination of SMAP and Sentinel-1A/B observations. In the present study, we assimilated CYGNSS-based SSM and SMAP/Sentinel-1A/B SM (3-km and 1-km) products into a land surface model (LSM) to improve the accuracy of SM estimations and achieve higher spatial and temporal resolutions. These products were then evaluated against ground observations over the U.S.A. The error characteristics of three DA products were intercompared: (1) CYGNSS DA and (2) SMAP/Sentinel-1A/B 3-km and 1-km DA. When the CYGNSS and SMAP/Sentinel SM data sets were assimilated into LSMs, the R- and ubRMSE values were greatly improved. Augmenting the SMAP/Sentinel-1A/B data with CYGNSS would give us a detailed prediction of antecedent SM, protecting livelihoods and lives from flood events.

Automated incorporation of accurate geospatial descriptors in large-scale flood modeling

Poster - Erich Plate Best Young Scientist

***Mr. Sayan Dey*¹, *Dr. Siddharth Saksena*², *Dr. Venkatesh Merwade*¹, *Ms. Sriya Arra*³**

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Topography is the most critical input in hydrologic and hydrodynamic (H&H) flood models. Since traditional topographic datasets lack complete representation of river bathymetry, they need to be supplemented with synthetic bathymetric datasets. Additionally, H&H models also require accurate geospatial descriptors such as river centerline, banks, bathymetry and hydraulic structures. Currently, they are manually digitized and/or updated as newer and better topographic datasets are obtained which is impractical for large-scale H&H applications spanning thousands of kilometers with constantly evolving topographic datasets. Nationally available descriptors, for example, the National Hydrography Dataset (NHD), may have poor spatial correspondence with fine resolution topographic data. This study presents an automated framework called System for Producing RIVER Network Geometry (SPRING) for creating and updating geospatial descriptors required for large watershed-scale H&H modeling. The ability of this framework to process entire river networks with minimal user interaction makes this ideal for large-scale applications. The extent of improvement in flood prediction using this framework is tested across several watersheds in the United States by comparing it to manually digitized datasets. Results show that the proposed framework provides comparable accuracy to manually digitized datasets while significantly reducing processing time and user input.

Keywords: Large scale flood modelling; bathymetry; river centreline; river banks; System for Producing RIVER Network Geometry (SPRING).

Communicating the Value of Freeboard through a Decision-making Tool for New Home Construction in Louisiana

Poster - PS II.b Risk communication

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Risk communication is an important tool in the decision-making process regarding hazards, including flood, which is one of the most impactful hazards in the U.S.A. Homeowners, builders, developers, municipal authorities, and others need the best available data, including on the Internet, to inform their decisions to enhance flood resilience, especially at the planning stage. Existing flood web portals mainly focus on flood forecasting or general information such as flood insurance and risk, historical flooding, and flood zoning, at global to regional scales. Few web portals show micro-scale (i.e., parcel or individual building-level) economic loss or exposure to enhance decision-making. While these portals may assess risk for existing buildings, none are tailored for new residential developments. In this project, we implement an interactive decision-making website (Flood Safe Home) that calculates the optimal freeboard based on user interests, for three parishes (i.e., counties) in Louisiana, U.S.A. Information such as location (parcel, address, subdivision, and community), building square footage, and the number of building stories is input. Then, information such as base flood elevation (BFE), flood zone, and flood depth for different return periods are extracted from the server database. The tool then calculates different flood risk parameters such as freeboard cost, insurance premium saving, annual avoided loss, total annual benefit, and payback time, for a range of freeboards. The web portal is built using “Django,” a Python programming language-based web framework that provides the web developing platform for communication between the interface and server database. This web portal will help potential homeowners to make better-informed decisions based on a menu of freeboard options. This tool will enhance protection to life and property, and therefore resilience, to the ever-present flood hazard in one of the most flood-prone U.S. states.

Discussion on appropriate pattern of integrated flood risk management in China

Poster - PS V.d Integrated flood risk management

Prof. Xiaotao Cheng¹, Ms. Yanyan Wang¹, Dr. Cheng ZHANG¹

1. China Institute of Water Resources and Hydropower Research

Over the past two decades, China's urban population increased from 450 million (36.1%) to 902 million (63.9%), while the built-up area has expanded from 22,439 km² to 60,300 km². Such high-speed urbanization exerts propound influences on the flood control situation, bringing challenges to both the urbanized areas and the vast rural areas. As the development of urban flood control and drainage infrastructure lags behind the rapid urban expansion, more than 100 cities inundated every year since 2006, largely by local rainstorms. In rural areas, as most young people go out to work, the strength of levee maintenance and flood fighting is weakened. "The most affected country by flooding in the past two decades was China", as pointed out by UNDRR and CRED in *The Human Cost of Disasters: an overview of the last 20 years (2000-2019)*. In fact, China has multiplied the spending on flood control systems since the devastating floods in 1998, and initiated strategic shift to flood management in 2003, with average annual economic losses decreasing from 2.28% in the 1990s to 0.58% in the 2000s, and further to 0.38% in 2010s; and the average annual flood death toll in the 2010s has fallen to about a tenth of that in the 1990s. In 2020, the Yangtze River experienced major floods like that in 1998, but it did not have an adverse impact on the post-epidemic economic recovery. To meet the increasing demands of flood security, we can neither blindly follow the traditional practices nor simply copy the experience of others, since the features of flood risk are undergoing marked changes in the context of environmental evolution and intensified human activities. Instead, it is urgent to seek appropriate pattern of integrated flood risk management in China according to local conditions of regions with significant geographical and economic differences.

DSM floodplain mapping model based on aerial photo stereoscopy

Poster - Erich Plate Best Young Scientist

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The Brazilian metropolis of São Paulo, with 22 million inhabitants, has an urbanization process marked by legal transgressions, inefficient territorial planning and urban appropriations in heavily dissected plateaus of humid tropical environment, creating a serious flood risk scenario. For the identification and mapping of susceptible areas, until the 2000s little has been done using known effective techniques such as pre-urbanization geomorphological restitution by stereoscopic photo interpretation. The use of this technique is also limited when aerial photos from a pre-urban period are unavailable. Thus, the objective was to develop a mapping model capable of using the contents and interpretations of this geomorphological mapping procedure as parameters to identify flood prone areas. The area of application is a highly urbanized basin with lithological characteristics, hydrographic density, occupation patterns and types of channel interventions that make it representative. Stereoscopy of aerial photographs identified the original boundaries of the fluvial plain units on the upstream half. A 12 cm resolution DSM was constructed using classified LIDAR data for the entire basin. A river profile extraction routine was performed to obtain the altimetric gradients between the natural form channels and the floodplain boundaries identified by stereoscopy. This way, projections of river profiles following those topographic patterns were created for the downstream half. Thus, the areas assumed as floodplains resulted from the surface difference between the DSM and the threshold elevations found in these projected profiles. The model was applied in reverse for validation purposes, using downstream floodplain profiles for upstream projection over the area analyzed by stereoscopy. The sum of the model correctly identified areas corresponds to 86.05% of the total area identified by stereoscopy. Approximately 93% of the stereoscopically identified floodplain area was also identified by the model, indicating its viability as complementary method to procedures fully supported by geomorphological interpretation.

East and West Nishnabotna, Iowa Watershed and Flood Resiliency Plans

Poster - PS V.d Integrated flood risk management

Mr. Richard Wilson¹

1. JEO Consulting Group, Inc.

Two recently approved innovative watershed management and flood resiliency plans were prepared for both the East and West Nishnabotna River Watersheds located in southwest Iowa. The plan sponsors, the East and West River Nishnabotna Watershed Coalitions respectively, developed these plans as part of the Iowa Watershed Approach (IWA). The IWA provides a vision for Iowa to engage stakeholders voluntarily throughout the watershed to achieve common goals and provide programs that can be replicated. The purpose of the Nishnabotna River Watershed Management and Flood Resiliency Plans is to provide a comprehensive action plan framework that addresses flood mitigation and resilience, water quality improvement, watershed management, and other resource concerns identified by local stakeholders. Implementation of the plans is completely voluntary; but these plans provide a roadmap to carry out specific community, landowner, and watershed resident projects over the next five to 15-years.

The plans address watershed management and flood resiliency at three levels: the HUC 8, HUC 12, and sub-HUC 12 watershed level. The plans comprehensively analyze water resources of prioritized watersheds, including assessments for hydrology, streamflow, topography, land use, soils, water quality, and other parameters of the watershed systems. The Agricultural Conservation Planning Framework (ACPF) Toolbox was used to identify potential sites for best management practices (BMPs) throughout the two HUC 8 watersheds. ACPF was developed by the USDA National Laboratory for Agriculture and the Environment and utilizes high-resolution geospatial datasets within ArcGIS to address soil and water conservation needs at the field level through a system of model processes, delineations, and risk assessments. The potential BMP sites serve as a roadmap to guide land managers and decision makers to target specific areas for implementation. This process serves to prioritize and expedite the implementation of conservation practices, while also preserving limited financial resources.

Key words: Resiliency, flooding, watershed, stakeholders, ACPF

Evaluation of flood susceptibility mapping using logistic regression and GIS conditioning factors

Poster - Erich Plate Best Young Scientist

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The maximum number of words is 300 (excluding the abstract title and authors). No figures or tables are allowed at the time of abstract submission

This paper investigates the application of logistic regression model for flood susceptibility mapping in southern Gaza Strip areas. At first, flood inventory maps were identified using Palestinian Water Authorities data and extensive field surveys. A total of 140 flood locations were identified, of which 70% were randomly used for data training and the remaining 30% were used for data validation. In this investigation, six causing flood variables from the spatial database were prepared, which are digital elevation model (DEM), topographic slope, flow accumulation, rainfall, land use/land cover (LULC), and soil type. Then, comprehensive statistical analysis techniques including Pearson's correlation, multicollinearity, and heteroscedasticity analyses were used, to ensure that the regression assumptions are not violated. The uniqueness of the current study is its inclusiveness of influential causing flood parameters and vigorous statistical analyses that led to accurate flood prediction. Quantitatively, the proposed model is robust with very reasonable accuracy. The prediction and success rates are 76 and 81%, respectively. The practical and unique contribution of this investigation is the generation of flood susceptibility map for the region. This is a very useful tool for the decision makers in the Gaza Strip to reduce human harm and infrastructure losses.

FLOOD SUSCEPTIBILITY PREDICTION USING MULTI CRITERIA DECISION ANALYSIS AND BIVARIATE STATISTICAL MODELS: A CASE STUDY OF LOWER KOSI RIVER BASIN, GANGA RIVER BASIN, INDIA

Poster - PS II.b Risk communication

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Advancements in flood prediction modelling algorithms and availability of GIS and RS resources, including high-resolution DEMs, flood prediction modelling studies are picking up pace in the research community. Advanced bivariate techniques and Multi-Criteria Decision Making (MCDM) models help in the identification of flood susceptible areas with more accuracy. The present work focuses on the comparison between Analytical Hierarchy Process (AHP), the most commonly used MCDM model, and three bivariate models: Evidential Belief Function (EBF), Weights of Evidence (WoE), and Frequency Ratio (FR) to predict the flood susceptible areas in the Lower Kosi River Basin (LKRB) of the Ganga River Basin (GRB). This work compares the results of flood susceptibility modeling in the LKRB part of GRB. Flood susceptibility in LKRB is attributable to topographic, hydrologic, soil, and anthropogenic factors and has been mapped using the above-mentioned models. Twelve flood conditioning factors, including topographic (altitude, slope, aspect, curvature, and geomorphology), hydrologic (rainfall, TWI, river density), anthropogenic (LULC, distance from road), and others (distance from river, soil) have been utilized for the modelling. The incorporated models suggest that geomorphology, TWI, land use, and river density (in descending order) are the most dominating factors in which geomorphology is the most contributing, followed by TWI, land use, and river density successively. Contribution of other conditioning factors in flood prediction, in descending order, are slope, altitude, rainfall, curvature, aspect, soil, and distance from the river. The area under Receiver Operating Characteristic (AUROC) method was used for validation of the used models. The value of the AUROC curve for MCDM model AHP was found to be 0.837, and for the bivariate models, the values were, 0.807 for FR, 0.820 for EBF, and 0.787 for WoE. Hence, the MCDM model predicted flood-susceptible areas more accurately than the bivariate statistical models for the flood-dominated region of LKRB.

Floodplain sediments as repositories of information for flood hazards management and mitigation: Upper Tennessee River case study

Poster - Erich Plate Best Young Scientist

Mx. Paula Perilla Castillo¹

1. *University of Tennessee*

Floodplain sediments are important and useful repositories of information for paleoenvironmental and paleoflood studies. In flood risk assessment, lack of long-term records to estimate parameters such as Annual Exceedance Probabilities (AEPs) create big uncertainties for planning of flood control. Paleoflood studies rely on records from geological, geomorphological, or botanical provenance to reconstruct magnitude and frequency of large floods that occurred before the time of human observation and can help increase the accuracy in estimating AEPs and worst-case flood scenarios. We studied five cutbank soil profiles in the floodplains of the Tennessee River, which recorded several major flood episodes interlayered with buried soils. We characterized the sediments using multiple analyses, including particle size (PS), portable X-ray Fluorescence (pXRF), magnetic susceptibility (MS), loss-on-ignition (LOI), and radiocarbon dating. The analyses (PS, MS, and LOI) show clear evidence of paleofloods, distinguished by larger grain sizes in the sediment with predominance of quartz and feldspar minerals, while the buried soils contain more fine grain sizes with larger proportions of ferromagnetic minerals and clay minerals. Paleofloods present lower MS than paleosols and LOI shows higher loss of mass in paleosols probably due to loss of OH water in the clay minerals lattice. pXRF shows a higher Zr/Rb ratio in paleoflood deposits compared to paleosols. An increased Zr/Rb is associated with larger grain sizes. Radiocarbon dating was used to date the sediment packages and therefore, reconstruct a chronology of events. Each of the profiles have characteristics that respond to the specific landform they occur and the behavior of the river and tributaries nearby. However, they show similar distinctive paleoflood layers that correlate for major floods between profiles, allowing for reconstruction of the flood history of the Tennessee River before the time of human observation and identification of frequency and magnitude of past major floods.

Free and Open Source Software for Mapping Flood Inundation Impacts using HAND and National Water Model Outputs

Poster - Erich Plate Best Young Scientist

Mx. James Coll¹

1. *University of Kansas*

When the National Water Model went online, for the first time in the modern computational era the nation went from a lumped basin parameterization to a fully distributed, coupled hydrologic/hydraulic representation of the water cycle. Not only does this implementation represent an almost 21,000-fold increase in our predictive potential of river discharge, its modular nature ensures that future efforts to improve individual aspects of the model are immediately integrated into the lifecycle of a hydrologic event. However, the methods of accessing these efforts for those not intimately familiar with the model or data science conventions are limited, and the means of consuming these within the emergency management realm are currently nonexistent. To rectify these shortcomings, a graphical user interface built on Free and Open Source tools is demonstrated; ideal users include first responders and decision makers. These intuitive and accessible properties enable virtually anyone with a modern computer to access, interact with, and make decisions based on National Water Model forecasts – effectively bridging the gap between federal scale efforts to guide and inform, and the local scales where actions are made.

Keywords: national water model, flooding, emergency management, FOSS, decision making

Historical and Future Snowpack and Melt Extremes for Snow-driven Flood Management using Regional Climate Models

Poster - Erich Plate Best Young Scientist

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Snowmelt is a dominant driver of flood generation in regions with seasonal snow-cover. Recent snowmelt floods in 1997, 2009, 2011, and 2019 in the north-central and northeastern U.S. had large societal and economic impacts on communities. The current engineering practice provides very limited guidance on designing infrastructure to accommodate snowmelt-driven floods using the historical data and no guidance regarding how to consider a non-stationary climate. Future designs are particularly critical because the changing climate is well understood to change winter temperature and precipitation regimes in a manner that will alter the characteristics of flooding. In this study, trends and designs of extreme 25- and 100-year return level snow water equivalent (SWE) and snowmelt events are quantified in the mid and late 21st century using the North America - Coordinated Regional Climate Downscaling Experiment (NA-CORDEX) ensemble of regional climate models under Representative Concentration Pathways 8.5. The future extreme SWE and snowmelt will be compared with the current condition over North America. The results are expected to provide the guidance needed to add flood risk factors driven by snowmelt events under a changing climate to North American infrastructure standards.

Keywords: Snowmelt Floods, Rain-on-snow (ROS), Climate Change, Regional Climate Model, Snow Water Equivalent

Impacts of urbanization, antecedent rainfall events, and cyclone track on extreme floods at Houston reservoirs during Hurricane Harvey

Poster - Erich Plate Best Young Scientist

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The objective of this study is to evaluate the effects of urbanization, an antecedent rainfall event (ARE), and varying cyclone tracks on the streamflow—and thus the subsequent reservoir status—during the floods caused by Hurricane Harvey in August-September 2017. Through a hydrological modeling approach, we examined how these factors influenced the inflows, peak pool elevations, and outflows of the two most important detention reservoirs in the Houston region, the Addicks and Barker Reservoirs. A high-resolution rainfall reanalysis dataset for extreme storm events, along with a suite of synthetic rainfall values from a variety of storm tracks, were adopted to represent both the truth and the maximum possible rainfall during the Hurricane Harvey period. The results showed the following: Urbanization only led to slight increases in peak inflows, not necessarily to an increase in peak pool elevations, and the ARE contributed to the peak inflow and pool elevation slightly. In contrast, if the cyclone had followed the most adverse track consistent with earlier forecasts (all else being equal), the total volumetric flow into the two reservoirs would have been significantly larger (37% and 49% respectively), thus increasing the peak pool elevations by 1.06 and 1.37 meters respectively. These results suggest that large uncertainties exist for flood management at a watershed scale during hurricanes, because of the uncertainties in the cyclone track. This would remain true even if storm-relative precipitation rates could be predicted perfectly.

Integration of wetland and depression water storage affects flood modeling across the Upper Mississippi River Basin

Poster - Erich Plate Best Young Scientist

Mx. Qianjin Zheng¹

1. *Texas A(and)M University*

Surface water storage in small yet abundant landscape depressions – including wetlands and other small water-bodies – is largely disregarded in conventional global flood hazard modeling. No quantitative evidence exists of how their exclusion may lead to potentially inaccurate model projections, which affects scientific understanding and management of high flows and potential flood inundation across the world’s major river basins. To fill this knowledge gap, we developed the first-ever surface depression-integrated basin modeling approach, focusing on the ~450,000 km² Upper Mississippi River Basin (UMRB) in the United States. We applied a novel topography-based algorithm to estimate areas and volumes of ~455,000 surface depressions across the UMRB and then aggregated their effects per subbasin. Compared to a “no depression” conventional model, our depression-integrated model (i) improved streamflow simulation accuracy with increasing upstream abundance of depression storage, and (ii) significantly altered the spatial patterns and magnitudes of water yields across 315,000 km² (70%) of the basin area. Initial results also suggest that daily and hourly high flows simulated by the depression-integrated model may be substantially different from the conventional model, which may impact the accuracy of simulated flood inundation extents. These findings stimulate a reassessment of our conventional modeling practices for global flood hazards assessment across the world’s major river basins.

Keywords global flood hazards; hydrologic modeling; natural infrastructure; wetlands

Investigation of an operational modeling framework to provide real-time flood forecast

Poster - Erich Plate Best Young Scientist

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1. George Mason University

Recurrent water related events showed that urban floods are still causing significant socioeconomic impacts over the United States, emphasizing the importance of build flood resilient communities to reduce damage and loss. An accurate water forecast system is a valuable tool in order to build resilience, once it can be used to identify significant oncoming events, to support decision making and to launch preparedness and response actions. In this context, the objective of this research is to identify an operational modeling framework that can provide real-time flood forecasts in a reasonable amount of time and computational cost. The approach includes the use the WRF-Hydro modeling system, a distributed hydrologic model, to combine the simulation of overland and river flows to generate flood maps. This framework allows the model to provide information at any given point in the watershed, allowing the identification of multiple types of flooding. It is expected to identify the best modeling framework by testing different model configurations and quantify the contribution of parameters and forcing data to the results. The Northern Virginia region was chosen for this study due to its exposure to combined water related hazards as riverine, urban and storm surge flooding, at the same time that is one of the most rapidly-growing urban region of the United States. This work is conducted as part of iFLOOD <http://iflood.vse.gmu.edu> that is a scientific experiment to incorporate multi-scale and multi-temporal physical processes for total water prediction, including large scale oceanic process, off-shore and near shore waves, estuarine hydrodynamics, coastal processes, riverine flows, urban runoff and storm water systems.

Keywords: distributed hydrology, WRF-Hydro, urban runoff

Investigation of reservoir inflow prediction in Sai river, Japan

Poster - Regular

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*Dr. Mohamed Rasmy*¹, *Mr. Katsuhiko Onuma*¹, *Mr. Hiroyuki Ito*¹, *Prof. Toshio Koike*¹**

1. International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM), 2. Nippon Koei Co., LTD.

In order to avoid non-regulated discharge during floods which increases the flood risk downstream of the reservoir, it is important to predict the inflow into the reservoir and its water level. For this purpose, it is required to develop a hydrological runoff model which accurately represent the water cycle in the basin and also the prediction of rainfall with high accuracy. Moreover, it is effective to have tools which delineate the basin models so easily.

In this study, a real-time reservoir inflow monitoring and forecasting system which consists of runoff model using the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) and ensemble rainfall predictions up to 39 hours ahead were developed and installed on the Data Integration and Analysis System (DIAS) for the Sai river, Nagano Prefecture in Japan.

The Sai river shows a unique basin characteristic with a steep mountainous topography in the upstream areas, and the flat area in the downstream which is called Matsumoto Basin. Usually, it is sometimes difficult to make a basin delineation for WEB-DHM in such topographical characteristics region but the Nippon Koei - Geographic Information Analysis System (NK-GIAS) WEB-DHM Tools were successfully used to support the basin delineation. The calibration of WEB-DHM was carried out during the warm season (June to September) in 2018 and validated it from June to September in 2015 to 2017 then confirm the accuracy of WEB-DHM. In the inflow prediction system, the rainfall forecast was applied in combination form short-term rainfall forecast issued by the Japan Meteorological Agency up to 6 hours ahead, and the ensemble rainfall forecast from 7 to 39 hours ahead. As a result, the system was able to predict the inflow with high accuracy at July and September flood events in 2018.

Keywords: WEB-DHM, NK-GIAS, Reservoir inflow, ensemble forecasting, DIAS

North Atlantic Coast Comprehensive Study: A Framework for Shared Results

Poster - PS V.a Governance and partnerships (shared vision & responsibility)

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1. U.S. Army Corps of Engineers

The Hurricane Sandy Emergency Supplemental, provided billions of dollars in the aftermath of the storm. One part of that, specifically, “up to \$20M” was provided to the U.S. Army Corps of Engineers to conduct a comprehensive study to address flood risk of vulnerable coastal populations within areas affected by Hurricane Sandy. The study of over 31,000 miles of coastline was completed within two years. Goals of the study were to provide a Risk Reduction Framework and Support Resilient Coastal Communities. The goals were meant to arm all of us with the ability to evaluate and know our risk, and then do something about it. All stakeholders want a more resilient future state of the coastline. Key outcomes included:

- Consistent coastal framework that is repeatable and transferable and able to be used by **all** (federal, state, regional, local, tribal, NGO, industry, academia, etc).
- New tools (closed data gaps).
- Integration with other stakeholders and *their* tools.
- More robust, risk-informed decision-making.

The Risk Reduction 9-Step Framework helps local communities and stakeholders answer the following questions, such that they can assess their risk and evaluate alternatives for creating resilience:

- Who/what is exposed to flood risk?
- Where is the flood risk?
- What are the appropriate strategies and measures to reduce flood risk?
- What is the relative cost of a particular strategy compared to the anticipated risk reduction?
- What data are available to make risk informed decisions?
- What is the residual risk?

The Framework and numerous tools, which were developed as part of the study, enable all parties to collaborate on a broad outcome, developing a shared result. This shared commitment catalyzes others to take ownership of the elements within their responsibility because they understand, that together, the shared result is achievable. Key words: decision-making, risk, vulnerability, comprehensive plan

Performance assessment of Synthetic Rating Curves for Continental scale flood mapping.

Poster - Erich Plate Best Young Scientist

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1. Purdue University

Accurate large-scale flood maps spanning entire continents can play a critical role in flood mitigation, preparedness and risk management. Current hydrodynamic models cannot span such large spatial extents owing to model complexities, computational requirements and data constraints. Therefore, empirical approaches of generating floodmaps, such as the Height Above Nearest Drainage (HAND) method in conjunction with Synthetic Rating Curves (HAND-SRC), are particularly appealing. The HAND-SRC method relies on simplified Manning's equation and its assumptions need to be evaluated comprehensively before it can be implemented reliably across entire Continental United States (CONUS). This study aims to assess the performance of synthetic rating curves (SRCs) across CONUS by comparing them to field measured rating curves obtained from United States Geologic Survey (USGS). Further, this study investigates the dependence of SRC performance on watershed characteristics, which can help in quantifying the reliability of the HAND-SRC method in data-scarce regions.

Keywords: Synthetic Rating Curves, Height Above Nearest Drainage (HAND), Large-scale Inundation Mapping, Continental United States

Retrofit of Brazilian detention reservoirs through NBS: Designing smart structures for quantitative and qualitative water control.

Poster - PS VI.b Nature-based solutions for flood management

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1. University of Sao Paulo, 2. Universidade de São Paulo

The hydrological safety of the São Paulo Metropolitan Region (SPMR) has historically been articulated through the use of structures based on the hard engineering, with the implementation of channelization and detention reservoirs, popularly called “piscinões” in Brazil. Currently, the SPMR has 53 detention reservoirs, resulting in a damping volume of 9.9 million m³. Brazilian detention reservoirs, while significantly acting on the hydrological safety of watersheds, have little or no effect on diffuse loads and uncontrolled sewage. Most Brazilian municipalities have not yet reached the universalization of sewage collection and treatment services, so the organic load received by the drainage system is significant. In addition, due to failures in the solid waste system, the holding reservoirs receive large amounts of waste during their operations, according to the city of São Paulo, 56.6 tons/day of solid waste are removed from the reservoirs. These reservoirs come into operation only a few months per year in the rainy season, remaining mostly unused for the rest of the time. Initially, it was foreseen the implantation of leisure structures inside, that could be used during the drought period, however, due to the water degradation, such use was discarded. In this context, a new design for the SPMR’s reservoirs was proposed to retrofit these structures through NBS. These new structures will be able to act not only in the water quantitative control but also in the qualitative, which would make these structures more functional and integrated to the landscape, building a network of stormwater treatment units through NBS. In this study, this proposed design was applied to the piscinão of Eliseu de Almeida Avenue, located in the Pirajussara watershed, one of the most important watercourses of SPMR.

Review of Flood Hazard Mapping Practices Across Canada

Poster - Erich Plate Best Young Scientist

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1. Civil and Environmental Engineering - Western University

Flooding is currently the most common and costliest natural hazard that is occurring across Canada, threatening human life and causing infrastructure damage, social disruption and internal migration. Flood hazard maps serve as critical decision-making tools in flood mitigation, land use planning, emergency management and general public awareness. They are engineering maps that display the results of hydrologic and hydraulic investigations.

A series of major flood events were the catalyst for the federal government to initiate the Federal Damage Reduction Program (FDRP) in 1976. The main products of the FDRP were engineering maps and public information maps. The engineering maps were the basis for zoning regulations which are used to manage development in flood-prone areas. Since the end of the active mapping phase of the FDRP in 1997, provinces, territories and other levels of government have continued flood mapping for new areas or updated previous mapping using their own resources.

This situation resulted in the use of different criteria and approaches for the development of flood hazard maps. Government of Canada in 2018 established a framework to promote efforts for a national approach to flood hazard mapping for Canada. The main objective of this paper is to provide an up to date analysis and review of current approaches that are being utilized in flood hazard mapping across Canada. A review of current flood hazard mapping approaches is being completed for each province and territory using existing guidelines and case studies. An analysis has been completed for each existing approach to identify similarities between the existing approaches and assess their advantages and disadvantages. The review will end up in a set of recommendations, based on the combined national guidelines and provincial/territorial practice, that should lead to the unification of the flood hazard mapping practice in Canada.

Streamflow Forecasting with Upstream Sensor Information using Deep Learning

Poster - Erich Plate Best Young Scientist

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1. The University of Iowa, 2. University of Iowa

This study presents a rainfall-runoff model using precipitation, evapotranspiration, stream runoff data for each sensor site and its upstream with deep recurrent neural networks (DRNN). 125 USGS streamflow gages are using in the study from the state of Iowa for water years 2011 to 2018. 62 USGS gages are located at the most upstream watersheds and the rest are located at downstream watersheds. After training with water years from 2011 to 2017, the proposed deep learning model had medium Nash-Sutcliffe Efficiency (NSE) values of 0.96, 0.91, 0.87, 0.83 and 0.80 for the first five days of the 24-hour predictions on the test water year 2018 for 63 USGS downstream gages. The results outperform the streamflow persistence (NSE values) of 0.96, 0.83, 0.66, 0.50 and 0.34. By removing the upstream runoff data, model NSE values decreased to 0.95, 0.87, 0.81, 0.79 and 0.76 respectively, which shows contribution of integrating upstream sensor network. Results also show that integrating Iowa Flood Center stage level sensors helps to improve the forecasts of USGS upstream gages that were underperforming. This study shows that deep learning has strong predictive power by integrating upstream streamflow gages in stream network for 5-day flood forecast.

1- StreamStats: A web-based application for retrieving basin characteristics and streamflow statistics (such as the percent flood) for gaged and ungaged streams.

Poster - PS II.b Risk communication

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1. U.S. Geological Survey, Water Mission Area, 2. U.S. Geological Survey

The U.S. Geological Survey's StreamStats program, version 4, is a geographically-enabled interactive web application (<http://streamstats.usgs.gov>) that can provide soil and water conservation practitioners and engineers with information they can use in their daily work. StreamStats users can locate and select USGS streamgages on the map-based user interface and obtain previously computed streamflow statistics and basin characteristics, as well as descriptive information for the streamgages. Users also can select any location along a stream and obtain the drainage-basin boundary, basin characteristics, and estimates of streamflow statistics for the location. As each state was implemented separately in StreamStats, the information that is available for the streamgages and for user-selected sites varies among the states. Examples of the more than 800 basin characteristics that may be available at a particular location are the drainage area, stream slope, mean annual precipitation, and percentages of various land uses and soil types with the basin. Examples of the more than 2,500 streamflow statistics that may be available at a location include the 1-percent (100-year) flood, the mean flow, and the 7-day 10-year low flow.

The drainage-basin boundaries obtained from StreamStats can be saved in a variety of formats, with the basin characteristics and streamflow statistics included as attributes. The statistical information also can be printed or saved in tab-delineated files. In addition, StreamStats version 4 allows users to obtain land-surface distances and elevation profiles. It also includes several tools that use stream-network navigation to determine paths of flow between selected points on the land surface and a stream, as well between points on streams, and also to identify and obtain information for points of interest along streams, such as streamgages and dams. This presentation will provide a description of StreamStats and discuss plans for future enhancements.

Study on flood control planning scheme for the Irrawaddy River Basin in Myanmar

Poster - PS V.d Integrated flood risk management

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Abstract:The Irrawaddy River is characterized by high peak, large volume, and weak flood control system, so the flood disaster is frequent and serious. Based on the in-depth analysis of flood and disaster characteristics in the Irrawaddy River Basin, the status quo and main problems of flood control in this basin were analyzed, and the principle, standard and goal of flood control were clarified. In light of the natural characteristics and regional flood control situation, combined with field research, the flood control planning scheme was made on the governance policy of “combined storage and discharge, and discharge-oriented” and the governance policy of “overall planning and ensuring the focus”, and the harmonious flood relationship between upstream and downstream reaches, left and right banks, mainstream and tributaries should be taken into account. The counter-measures for flood control were proposed combined with “blocking at upper”, “detention at middle” and “drainage at lower”, to ensure the basin safety of flood control.

Key words: Myanmar; Irrawaddy River; flood control; planning scheme; governance measures

Suitability of HEC-HMS for flood forecasting in Mozambique and France

Poster - PS II.c Flood decisions support systems

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In the past decades, important efforts to improve flood management were observed. The increased use of computer programs allowed to improve the modelling capabilities of many hydrologic processes. In the present study, the suitability of the open-source software HEC-HMS (from the Hydrologic Engineering Center) to perform event-based simulations of rainfall-runoff processes in the catchments of Revubue (sub-basin of Zambezi river in Mozambique) and Ardeche (sub-basin of Rhone river in France) rivers was tested. The hydrologic models were calibrated and verified based on observed (historical) precipitation and runoff data. The study highlighted some limitations imposed by the scarcity of rainfall and runoff data in developing countries such as Mozambique, in addition to the large time intervals of the time series. Despite these difficulties, the model for Revubue catchment performs relatively well in terms of time and magnitude of peak flows of the studied flood events. Better results were obtained for Ardeche catchment, (relative errors generally below 20%), serving as a benchmark. The Ardeche model was compared with results from the modelling platform ATHYS, developed by the French Institute for Development Research (IRD). It was seen that they have similar levels of accuracy. The good performance suggests that HEC-HMS may be suitable for flood modelling and/or forecasting in the studied catchments. To further illustrate the importance of the results, the output from HEC-HMS was introduced in a simple 1D HEC-RAS model of the Revubue river, developed entirely using open-source resources. This allows to predict the water levels resulting from the studied rainfall events, therefore, the associated inundation potential. The proposed hydrologic model is among the first in Mozambique. The use of such models for flood forecasting may contribute to reduce flood risks in these vulnerable regions. Nevertheless, their potential is conditioned by a good monitoring of hydrologic data.

System approach to flood risk management – Where are the system boundaries?

Poster - Erich Plate Best Young Scientist

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It is becoming well-established that flood risk management should be based on a “system approach”, encompassing the atmosphere, catchment, river, dike and floodplain components. Here, we suggest that the system boundaries need to be further expanded to cover additional processes, such as spatial planning, mobility, energy efficiency, among others. To illustrate this statement, we analyzed the interplay between urbanization and flood risk at two different spatial scales.

First, at the regional level, we set up a modelling chain involving an inundation model, an agent-based urbanization model and depth-damage functions. A remarkable feature of the agent-based model is that it enables simulating both urban expansion and densification. Based on this modelling chain, we compared future flood risk for two contrasting spatial planning policies: either a “business-as-usual” policy (involving substantial urban sprawl), or a more “sustainable” policy (promoting densification). While the latter should be preferred from the perspective of mobility, the flood risk modelling chain reveals that such an approach promotes development closer to already inhabited areas nearby rivers; and leads to higher future flood risk. This hints at a “competition” between sustainable spatial planning and flood resilience, which could only be disentangled if the studied system incorporates the various feedbacks between spatial planning, mobility and flooding.

Similarly, at the district level, we investigated the effect of the urban forms (i.e. the layout of buildings and streets) on urban flooding. By comparing 2,000 realistic urban forms, we found substantially lower flood hazard when space is kept in-between adjacent buildings (i.e. the buildings are detached). However, this is in contradiction with good practice in terms of energy efficiency. Again, to handle properly such competing effects, the studied system needs to reflect the processes influencing both flood risk and energy efficiency, which is broader than in current state-of-the-art flood risk management models.

The role of antecedent wetness on flood response: Observational and modeling results for a large number of watersheds in contiguous US.

Poster - Erich Plate Best Young Scientist

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The maximum number of words is 300 (excluding the abstract title and authors). No figures or tables are allowed at the time of abstract submission

At a catchment scale, soil moisture conditions prior to heavy precipitation can have a significant role in modulating both the magnitude and timing of flood response. While the importance of antecedent wetness conditions on flood response is largely recognized, most of the studies so far have been focused on the analysis of single storm events and/or single catchments. Therefore, limiting our understanding of the dependence of flood response to antecedent wetness conditions (AWC) as a function of scale, precipitation severity and catchment attributes. In this study, we carry out an analysis on a large number (>500) of catchments using the CAMELS dataset (Newman et al. 2015; Addor et al. 2017) to investigate the importance of AWC under various hydrometeorological conditions and land surface characteristics. We use machine learning based algorithms to a) classify the various responses and identify hydrologically similar catchments and b) develop predictive models for peak flow response. Findings from this work provide a comprehensive view on the role of AWC on flood response and highlight the importance of AWC for flood prediction.

Keywords: antecedent moisture condition, precipitation, flood response, catchments, machine learning

The Upper Tail of Precipitation in Convection-Permitting Regional Climate Models and Their Utility in Nonstationary Flood Frequency Analysis

Poster - Erich Plate Best Young Scientist

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Computational advances have made atmospheric simulations at convection-permitting (≤ 4 km) resolutions increasingly feasible. These simulations hold great promise in weather forecasting, land-atmosphere studies, and projection of climate change impacts including rainfall and flood extremes. The relatively short (~ 10 -year) model runs that are currently feasible, however, inhibit the assessment of the upper tail of rainfall and flood distributions (e.g. >100 -year recurrence intervals) using conventional statistical methods, which generally require multi-decadal records. Stochastic storm transposition (SST) and process-based Flood Frequency Analysis (FFA) are two approaches that together can help overcome this limitation. SST can generate large numbers of extreme rainfall “scenarios” by temporal resampling and geospatial transposition of rainfall fields from “medium-term” (10+-year) observational datasets or climate simulations. Coupling SST with process-based FFA and the WRF-Hydro modeling system enables exploration of flood behavior at a variety of spatial and temporal scales and for recurrence intervals beyond 100 years. The National Center for Atmospheric Research has completed 13-year present and late 21st century regional climate model (RCM) simulations for the conterminous U.S. We apply our RainyDay SST software and process-based FFA approaches with outputs from these climate simulations (precipitation, radiation, humidity, temperature, etc.) to examine current and future extreme rainfall and flood quantiles in a medium-sized watershed in the Midwestern United States. We first use a stochastic approach to correct seasonal RCM biases. These bias-corrected precipitation fields are then used to generate rainfall intensity-duration-frequency (IDF) curves from 2 to 500-year recurrence intervals for both current and future climate using RainyDay. Finally, we use RainyDay rainfall “scenarios” as inputs to the process-based FFA framework, showing both the potential and limitations of convection-resolving simulations to understand potential changes in flood magnitude and seasonality across a range of watershed scales.

The Use of Unmanned Aerial System (UAS) For Pavements Condition Assessment Before and After Hurricane Events

Poster - Regular

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Collecting condition data of pavement structures before and after the occurrence of hurricane events are vitally important in any effort to reduce future economic losses from natural hazards. These data are used as a record of infrastructure condition/performance and as a major component for statistical analysis and damage modeling studies. In cases where these data are collected, they are usually lost soon after the event, rather than kept to longitudinally assess the pavement conditions in severe natural hazard events over the long term. Hurricanes are multi-hazard events (e.g., flood, surge, wave) and therefore are special type of coastal flooding. The objective of this research is to collect the pavement condition data (i.e., cracks, potholes, and rutting) using the Unmanned Aerial Systems (UAS), e.g., DJI Matrice 210 with X4S Camera, to be used for the development of damage assessment process for infrastructure and pavement sections subjected to hurricane flood hazard. The process divides the assessment into three phases (pre- during and -post assessment phase) and identifies the practices and data needed in each phase. The data will also be used for the development of a protocol to be implemented into the process to standardize infrastructure and pavement flood data collection and damage assessment. While most of the existing data collection practices focus on collecting data for structures highly affected by hurricane such as residential buildings, more data regarding the infrastructures and pavement sections are needed to improve our understanding of pavement performance after hurricane events. The data will serve as the base for developing enhanced performance-based design standards, which will lead to more reliable performance of infrastructures.

Tide Equivalent Rainfall: A new metric to improve the resilience of global coastal regions to pluvial and tidal impacts

Poster - Erich Plate Best Young Scientist

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For centuries, the global coastal cities have had no option but 'live with floods'. The conservative scientific consensus further highlights that these regions contain the highest probability in experiencing unprecedented human and socio-economic losses with rising precipitation extremes, storm-surges, and sea-levels, expected to be intensified by concomitant climate change. While many of these cities have invested massively in short-term technical solutions to keep the flood losses at bay, there is a need to plan for long-term measures, especially at the planning stage to improve the resilience and provide feasible solutions for the future generations. In these regions identified as 'flood hot-spots', the inland areas are susceptible to pluvial (rainfall) impacts, while the coastline is threatened by the tide. Although much efforts have been put into understanding the joint impacts of rainfall and tide, a major gap in understanding their individual impacts is missing. To bring further understanding on this aspect, we propose a comprehensive framework which utilizes a set of design rainfall and design tide scenarios into a 1D 2D coupled MIKE FLOOD model to build a new metric termed as 'Tide Equivalent rainfall (TER)'. The behavior of this metric helps in understanding the propensity of coastal flooding and designating them as either 'pluvial-dominated' or 'tidal-dominated' flood-prone regions. The proposed framework is demonstrated on three flood-prone coastal cities of India, namely Mithi catchment in Mumbai, Jagatsinghpur in Odisha and Greater Chennai Corporation in Chennai. Based on our analysis, we discover that the former is 'pluvial-dominated' while the latter is 'tidal-dominated'. This new concept puts forward several amendments to the existing flood management practices in coastal regions by rationalizing the structural and non-structural options, for lowering flood risk by improving resilience.

Towards making a Flood Proof City: A Case Study of Gurugram in India

Poster - PS IV.a Flood-proof cities

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High population density, urbanization and inadequate drainage facilities alongwith frequent enhanced peak storms due to climate change conditions lead to flooding in an urban setting. Urban flooding leads to virtual collapse of life as infrastructural facilities get jeopardized. Gurugram, a satellite city of the National Capital Region in India, is a leading financial as well as industrial hub with the third-highest per capita income. It is one of the hundred cities which are proposed to be converted into smart cities by the government of India. However, this city has faced severe flooding events in recent years. Therefore, it has become necessary to think of adopting measures so as to make the city as flood proof. This study highlights the geographical settings of the area, key locations and the issues like volume, depth and time of flooding. Thereafter, it discusses the structural and non-structural measures that should be undertaken to prevent or reduce the flood menace. It is suggested that besides the cleaning and desilting of drains, it is important to reduce the illegal encroachment on the natural drains. Further, it is desired to plan and implement measures so that the city can act as a sponge city.

Uncertainty and risk analysis during flood routing by Fuzzy Theory approach

Poster - Erich Plate Best Young Scientist

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Many hydrodynamic problems that involve of the propagation flood waves along the length in natural channels are solved by Saint-Venant equations. In most practical applications the diffusive and kinematic wave routing are applied to study the flow routing in natural channels. These wave equations are derivations of the Dynamic Wave Routing, from simplifications of Saint-Venant Equations, where some terms are neglected. This research aims to apply the Fuzzy Theory in hydrodynamic models at natural channels, in order to verify the uncertainties and risks related to the hydrodynamic parameters present in these models. Introducing fuzzy logic into the hydrodynamics model, to calculate the membership functions associated with the control variables, provides a suitable and readily efficacious procedure for the analysis of the risk fields in the flood wave routing process. Through the finite difference schemes was solved partial differential equations present in Saint-Venant equations, explicit approach was applied for dynamic and kinematic wave, while implicit approach was applied for diffusion routing equation. In addition, some specific simulations were performed for the analysis of the flood risk and safety behavior, evaluating in which manner certain changes, for example, in the roughness coefficient and in the bed slope may affect the risk function behavior. Results allowed establishing some interesting analysis with regard to the behavior of dynamic, diffusive and kinematic wave flood routing, as well as the risk and the safety functions behavior are highly influenced by the channel hydraulic parameters. Results allowed concluding that the application of the Fuzzy Theory, in the hydrodynamic systems, in the evaluation of uncertainty is a viable alternative to determinate the risk of flooding and thus be more a support tool in Water Resources Management programs.

Keywords: Hydrodynamic Wave Models. Flood Routing. Fuzzy Theory. Uncertainty. Risk.

Understanding minimum data requirements for flood risk assessment in data-scarce environments.

Poster - Erich Plate Best Young Scientist

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Urban floods are a global risk. The frequency of floods has increased in the last decade, and flooding has become one of the most recurrent and destructive natural hazards impacting developed areas around the world. The lack of reliable data and the costs related to obtaining data restrict flood risk assessment. Therefore, urban and metropolitan areas are especially susceptible to increased flood risk, and Panama City is no exception. The objective of this research was to investigate which parameters of the hydrological, hydraulic, and statistical models were more critical to characterize flood risk and which were the tradeoffs between data acquisition cost and model uncertainty. Historical records of flood events in Panama City from 1930-2013 were obtained from the Network of Social Studies in Disaster Prevention in Latin America. The observations were georeferenced to identify the critical flood points in the city as well as their origin (fluvial, pluvial or coastal). Most of the flood events were localized in the Juan Diaz River Basin. The data also included a survey of 103 cross-sections along 22.5 km of the Juan Diaz River Basin mainstream and simulations from a HEC-HMS and HEC-RAS model. Monte Carlo simulations were used to test the importance of each model parameter in varying data availability scenarios. Preliminary results indicate that discharge calibration might be more significant than stream geometry to simulate flooding. The results of this study can be used as guidance in Panama and other data-scarce areas by understanding the amount of data necessary to get reasonable certainty.

Keywords: Juan Diaz, data scarcity, value of information, HEC-HMS, HEC-RAS.

Urban Flood Forecasting Techniques by coupling Weather Forecast, Hydrological and Hydrodynamic Models

Poster - PS III.d Cooperation in the management of large flood events

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Flood forecasting is one of the most significant tools for reducing flood risk and avoiding losses. To solve the problem of low resolution and short lead time of the traditional urban flood forecasting method, this work develops a novel high-accuracy and long lead time model through coupling the atmospheric and hydrodynamic models. The GRAPE_MESO model is applied as atmospheric model predicting rainstorms. To improve the reliability, a reconstructed method is put forward to correct predicted rainstorm data. The reconstructed predicted rainstorm is then used as input data for the hydrodynamic flood model. Finally, the urban flood inundation process is forecasted by the coupled atmospheric and flood model. Though applying the coupled model at Fengxi New Town (China), the performance is evaluated for realistic urban flood forecasting. The results show that the coupled modeling system can predict satisfactory urban flood inundation process with high-resolution and long lead time.

Key Words: urban flood, forecasting, hydrodynamic model, atmospheric model, inundation.

Using hydrologic and hydraulic models to simulate flood mitigation practices for the West Branch Wapsinonoc Creek Watershed in West Branch, Iowa

Poster - Regular

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The West Branch Wapsinonoc Creek watershed includes the West Branch Wapsinonoc Creek and its tributary, Hoover Creek. Located within the 21.8 square kilometer watershed are the City of West Branch, Iowa, and the Herbert Hoover National Historic Site, managed by the National Park Service. Periodic flooding along these creeks causes damage to city infrastructure and poses a risk to artifacts located within the historic site.

Hydrologic and hydraulic models were developed for the West Branch Wapsinonoc Creek watershed and calibrated to historic rainfall events using U.S. Geological Survey streamgauge data and surveyed high-water marks. The hydrologic model was used to simulate streamflows from design rainfall events of 24-hour duration ranging from 20-percent to 1-percent annual exceedance probability (9.65 to 18.7 centimeters). The hydraulic model was then used to simulate the effects of three flood mitigation scenarios, (1) increasing upstream flood storage by adding four detention basins, (2) improving conveyance within the flood plain by removing an abandoned railroad embankment and truss bridge along a stream section, and (3) combining both the flood storage and conveyance scenarios.

Results from the simulations showed the detention basins decreased peak water-surface elevations by 0.08 to 0.39 meters (m) at bridges on the West Branch Wapsinonoc Creek and peak surface water elevations decreased from 0.06 to 0.16 m in Hoover Creek at the bridge nearest to its confluence with the West Branch Wapsinonoc Creek. Improving stream conveyance decreased peak water-surface elevations from 0.06 to 0.18 m at bridges upstream of the railroad embankment. A combination of detention basins and improved conveyance resulted in the largest decrease (0.11 to 0.40 m) in peak water-surface elevations at all bridges.

These calibrated hydraulic and hydrologic models will aid the City of West Branch and the National Park Service in deciding the best implementation of flood mitigation scenarios.

USING JW ECO-TECHNOLOGY TO CREATE A SPONGE SCHOOL MODEL HAVING FUNCTIONS OF FLOODING CONTROL AND SUSTAINABLE WATER RESOURCE

Poster - PS VI.a Flood resilient communities

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Taiwan receives an average of 2,600 millimeters of rain per year, which is 2.6 times that of global annual rainfall average. However, it also ranks as the 18th most water-deficient region in the world. In the event causing severe flooding in southern Taiwan during August 2008, 600mm extreme rainfall poured within 24 hours, causing severe flooding. Li Ming Senior High School (LMSH), although located at the worst-hit area of the flooding, showed no waterlogging. This is achieved by the interconnected JW Eco-Technology pavements applied within the campus, acting as a water-absorbing sponge and forming a huge underground reservoir, demonstrating the feasibility of creating campus water banks through “sponge school” models. LMSH has applied JW Eco-Technology and transformed its campus into the world’s first sponge campus without drainage gutters, namely the “LM&JW Ecological Green School”. By adopting JW Eco-Technology, 8,000m² of JW Eco-Pavement was installed within the 38,000m² LMSH campus, it allows LMSH to be totally water-permeable, able to absorb more than 20,000 tons of rainwater (38,000 m² * 0.6m = 22,800 m³). The absorbed rainwater can be completely recycled for reuse or replenishing groundwater, other additional benefits include a reduced dengue virus prevalence rate and reduced heat island effect, etc. In the recent event of Taiwan’s worst drought in 56 years, LMSH was able to use its own sustainable water source without needing to ration water, proving that the JW Eco-Technology can be implemented to create JW Eco micro-flood detention spaces and underground reservoirs under pavements like roads, parking lots, and squares, “Converting Stormwater into Resources by Creating City Water Banks”. Therefore, this is a new idea for adaptation solutions of extreme weather conditions.

Validation of a debris-flow rainfall threshold, calibrated with the Backward Dynamical Approach, using a back-analysis and a forecasting approach

Poster - Erich Plate Best Young Scientist

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Rainfall thresholds may be a key tool for the management of the risk related to rainfall-induced debris flows. Their reliability is crucial to properly forecast the possible occurrence of these phenomena and develop an effective early warning system. For this reason, thresholds prediction capability should be verified by performing a validation analysis.

This work aims to validate a rainfall threshold for stony debris flow calibrated with the Backward Dynamical Approach (BDA), an innovative method in which the rainfall volume relevant to a debris flow is estimated based on a simplified description of the dynamic of the phenomenon.

The validation is performed considering a subarea of the study zone employed in the calibration work and the debris flows and rainfall events that have occurred in a reference period outside the calibration one. The validation is composed of two analysis. The first one aims to assess the threshold validity in a back-analysis framework: the rainfall duration and average intensity related to the occurred debris flows are computed by applying the BDA method and compared with the calibrated threshold in the intensity-duration plane. The second analysis evaluates the threshold predictive capability in a forecasting context, simulating its use in an early warning system and considering all the rainfall events that occurred during the reference period. Since the BDA method cannot be applied in a forecasting context, each rainfall event is characterized by several possible rainfall conditions (i.e. durations and related intensities) and then categorized in true positive, false positive, false negative and true negative, based on the rainfall conditions location with respect to the threshold and the occurrence or not of a debris flow associated with the rainfall event. Finally, the threshold prediction capability is assessed by introducing skill scores. Both analyzes provide satisfactory results.

Debris flow, BDA, validation, forecasting, threshold

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