WORLD METEOROLOGICAL ORGANIZATION

REPORT OF THE FIRST MEETING OF THE REGIONAL ASSOCIATION II (ASIA) WORKING GROUP ON HYDROLOGICAL SERVICES (2017-2020)

Seoul, Republic of Korea
17 to 19 October 2017

FINAL REPORT
November 2017

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1. MORNING SESSION

1.1 At the kind invitation of the Government of the Republic of Korea, the third meeting of the Working Group on Hydrological Services (WGHS) of the WMO Regional Association II (Asia) was held in Seoul, Republic of Korea, from 17 to 19 October 2017.

1.2 The meeting was opened at 09:00 on Tuesday 17 October 2017 at the Han River Flood Control Office, Seoul, Republic of Korea.

1.3 Mr Hajoon PARK, Director General, Han River Flood Control Office, welcomed participants to the Republic of Korea and, in particular, to the Han River Flood Control Office. He noted the rising losses in the countries of Regional Association II (Asia) from natural disasters, with flooding being the largest contributor to losses from weather-related natural disasters. He also noted the increased severity of events leading to increased losses. He stressed the importance of the Working Group on Hydrological Services (WGHS) efforts pertaining to Water Resources Assessment (WRA), as this allows a Member to track current water availability and its predicted states. As such, this assists disaster managers with knowledge of potential drought and flooding, allowing early actions to be taken to reduce losses. He also noted the importance of the meeting in establishing the future work programme of the RA II WGHS. In closing, he wished everyone a pleasant stay in Seoul and for a successful meeting.

1.4 Mr Sung KIM welcomed everyone to the meeting and to the Working Group on Hydrological Services. He stressed the importance of each and everyone's contributions to the efforts of the working group, commenting that this meeting was very important in establishing the individual work plans. He requested everyone to introduce themselves. Mr Paul PILON, WMO Secretariat, thanked the Republic of Korea and the Han River Flood Control Office (HRFCO) for hosting the fourth meeting of the RA II WGHS, and welcomed everyone to the fourth meeting on behalf of the Secretary-General WMO, Mr Petteri TAALAS.

2. ADOPTION OF THE AGENDA AND ORGANIZATION OF WORK

2.1 The meeting was attended by 8 members of the WGHS, which were from 5 countries of RA II. One member of the WGHS sent his apologies for not being able to attend the meeting.

2.2 The list of participants is given in **Annex 1** to this report. Mr Paul PILON acted as Secretary for the meeting and Mr Sung KIM, Senior Research Fellow, Korea Institute of Civil Engineering and Building Technology (KICT), chaired the sessions of the WGHS.

2.3 Mr KIM noted the importance placed on this first meeting given its primary purpose was to prepare and agree upon the future work of members. Mr KIM briefly described the agenda, and the WGHS discussed it and adopted it with minor revisions (**Annex 2**).

3. PRESENTATIONS

3.1 Mr Paul PILON provided a presentation, which can be found on the WMO website[1], on the activities of the WMO Commission for Hydrology (CHy), on activities being undertaken stemming from its Fifteenth Session that was held in Rome in December 2016. He noted various major initiatives and reviewed the work plans of the three main focus areas adopted by CHy-15, as well as some major efforts, such as HydroSOS, HydroHub, WHOS, the WMO Flood Forecasting Inititive (FFI), and the new seamless Global Data-processing and Forecast System (GDPFS). He also pointed out that the CHy was making special efforts to link with the various RA Working Groups on Hydrology (WGsH), and noted that Ms Hwirin KIM, who is a member of the RA II WGHS, was also a member of the CHy Advisory Working Group (AWG).

3.2 Messrs Sung KIM and Paul PILON provided a presentation on decisions and recommendations of RA II (Asia) as a result of its Sixteenth Session that was held in February 2017 (please refer to the WMO website for the presentation). Mr Sung KIM noted that there were three items represented in decisions of the session (RA II-16 Decision 5.4) on Dynamic Water Resources Assessment Tool (DWAT), Guidelines for Verification of Hydrological Forecasts, and the software tool for implementing the index velocity methodology. These were presented to the WGHS as:

Major Accomplishments	Session	Decision
Dynamic Water Resources Assessment Tool (DWAT)	RA II-16	CHy: urges CHy to assess the Tool testing its ability and to provide guidance on its further development for global utility RA II: requests RA II Members to assess the Tool, testing its ability and to provide guidance to the RA II WGHS Chairperson on its further development for the benefit of Members
Guidelines for Verification of Hydrological Forecasts	RA II-16	CHy: urges CHy to review and assess the global utility of the Guidelines as a potential contribution to the WMO Flood Forecasting Initiative RA II: requests RA II Members to review and apply the verification procedures, reporting their results and views on the procedures to the RA II WGHS Chairperson
Software tool for index velocity method	RA II-16	CHy: urges CHy to assess the utility and applicability of the software tool and methods therein for measuring discharge under backwater and tidal influence RA II: requests RA II Members to test the Software Tool, reporting their results and views on the procedures to the RA II WGHS Chairperson

He noted that there was follow-up actions needed with both CHy and Members of the WGHS to reflect these in their work plans to allow adequate following-up on these accomplishments. Discussions also stressed that additional efforts were needed to bridge the meteorological and hydrological communities to allow making best use of advances in meteorological science in hydrological forecasting that can lead to more effective early warning systems. Mr KIM also highlighted that the RA II-16 had added a new thematic area to those that were already tabled. It was on cryosphere

[1] Presentations and material of the 1st Session of the WGHS can be found on the WMO website: http://www.wmo.int/pages/prog/hwrp/RA2/RAII-WGHS-I-Seoul2017.php

modelling, for which Mr Sergei BORSHCH had been appointed. In addition, Mr PILON provided a few slides on the *Pilot Project: Cryosphere Monitoring to understand Trends of Glaciohydrology of High Asia*, which was also adopted at RA-16.

3.3 Ms Jiyoun SUNG (Water Resources Information Center, Han River Flood Control Office) provided a presentation on the annual operating plan (AOP) and recent activities of the ESCAP/WMO Typhoon Committee Working Group on Hydrology. It was noted that there were several topics of interest on its AOP with that of the RA II WGHS. For example, earlier efforts had focused on developing an extreme flood forecasting system with a special focus on Lao PDR, Philippines and Thailand.

3.4 Ms SUNG also mentioned that within its new AOP, efforts will be undertaken to advance the use of radar data for flood forecasting in the Republic of Korea (ROK). It was also noted that another activity within the new AOP will be on advancing approaches for data quality control, including both field and office aspects. There was interest expressed on having the efforts on quality assurance guidance material shared with the WGHS members. It was mentioned that the new AOPs will start in 2018 and would eventually result in a technical report providing such guidance material in 2022, which would then be shared with the WGHS. This specific effort comprises two aspects, one is on developing a software system and the other focuses on developing the needed guidance material.

3.5 Ms Hwirin KIM introduced efforts that have been undertaken on developing the Dynamic Water Resources Assessment Tool (DWAT), which provides a local basin water resources assessment for policy development and planning purposes. She noted that Mr Cheol-Hee JANG has been making significant contributions to the development of DWAT. She indicated that a workshop on it is being planned for next year. She explained that the model has a water balance component, including snowmelt functionality, infiltration, evapotranspiration, channel routing and other hydrological cycle functionalities. Importantly, it can also include storage regulation structures, as well as a GIS pre-processor to facilitate setting-up the model on basins. She noted that the model has been applied in ROK, and they are applying it to a test basin in Thailand. She indicated that the English version of the manual should be available this year for CHy review, with plans to have a user workshop next year. Version 2 is slated for completion in 2019 and a training workshop is scheduled for 2020. Data requirements were given as being discharge, temperature, precipitation, solar radiation, wind speed, and relative humidity.

4. DEVELOPMENT OF THE WORK PROGRAMME

4.1 The work plans of all members were reviewed and finalized during the meeting. It should be noted that although Mr Xin Zhao, Leader in the provision of hydrological services, was not in attendance, his work plan is contained herein and has been reviewed by the chair of the WGHS, Mr Sung KIM, subsequent to the conclusion of this meeting. Hence, the work plans of all *appointed* members appear in this Chapter. Each work plan is introduced by a related section that outlines the efforts that will be undertaken during the intersessional period. Please note that efforts are being undertaken to identify an expert to lead the thematic area of mass movements (sediment disasters and debris flow). Once the individual has been appointed, his or her work plan will be developed and made available on the WMO website pertaining to this meeting.

4.2 Chairperson and Coordinator Expert Group on Measurements, Monitoring and Infosystems (EG-MMI)

4.2.1 The Work Plan of the RA II Working Group on Hydrological Services (WGHS) was developed to include all the deliverables and activities specified in Draft Resolution 5.2/4 (RA II-16) and Annex to draft Resolution 5.2/10 (RA II-16) RA II OPERATING PLAN 2016-2019. The Chair's work plan includes provision of assistance to the RA II President, attendance at the EC and WGHS meetings, promotion of the long-term operation of hydrological observation stations, submitting of the annual report to the president, designing and undertaking a Hydrological Survey of RA II, and leading the development of and championing the use of a Virtual Hydrology Forum for the WGHS.

4.2.2 The Expert Group on Measurements, Monitoring and Infosystems (EG-MMI) is comprised of four members including 3 thematic leads. The coordinator and thematic area of each member is listed below:

1 Coordinator EG-MMI
2 Leader in hydrometric measurements
3 Leader in mass movements (sediment disasters and debris flows)
4 leaders in provision of hydrological services

4.2.3 The coordinator will coordinate closely with each theme leader as mentioned above regarding their progress on their very important respective assignments and activities, to complete the tasks and to assess if work plans need adjusting.

4.2.4 As the RA II Regional Hydrological Advisor, Mr Sung KIM attended EC-69, the RA II Management Group (MG) meeting and the Regional Hydrological Advisors' meeting with the CHy AWG in Geneva in May 2017. He has also assisted the RA II president and has collected information for preparation of the RA II hydrological activities. He also attended the CHy Global Hydrological Status and Outlook System (HydroSOS) meeting in Entebbe, Uganda in September 2017 and advised on the initiation of development and implementation of the System as well as its South Asia Pilot Project. As the Chairperson, he helped organize this meeting, namely the 1st WGHS meeting for the 2017-2020 period in Seoul, 17-19 October 2017. As a broad result of this meeting, this report contains the WGHS work plans for the period that were developed by thematic leads. In order to undertake specific activities as Chair of the WGHS, Mr KIM has also requested and has obtained the list of RA II NHAs and a recently developed questionnaire for NMHSs that was prepared by the WMO Secretariat. He will be reviewed it as input to the design of the Hydrological Survey of RA II Members.

4.2.3 WORK PLAN: Chairperson of WGHS **Sung KIM**

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. In his capacity as Hydrological Adviser, provision of assistance to the president of RA II in accordance with the duties stipulated in Regulation 168 (b) of the WMO General Regulations	(a) Represent WGHS as and when required, (eg at MG and EC) (b) Attend meetings of chairpersons of Working Groups (c) Other duties as required of chairpersons WGHS (see General Regulation 168 (b))	• Hydrology and Water Resources issues remain a key aspect of the work of RAII • NMHSs are assisted in fulfilling their roles and responsibilities. • WGHS is adequately represented within the RAII environment.	• Resources are provided to meet the needs of the theme leaders in doing the work of the Working Group. • Secretariat support	• Meetings and other activities according to the WMO Schedule of meetings. • Report at WGHS meetings • Report at MG Sessions • Final Report to RAII-17 (2020).	• WGHS • RAII • MG • EC	• Attended EC-69 (Geneva, May, 2017) • Attended RA II MG (Geneva, May, 2017) • Attended HydroSOS Initiative Meeting (Entebbe, Sep. 2017)
2. Preparation of a Working Group implementation plan in consultation with the president and the Management Group of the Association, with reference to the key performance indicators/targets and action plans under the respective expected results of the RA II Strategic Operating Plan, to undertake	(a) Chair theme leader meetings of the WGHS to develop implementation plan (b) Coordinate the activiites of the Expert Group on MMI (b) Brief MG meeting on WGHS activities Submit annual report to RA II president	• WGHS implementation plan • Work Plan for the EG on MMI • Annual progress report	• Resources are sought to meet the needs of the theme leaders in doing their work	• WGHS meeting (2017) • WGHS implementation plan (Oct 2017) • Report at MG Sessions for consultation and submit a report to RA II president annually	• WGHS • RA II MG	• Develop WGHS work plan (Seoul, Oct 2017) • Report WGHS work plan to RA II president, Nov 2017

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
work on the various theme areas under the charge of the Working Group						
3. Participate in Executive Council sessions, when invited, representing the regional interests in relation to hydrology and water resources and to coordinate the WGHS activities with the Commission for Hydrology and other regional Working Groups on Hydrology	Attend EC meeting if required Develop WGHS work plan in consideration of CHy and other regional WGHS activities Organize WGHS meetings	• Meeting reports • WGHS implementation plan	• Resources are sought to meet the needs of the theme leaders in doing the work of the WGHS	• WGHS meetings (2017, 2018 and 2019) • WGHS implementation plan (Oct 2017) • Tracking progress annually of WGHS activities • Report at MG Sessions for consultation and submit a report to RAII president (2017)	• WGHS • RA II MG	• Attended EC-69 • Attend Hydrological Advisors Meeting during EC-69 • Report of WGHS and implementation plan (Oct 2017)
4. Preparation and submitting to the president of the Association an annual report by 31 December every year and a final report in time for presentation to the sixteenth session of the Association, both copied to the WMO Secretariat	Develop WGHS activity report with input from Coordinator EG-HA and thematic leaders	• WGHS activity reports	• Resources are sought to meet the needs of the WGHS theme leaders	• Submit annual reports to RAII president and WMO Secretariat (Dec 2017, Dec 2018, Dec 2019) • Submit final report to RA II president and WMO Secretariat (Dec 2020)	• WGHS • RAII MG • WMO	• Submit Annual Report (Dec 2017)
5. Promote long-term operation of	Encourage Members to	• Letter to National Hydrological	• RA II Survey Report on obs.	• Report to RA II president (2018)	• WGHS • RA II	• Requested List of NHAs

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
hydrological observation stations suitable for climate change and variability studies	maintain stations having long hydrological records for climate studies.	Advisors • Recommendations on improvements to the RA II Survey regarding NHSs including hydrological stations	• List of RA II National Hydrological Advisors		• WMO	
6. Improved knowledge of the status and structure of NHSs in RA II	(a) Design and conduct survey by e-mail of NHS' activities and status - hydrological observations - WRA and management activities - forecasting	• Survey report for hydrological services in RA II	• Hydrological survey questionnaire developed by WMO Secretariat • List of RA II National Hydrological Advisors	• Report work plan to RA II president (2017) • Develop survey questionnaire and send (2018) • Analyse survey results and complete report (2018) • Submit report to RA II President and Pres. CHy (2018)	• WGHS • RA II Members • WMO	• Received WMO questionnaire (2017) • Requested and received List of NHAs (2017)
7. Development and active use of an on-line RA II Virtual Hydrology Forum designed to facilitate broad engagement of experts throughout the Region in its activities and to help advance collaboration on its activities.	(a) Design and development of RA II Virtual Hydrology Forum on the WMO Homepage (b) Invite PRs of Members that do not have designated NHAs to do so (c) invite the RA II WGHS	• Operation of RA II Virtual Hydrology Forum • Increased number of Members having designated NHAs in RA II • Increased capacity building on hydrological issues of importance to RA II Members	• CHy Virtual Hydrology Forum • WGHS members • RA II National Hydrological Advisors • RA II Hydrological Experts	• Design and develop the RA II Virtual Hydrology Forum (2018) • Invite and use of the RA II Virtual Hydrology Forum (2019) • Facilitate and access the use of the Forum (2020)	• WGHS • RA II Members • RA II Hydrological Experts • WMO	• Requested and received List of NHAs (2017)

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
	members, RA II National Hydrological Advisors and hydrological experts in RA II to participate in the Forum (d) Facilitate the use of the RA II Virtual Hydrology Forum by e-mail					

4.3 Hydrometric measurements

4.3.1 In order to improve the accuracy of field measurements, it is necessary to review and research relevant techniques. It is also very important to use appropriate instrumentation and analytical techniques for specific flow conditions. The main objective of the activity is to provide a technical report or guidelines document, based on case studies for various conditions, comprising three parts: hydrological observation techniques; real-time discharge measurements (IRDIMS, Integrated Real-time Discharge Measurement System); and sediment measurement and development of rating curves.

4.3.2 In the activities on hydrometric measurements with quality and accuracy, the first action is to **'Provide guidance on the use of appropriate instruments and methods of observation in diverse conditions'**. In terms of the use of appropriate instruments and methods of observation in diverse conditions, the actions have focused on IRDIMS, which has been used to guide the design and construction and subsequently the operation for difficult sites. This was for measuring discharge under backwater and tidal effects in the Republic of Korea. The main purpose of this action is to provide technical information and guidance on the application of real-time discharge measurements for difficult to monitor sites.

4.3.3 Two sub-actions were conducted in this action plan: (1) Collection of the existing technical information of IRDIMS and (2) Case studies on the measurement of IRDIMS for 52 sites. Technical information related to real-time measurement include measurement instruments, method of discharge calculation, and the construction and operation of IRDIMS. Case studies were used to assess the result of measurements attained using IRDIMS for various specific conditions categorized on characteristics of flow conditions, such as tidal affected areas and backwater affected areas caused by weir, sluice gate, junctions, etc. These case studies also include an evaluation of the results by a comparative analysis using individual measurements and assessment of runoff between upstream and downstream stations. Technical report of case studies were completed and draft of the report has been prepared for review. In regards to the development of index ratings, the procedure and software tools (EDpad, MCDpad) have been introduced including analysis of the available measurement range of the ADVM and development of index rating curves, which have been developed using Microsoft Excel. Development of 2 software tools were completed and ready to be provided to other members to help standardize and facilitate developing index ratings for real-time discharge measurement. The user manual of the software tool was included in the appendix of the technical report.

4.3.4 The 2nd action to **'Improve sediment measuring techniques'** is achieved by providing technical information related to sediment measurement and a case study of how to do so reflecting various conditions. Two sub-actions were conducted in this action plan : (1) collection of the technical information related to measurement and analysis of sediment and (2) case studies on sediment measurement under various conditions. The collected technical information about sediment measurements will include existing and advanced new technologies and their application. Case studies will focus on sediment measurement under various conditions, including an analysis of the characteristics of suspended sediment in rising and falling flow conditions (known as a loop in the concentration-discharge or C-Q rating curve), comparative analysis before

and after construction using 4 major river projects, and the characteristic of suspended sediment for successive rainfall events. Outcome of this action will be a technical report, which was delayed and will be completed by Dec 2017.

4.3.5 In the activity of Calculation of runoff with quality and accuracy, the main action was entitled **'Focus on the development of H-Q rating curve'**. This action aimed to provide a report outlining procedures for developing the optimal H-Q rating curve under various conditions in the Republic of Korea and providing technical information about improved development procedures and introducing a development tool for establishing the H-Q rating curve. Two sub-actions were conducted in this action plan: (1) Collection of the existing technical information and (2) Case studies on development of the H-Q rating curve under various field conditions. For the first sub-activity, the procedure of discharge measurement and its calculation, the evaluation of the measurement and its data quality control (QC), and procedures for the development and evaluation of rating curves were introduced in software tool being used in Hydrological Survey Centre (HSC) of the Republic of Korea. Case studies were used to illustrate the proper development of H-Q rating curves under various fields conditions based on practical experience. The case studies also recommended methodologies and introduced the evaluation using the basin's water balance. The case studies focused on developing rating curves for backwater affected areas as caused by weirs and stream junctions. Consideration was also given to the development of H-Q rating curves that reflect changing aquatic vegetation conditions (method and procedure of vegetation monitoring), and the effect of stream-bed changes on H-Q rating curves. The technical report for this action plan is in preparation and should be completed by Dec 2017. Furthermore, in this activity, the software tool (CalPad) was developed, which calculates discharge for all kinds of point velocimetry (Price type, ADV etc.) meters using midsection and mean section method. This software and user guide also are ready to be provided to other members.

4.3.6 The plan for the period (2017~2020) was prepared as an extension of activities that have been conducted during the last period. Firstly, related to real-time measurement system, the activity for **(1) providing guidelines for application of real-time measurement system (focused on IVM and IRDIMS) and development of new measuring technique** will be conducted. The guidelines will be specific and will give details as a user guide from installation to operation for measurement systems using IVM, such as IRDIMS. It will also be helpful in standardizing the use of IVM by having documented systematic procedures using relevant software tools.

4.3.7 In developing new measuring techniques to be applied to the IVM and IRDIMS, other measuring equipment, such as surface velocimetry, will be applied to measure the index velocity. It is necessary to undertake an applicability analysis on new equipment and develop new measuring techniques to be applied with the IVM. The test bed will be operated to analyze new techniques.

4.3.8 Secondly, the activity for **(2) improvement of sediment measuring technique** will develop the method to estimate suspended sediment using ADVM. The signal intensity of the ADVMs vary with concentration of suspended sediment. Using the ADVMs, concentration of suspended sediment can be approximated. In the Republic of Korea, suspended sediment has being measured every year using manual methods at the main hydrometric gauging station, and there are some IRDIMS stations using ADVM among them. The purpose of this activity is to develop techniques to estimate

suspended sediment through analysis on the variation of Signal Intensity (SI) of the ADVM with concentration of suspended sediment using data from the IRDIMS stations.

4.3.9 Lastly, in the activity for **(3) improvement and development of systematic procedure for use of rating curve**, there are two sub activities, providing specific guidelines on the development of rating curves and development of software tools. The specific guidelines will be for all procedures on developing rating curve, which will include discharge measurements using all kinds of instruments such as the current meter, ADV, ADCP, float rod, and surface velocimetry. It will also include material on maintenance and management of the measuring instruments, data processing and QC, and development and assessment of rating curves for various conditions. These guidelines will be specific and will provide a detailed user guide for practical field work. In regard to development of rating curves, the second sub-activity is to develop relevant software for all procedures. This will provide software tools to calculate discharge for each measuring instrument and develop and evaluate rating curves, which will be connected with guidelines developed by the first sub-activity.

4.3.10 In addition, software tools (EDPad, MCDPad) have been designed to develop index ratings as part of the last session's activities, which are ready to be provided to other members. Furthermore, we expect these software tools to be widely used for procedures related to real time discharge measurements. So, a new deliverable in the work plan has been added. It is entitled **global application of software tools and methods for measuring discharge**. In this deliverable, an activity is the **assessment of applicability of software tools**, including methods for measuring discharge having backwater and tidal influences. These will be provided to CHy and RA-II members in order to review and test the software tools. Based on these reviews, the software tools will be improved or supplemented to enhance them.

4.3.11 WORK PLAN: Hydrometric Measurements — Youngsin ROH

Deliverables	Activity	Outputs	Resources	Milestones	Linkages	Progress
1. Improvement in hydrometric measurements in both quality and accuracy	a) Providing guidelines for application of real-time measurement system and development of new measuring techniques • Providing guidelines for application of IVM and IRDIMS • Development of new measuring techniques to be applied to the IVM and IRDIMS	• Guidelines related to IRDIMS - Installation and operations - Maintenance - Development of index ratings • Technical report on new applications of IRDIMS - New application using surface velocimetry - Case studies using test bed	Republic of Korea (ROK)	• Guidelines by Dec 2020 • Construction of test bed by Dec 2017 • Technical Report by Dec 2019	CHy ROK	
	b) Improvement of sediment measuring techniques • Development method to estimate suspended sediment using ADVM	• Technical report on estimation of suspended sediment using ADVM	Republic of Korea (ROK)	• Technical report Dec 2020	CHy ROK	
	c) Improvement and development of systematic procedures for use of rating curve • Providing specific guidelines for development of rating curves (for all procedures) • Development of software tools to calculate discharge (including post processing and data QC) and develop rating curves	• Guidelines on development of rating curves (from field measurement to assessment of rating curves) • Software tools - Discharge calculation for all kinds of instruments - Development of rating curves	Republic of Korea(ROK)	• Guidelines Dec 2018~ Dec 2020 • Software tools Dec 2018~ Dec 2020	CHy ROK	

Deliverables	Activity	Outputs	Resources	Milestones	Linkages	Progress
2. Global application of software tools and methods for measuring discharge	(a) Assessment of applicability of software tools • Request CHy to review and test software tools • Request RA II members to test software tools and report to WGHS Chairperson • Improvement of software by considering results of the testing	Software tools and methods for measuring discharge including backwater and tidal influence	• Republic of Korea (ROK) • CHy AWG • RA II Members	• Request test and review by Dec 2018 • Development of Ver 2.0 Dec 2019 • Development of Final ver. Dec 2020	CHy RA II	(Development of Ver. 1.0 has been completed in 2016)

4.4 Mass Movements (sediment disasters and debris flow)

4.4.1 As an expert is being sought for this thematic area, a draft work plan was developed and was inserted as a placeholder hereunder until the expert has been appointed and a work plan has been developed and approved by the Chair of the WGHS, Mr Sung KIM. Once approved, it will be entered herein.

4.4.2 WORK PLAN: Mass Movements (sediment disasters and debris flow) To Be Determined

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. Improvement in capacity to deal with water related disaster management (Hydrological Extremes)	• Attend seminars on sediment disasters in order to communicate and cooperate among member countries.	• Workshops on the provision of sharing knowledge for sediment disasters (e.g. attend workshop of TC DRR) • ODA projects which transplant knowhow to developing countries	• National Disaster Management Institute (Republic of Korea) • WMO/ESCAP Typhoon Committee, Disaster Risk Reduction (TC DRR)	• Report for feasibility survey for ODA projects by April 2016 • Attend Workshop of TC DRR on May 2015 • Attend International Workshop among Korea, Taiwan, and Japan	• SOP 2.1.3 • RA II • WMO Secretariat • TC DRR • ROK (MPSS and KOICA)	

4.5 Provision of Hydrological Services

4.5.1 The Work Plan of the RA II Working Group on Hydrological Services (WGHS) was developed to include all the deliverables and activities specified in Draft Resolution 5.2/4 (RA II-16) and Annex to draft Resolution 5.2/10 (RA II-16) RA II OPERATING PLAN 2016-2019. The work plan of hydrological services is to develop national and regional capacity-building programmes and related training activities for hydrological services. The main objective of hydrological services is to facilitate the rational development and operation of NHSs, including staff education and training, water-related risk management, increased public awareness of the importance of hydrological work, and provision of support through technical cooperation activities.

4.5.2 It will also help to achieve the result of well-trained and skilled staff available for integrated water resources management, and effective and efficient NHSs that meet users' needs through synthesizing of reports from individuals and participating countries in RA II on national and regional capacity development activities in hydrology and making recommendations on their enhancement.

4.5.3 WORK PLAN: Provision of Hydrological Services — Xin ZHAO

Deliverables	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. Development of national and regional capacity-building programmes and related training activities for hydrological services	• Synthesize reports from individuals and participating countries in RA II on national and regional capacity development activities in hydrology	• Computer files and/or collected printouts from individuals and participating countries in RA II on national and regional capacity development activities in hydrology • Report showing synthesized results and recommendations on their enhancement	• Hydrological capacity development programmes in RA II countries	• Request programme lists, materials and reports to national hydrological advisors in RA II (2019) • Synthesize reports (2019) •	• WGHS • RAII • CHy •	•
	• Synthesize reports from individuals and participating countries on training courses, seminars, and workshops in hydrology	• Report showing synthesized results and recommendations on their enhancement	• Hydrological capacity development programmes in RA II countries	• Synthesize reports (2019)	• WGHS • RAII • CHy	•
	• Make recommendations on their enhancement	• Report showing synthesized results and recommendations on their enhancement	• WMO hydrological capacity development programmes	• Make recommendations (2020)	• WGHS • RAII • CHy	•

4.6 Coordinator Expert Group on Hydrological Applications

4.6.1 The Expert Group on Hydrological Applications (EG-HA) is comprised of six members including 5 thematic leads. The coordinator and thematic area of each member is listed below:

1 Coordinator EG-HA
2 Leader in water resources assessment reflecting climate change and variability
3 Leader in water related disaster risk management
4 leaders in cryosphere modelling
5 Leader in flood forecasting
6 Leader in hydrological drought forecasting and prediction

4.6.2 The coordinator will coordinate closely with each theme leader as mentioned above regarding their progress on their very important respective assignments and activities, to complete the tasks and to assess if work plans need adjusting. The coordinator will also prepare the annual report for submission to the Chair of the WGHS.

4.6.3 The coordinator EG-HA will also develop recommendations on the best use of hydrological forecasts to support and facilitate flood management by disaster management authorities and flood fighting agencies. These recommendations will also be potentially useful for planning purposes.

4.6.4 WORK PLAN: Coordinator – Expert Group on Hydrological Applications Muhammad RIAZ

Deliverable	Activities	Output	Resources	Milestones	Linkages	Progress
1. Assist the chair in accomplishing his tasks	(a) Tasks as assigned by the chair	Various tasks achieved	Chair EG-HA	TBD	TBD	
2. Preparation of the annual report of EG-HA and submitting it to the chair .	(b) Regularly contacting the theme leaders to assess progress in their assignments and activities (c) Ensuring that the thematic work plans as submitted by the EG-HA are well coordinated and aligned with overall RA II and CHy AWG (d) Preparing input to WGHS annual reports.	Input to the Annual Report	Chair EG-HA	Input to annual reports November 2017, 2018 and 2019 Input to final report of the WGHS for RA II-17 by July 2020		
3. Development of recs on the best use of hydrological forecasts to support flood management decision making	• Review practices of water resource management agencies for averting losses from flooding and their use of flood forecasts • Interview flood management practitioners and decision makers to ascertain needs for	Draft recommendations on the best use of hydrological forecasts to facilitate wise flood management practices	Flood Management Experts, Flood Forecasters and decision makers	• Literature review by June 2018 • Interviews of small number of flood management practitioners by August 2018 • Interviews		

	flood forecasts to gain insights on their best use • Draft report on best practices making recs			of small number of decision makers by October 2018 • Prepare draft report on recs by Feb 2019 • Finalize report by May 2019		
4. Provision of assistance from the WGHS to RA II Pilot Project on Cryosphere	• Contacting RA II Pilot Project lead through PR of Pakistan to offer assistance • Developing separate Pilot Project work plan of the WGHS drawing on members of WGHS to advance project goals with Chair WGHS • Coordinating and tracking of WGHS input to Pilot Project with Chair	Work plan of the WGHS on Pilot Project to assist it in attaining its goals WGHS input to Pilot Project, based on work plan developed	WGHS members, OPACHE, NMHSs experts, University Professors, IAHS	TBD based on work plan developed		

4.7. Water Resources Assessment

4.7.1 The deliverable 'Improvement of water resources assessment techniques to assist decision making in water resources management' includes two activities, namely: (1) develop water resources assessment techniques (the Dynamic Water Resources Assessment Tool (DWAT)) and (2) provide guidance materials for DWAT.

4.7.2 During the meeting, Ms Hwirin KIM provided a presentation informing the WGHS of the efforts being undertaken in the Han River Flood Control Office, Ministry of Land, Infrastructure and Transport, Republic of Korea, with technical support on Water Resources Assessment being given by the Korea Institute of Civil Engineering and Building Technology. She provided a presentation explaining the concepts and approaches undertaken, including a description of the hydrological process model used within the DWAT beta version, and how various elements within the hydrological cycle are mathematically modelled. She noted that the DWAT had been originally conceived to assist long-term planning and policy assessment and development. Its application can allow assessment of land-use changes within the basin over time, the impacts on water availability under differing consumptive use scenarios, and the impact on availability due to climate change through the application of scenarios. DWAT is intended to help users, particularly policy specialists and water resource managers to identify current and future water management challenges and compare these with the current and past states of water resources availability. This tool also can improve understanding of the impacts of past and present water management practices on water resources and better understand interactions between climate, water and landscape. She noted that its use can contribute to water reform by providing nationally and regionally consistent water resources information and data, such as, surface water, groundwater, urban and agricultural water supply and use. Moreover, it will assist government policy formulation and the development of broad scale strategic plans and decision-making. She also indicated that it also has been adapted to allow for short to medium term use to facilitate local decision making on use of available water resources. Her presentation is available on the webpage for this meeting of the RAII WGHS.

4.7.3 The DWAT version 1.0 will include development of snowmelt function, pre-process GIS, paddy and a calibration function. The snowmelt function was strongly requested by the RA II vice-chair during RA II-16 for inclusion in future DWAT functionality. Hydrological models like DWAT require land use and soil data to determine the area and the hydrological parameters of each land-soil category simulated within each sub-catchment. Pre-process GIS capability will allow users to load land use and soil themes into the current project and determine the land use/soil class combinations and distributions for the delineated catchment. As there are many rice paddy dominated areas in RA II, paddy representation within the model was felt to be necessary. DWAT version 1.0 will also incorporate a calibration routine to increase accuracy of model results.

4.7.4 The deliverable 'Globally implemented DWAT to assist decision making in water resources management' includes: (1) a request to CHy to review and test DWAT; (2) the implementation of DWAT in select RA II basins; (3) the development of training material to allow broad implementation of DWAT; and (4) the organization of one small global DWAT workshop for members of RA WGsH including CHy AWG. The draft DWAT manual will be finished by the end of 2017 and will be provided to CHy so that it may be

reviewed as per the request of RA II-16. Following the review by CHy, training material will be developed.

4.7.5 The 1st global DWAT workshop will be hosted by HRFCO of MOLIT and KICT, Republic of Korea and will be held in 2018. The intent of the workshop is to make DWAT widely known and used by an initial group of countries. Experts from each WMO Region and the AWG will be invited to participate in the event. Data will be requested from trainees in advance of the workshop. A DWAT webpage will be developed and will be hosted on the WMO website. It will report among other items on user manual and case studies that resulted from the 1st Global DWAT Workshop.

4.7.6 WORK PLAN: Water Resource Assessment — Hwirin KIM

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. Improvement of water resources assessment techniques to assist decision making in water resources management	(a) Develop water resources assessment technique(DWAT, Dynamic Water resources Assessment Tool) (b) Provide guidance materials for DWAT(water resources assessment technique)	• DWAT 1.0 Software • User manual for DWAT 1.0	• Han River Flood Control Office (HRFCO),Min. of Land, Transport and Infrastructure (MOLIT), ROK • Korea Institute of Civil engineering Technology (KICT)	• Completion of DWAT version 1.0 by December 2017 • Draft manual of DWAT by November 2017 • Development of snowmelt function - by March 2018 • Completion of DWAT version 1.x to include snowmelt by March 2018 • Final user manual for DWAT by October 2019	• RA II • CHy AWG	• (DWAT beta version was completed in 2016)
2. Globally implemented Dynamic Water Resources Assessment Tool (DWAT) to assist decision making in water resources management	(a) Request CHy to review and test DWAT (b) Implement DWAT in select RA II basins (c) Develop training material to allow broad implementation of DWAT (d) Organize and conduct one small global DWAT workshop for members of RA WGsH including CHy AWG	• Training Material for DWAT 1.0 • Report on case studies for DWAT 1.0 application	• Han River Flood Control Office (HRFCO),Min. of Land, Transport and Infrastructure (MOLIT), ROK • Korea Institute of Civil engineering Technology (KICT) • CHy AWG	• Request CHy review by November 2017 • Collect data for case studies by May 2018 • Invite Chairs of RA WGsH and Pres. CHy to appoint trainees and request data from trainees of the 1st Global DWAT workshop by August 2018 • 1st Global DWAT	• RA WGsH • CHy AWG	• (Workshop on DWAT progress was held in October 2016) • Case studies are being collected and DWAT 1.0 is being implemented in basins in Korea and Thailand

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
				workshop by October 2018 • DWAT webpage by December 2018 • Report on case studies of DWAT 1.0 by March 2019		

4.8 Water-related Disaster Risk Management

4.8.1 Improving the understanding of the potential impacts of severe hydrometeorological events poses a challenge to National Multi Hazards Early Warning Centres and their partner agencies. This work plan is being developed for Water-related Disaster Risk Management in order to improve National and Regional Flood Forecasting and Warning capabilities for disaster risk management. The key objective of the work plan is to move from flood forecasts and warnings to flood impact-based forecast and warning services. The work plan deliverables consists of (1) Enhancement of use of national and regional hydrological forecasting for water-related disaster management (Hydrological extremes of floods) and (2) the improvement of the availability of risk-based information upon which to base risk-based riverine flood forecasting and flood management activities.

4.8.2 In order to carry out this deliverable, the main activities were felt to include:

- organizing a workshop involving some South and Southeast Asian countries to inform national disaster agencies of typical forecast products and seek input on tailoring products and services to meet their needs;
- preparing guidance material on critical needs of NDMAs for flood forecast and landslide products;
- training of hydrologists on flood risk mapping and risk-based flood forecasting techniques;
- developing a Concept Note on a Pilot Project to implement Flood Risk Mapping and Impact-based Flood Forecasting on one targeted damage centre (community); and
- implementing impact-based flood forecasting for advancing Flood Risk-based Warning Services for the targeted damage centre (community).

4.8.3 The pilot project for the flood risk-based warning service will be implemented for one targeted damage centre (community) as a case study. In order to implement this flood risk-based warning service project, a training workshop will be organized. Financial assistance will need to be acquired, and there will need to be collaboration with others who have the additional necessary expertise, resources and knowledge to undertake the activities.

4.8.4 WORK PLAN: Water-related Disaster Risk Management — Htay Htay THAN

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. Enhancement of use of national and regional hydrological forecasting for water-related disaster management (Hydrological extremes of floods)	(a) Organize a workshop involving some South and Southeast Asian countries to inform national disaster agencies of forecast products and seek input on tailoring products and services to meet their needs (b) Prepare guidance material on critical needs of NDMAs for flood forecast products	• Documentation of needs and requirements of national disaster management agencies for hydrological forecast products and services	• RAII members • National DMA experts • Funding for workshop • Forecast experts • HRC	• Workshop in October 2018 • Draft Report - February 2019 • Final Report - April 2019	• WGHS • RAII • FFI-AG • OPACHE	•
2. Improvement of the availability of risk-based information upon which to base risk-based riverine flood forecasting and flood management activities	(a) Training of hydrologists on flood risk mapping and risk-based flood forecasting techniques (b) Developing Concept Note on Pilot Project to implement Flood Risk Mapping and Impact-based Flood Forecasting on one targeted damage centre (community) <u>Pilot Project</u> (c) Developing the location-based flood disaster risk information	• Trained hydrologists on flood risk mapping and risk based forecasting • Concept Note for Pilot Project and bankable proposal • Documentation on flood disaster risk information requirements • Documentation on gaps, obstacles, challenges and requirements for flood disaster risks for the targeted disaster centre (community) • Documentation on	• Funding to conduct necessary training workshop(s) • Funding of Pilot Project - Funding for meeting(s), workshop(s), conducting work, etc • OPACHE	• Training Workshop early June 2018 • Concept Note and bankable proposal by August 2018 • Collection of the flood disaster risk information, gaps, obstacles, challenges and requirements - August 2018 • Documented functional requirements for impact-based forecasting and warnings - November 2018	• WGHS • RAII • WMO	•

	requirements for one damage centre (community) of an RA II target community as a case study (d) Assessing the gaps, obstacles, challenges and requirements for flood disaster risk mapping of the targeted disaster centre (community) (e) Developing the functional requirements for impact-based forecasting& warning (f) Implementing impact-based flood forecasting for advancing Flood Risk-based Warning Services for the targeted damage centre (community)	functional requirements for impact-based forecasting and warnings • Documentation of pilot project on Impact based Forecast and Flood Risk-based Warning Services		• Flood Risk maps are available for risk-based flood forecasts and warnings for targeted damage centre by June 2019 • Implementing the pilot project (November 2018-December 2020) • Pilot Project Report on Impact based Forecast and Flood Risk-based Warning Services - December 2020		

4.9 Cryosphere Modelling

4.9.1 Cryosphere and cryoshperic processes are wildly distributed in Asia as in the northern part of this continent, as well as in high mountainous areas. They strongly influence not only human life and infrastructure, but also the features governing river streamflow formation. Hydrological models applied in cold climate conditions, as a rule, take into consideration cryospheric processes. The most developed models are the snow models and ice models that describe the processes of snow pack and ice cover formation, accumulation and thawing. The other component of cryosphere that plays a huge role in the formation of snow melting water losses in the plain river basins is the depth of soil freezing during the winter. For a long time, hydrologists attempted to describe the winter processes in the soil layer of river basins as well as possible. Now there are many schemes describing these processes, which may be included in hydrological models for operational streamflow forecasting. It is necessary to determine the usefulness of these schemes for use in hydrological runoff formation modelling.

4.9.2 The thematic area of cryosphere modelling, with an emphasis on their contributions to operational hydrological modelling of river runoff and groundwater, is a new direction for the WGHS RA-II. RA II-16 (Decision 5.2/4), which was held in Abu Dhabi, United Arab Emirates, 12-16 February 2017, specified the inclusion of cryosphere modelling as one of the terms of reference for the RA-II WGHS for the period from 2017 to 2020. Preparation of material and provision of guidance on modelling of cryosphere components with an emphasis on their contributions to streamflow discharge and groundwater in river basins have be developed and provided as a result of this new mandate.

4.9.3 During this new period of activity, the expert in cryosphere modelling will investigate the ability of cryosphere models to adequately describe the processes of: snow cover formation, accumulation and ablation; freezing and thawing processes in soil; and modelling of glacier morphological processes. It will be necessary to explore the ability of cryosphere modelling routines used in operational hydrological practice. As result of this activity, a technical report will be prepared on “The influence of cryospheric processes (including modelling) on the generation of river discharge and groundwater levels in Asia”. Training material on best practices for modelling cryospheric influences on river discharge and groundwater levels will be developed and provided. On the bases of reviewed material, recommendations on best practices for mathematical modelling of cryospheric processes will be made for use in operational hydrological modelling of streamflow discharge. It is anticipated that this will result in improvements in modelling the influence of cryosphere processes on the formation of river discharge and the existing models of freezing and thawing processes in the cryosphere.

4.9.4 The prepared document will be useful to operational hydrologists of NMHSs in Asia and to those attempting to model cryospheric processes for the generation of streamflow discharge and groundwater levels.

4.9.5 WORK PLAN: Cryosphere modelling. Sergei BORSHCH

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
1. Improvements to the mathematical representation of cryospheric processes in operational hydrological forecasting models (excluding GLOFs)	(a) Reviewing suitability of and make recommendation on best practices for mathematical modelling of the cryosphere excluding GLOFS (b) Developing guidance material on (a) with an emphasis on their contributions to streamflow discharge and groundwater (c) Reviewing suitability of and make recommendation on best practices for mathematical modelling of the cryosphere with emphasis on glacier morphology	• Technical report on review of the "experiences on modelling of snowpack and glacier component in operational hydrological modelling to produce streamflow discharge and ground water contributions" • Training Material on modelling of cryosphere components within hydrological modelling with an emphasis on their contributions to streamflow discharge and groundwater	• AWG Members, • HMC of Russia, • SHI (Russian State Hydrological Institute) • AARI (Russian State Research Center "Arctic and Antarctic Research Institute"), • YAHMS (Yakutsk Administration of the Hydro meteorological Service) • FESRHMI (Far East Scientific Research Hydrometeorological Institute), • WSRHMI (West-Siberia Scientific Research Hydro meteorological Institute), • NMHSs with expertise in snowpack process modelling	(a) Gathering of reference material, documents and investigations about the main cryospheric components in the plain and mountain river catchments of Asia with an emphasis on *modelling of snowpack and glacier morphological processes*. (March 2018). (b) Gathering of background material, documents and investigation about the influence of cryosphere processes, excluding GLOFs, on the formation of *river discharge* in plain and mountainous river catchments of Asia. (July 2018). (c) Gathering of background material, documents and investigation about the influence of cryospheric processes on the formation of	OPACHE's Artic-HYCOS Polar RCCs WIGOS Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS)	

				groundwater in Asia. (September 2018). (d) Gathering of back-ground material, documents and investigations about the *modelling of freezing and thawing processes of soil* in operational hydrological modelling of streamflow discharge". (March 2019). (e) Technical report on "The influence of cryospheric processes (including modelling) on the generation of river discharge and groundwater levels in Asia - Draft Report (May 2019) - Final Report (August 2019) (f) Training material on best practices for modelling cryospheric influences on river discharge and groundwater levels		

4.10 Flood Forecasting

4.10.1 A number of National Meteorological and Hydrological Services already have experiences in developing and applying recommended practices in flood forecasting. Such services engage both hydrologists and meteorologists in the process. There is also sharing of meteorological and hydrological data and model outputs. However, many flood forecasting systems have separate hydrological and meteorological models, and there is a need to couple the numerical weather forecasts both temporally and spatially to meet the needs of hydrological models that are producing the flood forecasts. Thus, having a recommendation on use of numerical weather forecast and documenting the approaches to ascertain the deterministic error of ensemble outputs of numerical weather prediction will be helpful

4.10.2 The Flash Flood Guidance System (FFGS) has been developed by the Hydrologic Research Center in San Diego (USA), and it is being implemented with the assistance of the USAID/OFDA, NOAA NWS and WMO. The System is now being used in several countries. The SAsiaFFG application is underway. It would be beneficial to prepare, document and disseminate verification results for the SAsiaFFG System with assistance of some of the participating countries' experts. As well, as part of this effort, feedback on use of systems by forecasters will be obtained.

4.10.3 To assist in improving the accuracy of hydrological forecasts, a report has been prepared entitled "Guidelines for verification of hydrological forecasts. It is felt that this report will be useful for professionals involved in operational hydrological forecasting, as well as for professionals involved in the development of forecasting methods. The Draft Version of the above report was submitted to CHy in 2016 by Mr Sung KIM on behalf of the WGHS. This report is under review by CHy, and once the review has been completed, the report will be finalized.

4.10.4 WORK PLAN: Flood Forecasting — Sangay TENZIN

Deliverables	Activity	Outputs	Resources	Milestones	Linkages	Progress
1. Improvement in hydrological warnings capability through enhanced and effective cooperation with other NMHSs (2.1.1)	(a) Preparing recommendations on the use of numerical weather prediction outputs in flood forecasting (b) Documenting approaches to ascertain the deterministic error of each ensemble element of a NWP output, for example over the previous thirty day period, using this deterministic signal to provide a weighting on the confidence of the forecasted ensemble elements (c) Preparing training material on (b) for NHSs	(a) Guidance on the use of NWP outputs for use in flood forecasting systems (b) Technical report on the approaches to establishing the deterministic error in NWP outputs and how they should best be used in establishing hydrological forecasts with enhanced accuracy.	NCHM, Bhutan, ICIMOD, IMD, RIMES, Scientific papers, NHMC of Russia	(a.1) Gathering of background material and documents on the use of NWP output in FFS and associated activities - January 2018 (a.2) Preparation of Draft Guidance material - August 2018 (a.3) Final document on Guidance - October 2018 (b.1) Gathering of materials on NWP error and EHP - January 2018 (b.2) Preparation of Draft Report on recommended procedures – June 2018 (b.3) Final Report on approaches - Sept 2018 (b.4) A draft document on basin scale NWP Rainfall/Temp bias correction by April 2018	OPACHE's FFI-AG CHy AWG member with expertise in ensemble hydrological prediction (EHP)	
2. Issuance of flood, flash and urban warnings and constantly improving upon them (2.2.1)	(a) Documenting verification results for the SAsiaFFG System with some of the participating countries' experts and obtaining feedback on use of systems by forecasters	(a.1) Report documenting verification results. (a.2) Report documenting experiences, including recommendations on approaching	(a) Hydrologists and meteorologists of the SAsia countries on use of the FFGS in operative hydrological practice.	(a.1) Background material and documents on the FFGS used in South Asian countries and associated activities - April 2019 (a.2) Preparation of Draft Reports on verification results and feedback of forecasters on FFGS– June	(a) NMHSs Hydrological Research Center in San Diego (USA), WMO	

		implementation of FFGS and its use.		2019 (a.3) Final Report - Sept 2019 (a.4) Participate in Project Steering Committee meeting to present reports' results– According to SAsiaFFGS plans 2019-2020		
	(b) Develop the final version of guidelines for verification of hydrological forecasts with S Borshch (author).	(b) Final version of guidelines for verification of hydrological forecasts.	(b) S Borshch	(b.1) To receive and analyze the review comments on the draft guidelines – once they are available (b.2) To prepare the final version of guidelines – March 2018	(b) WGHS S Borshch	

4.11 Hydrological Drought Forecasting and Prediction

4.11.1 The work plan is being developed for the hydrological drought forecasting and prediction in order to improve National and Regional Drought Forecasting and Prediction capabilities for disaster risk management. The very objective of the deliverable is to provide runoff outlooks every 3 months using 10-day time steps for all the key basins in Bhutan and providing them to major water users.

4.11.2 This deliverable will be undertaken for the dry season. The first step is the development of the hydrological methodology. This includes determining seasonal and 10-day moving precipitation depths for the key basins using basin average Precipitation, determining seasonal and 10-day moving runoff using the river flow data for the key basins. Once these data have been created, efforts will then be dedicated to developing Precipitation-Runoff seasonal and 10-day relationships. Assessment of the uncertainty of the relationships will be conducted. Additional analysis will be decided once the outcomes from this effort has been assessed.

4.11.3 Using the seasonal precipitation forecast, the runoff for key basins will be computed for the dry season, provided there are satisfactory outcomes from the analysis performed in section 3.6.2.

4.11.4 Analysis will be undertaken to investigate the applicability of a recession curve approach for forecasting discharges. The use of various drought indices will also be explored for dry season streamflow.

4.11.5 Finally, an evaluation of the hydrological seasonal outlooks will be undertaken by analyzing statistically the differences resulting from use of the outlooks versus no outlook scenarios through workshop/meeting and comments. Feedback for improvement of the deliverable will be collected from users.

4.11.6 WORK PLAN: Hydrological Aspects of Drought — Pema WANGDI

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
1.Improve National and Regional Drought Forecasting and Prediction capabilities for disaster risk management through enhanced and effective cooperation with other NMHSs	(a) For the dry season, develop hydrological methodology: - Determine seasonal and 10-d moving P depths for the key basins using basin average P - Determine seasonal and 10-d moving runoff using the river flow data for the key basins - Develop P-R seasonal and 10-d relationships and assess uncertainty - Using the seasonal P forecast, calculate the R for key basins (b) For the dry season, investigate the applicability of a recession curve approach for forecasting discharges. (c) Investigate the use of various drought indices for dry season streamflow. (d) Provision of Seasonal	• Seasonal hydrological outlook report provided to major water users every 3 months based on - 10-day runoff forecasts for next 3 months period - assessment of water scarcity and deficits • Evaluation report of the efficacy of seasonal outlook	▪ Hydrology and Water Resources Services Division, NCHM, Bhutan experts ▪ Forecast of weather and climate data of NCHM, Bhutan ▪ Research documents	• Preparing data and information to develop the seasonal hydrological outlook – Dec 2018 • Draft Evaluation Report for comments and feedback – Jan 2019 • Final Evaluation Report- Oct 2020	• WGHS • HydroSOS • RAII • WMO • NMHSs • UK Met Office and ECMWF, • APCC, Korea	

Deliverable	Activities	Outputs	Resources	Milestones	Linkages	Progress
	Hydrological Outlooks to water managers - Provide runoff outlook report every 3 months using 10 day time steps for all the key basins in Bhutan. (e) Evaluate Hydrological Seasonal Outlooks - Analyze statistically the differences resulting from use of the outlooks versus no outlook scenarios through the workshop/meeting, comments, feedback for improvement					

5. ADOPTION OF THE REPORT

5.1 Participants agreed that the draft final report would be circulated to participants for review with a two week period for provision of revisions. Mr Sung Kim would update the report pertaining to the work plan for the member who was not in attendance and the yet-to-be-appointed member. Once their views have been incorporated, the report would be updated and placed on the WGHS website. It was agreed that the final endorsement of the report should be sought from the Chair of the Working Group before finalizing it and seeking approval of the President of RA II for its publication.

6. NEXT MEETING

6.1 The dates and location for the next meeting of the Working Group on Hydrological Services were tentatively set as 23-25 October, 2018, in Thimbu, Bhutan. The Chair noted with appreciation the kind offer of the representatives from Bhutan to host the next meeting and will await confirmation of the representatives on their offer.

6.2 During the discussions on the potential location of the next meeting of the WGHS, Ms Hwirin KIM noted that there was a workshop on DWAT that was also being tentatively planned for April or May of 2018., which would also be a 3-day event. She indicated that invitations would be sent in advance of the event and would also request data for one basin from each participant's country. This would allow time for the workshop organizers to set-up the model. The event would allow the participants to calibrate and tune the model and to test its use for various purposes. She anticipated extending invitations to an expert from each WMO Region and interested members of the CHy Advisory Working Group.

7. CLOSURE OF THE MEETING

7.1 The Chairperson, Mr Sung KIM, thanked the participants and the WMO Secretariat for their contributions and professionalism that made the meeting a success. He also thanked experts for their hard work and indicated his pleasure with the high quality of plans that had been developed and finalized at the meeting.

7.2 Mr P. PILON expressed his gratitude on behalf of WMO and the participants of the meeting to the Government of Korea for their having provided financial assistance for the event and for the provision of the excellent meeting facilities. He also thanked Mr Sung KIM, Mr Cheol-hee JANG and all staff in supporting the effective organization of the meeting and for their efforts and assistance. He also thanked Mr Sung KIM specifically for his leadership in crafting the work plans of the WGHS and for chairing a very effective meeting. In closing, he underscored the importance of fulfilling the work plans as outlined prior to the next session of RA II to be held in the 4th quarter of 2020, not only for the benefit of National Hydrological Services in RA II, but for all Regions.

7.3 Participants thanked everyone for the excellent, productive meeting.

7.4 The meeting closed at 18:00 on the 19th of October 2017.

ANNEX 1

List of Participants - RA II (Asia) Working Group on Hydrological Services (WGHS)

(Seoul, Republic of Korea, 17-19 October 2017)

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ANNEX 2

World Meteorological Organization **RA II - WGHS/Doc. 1**

REGIONAL ASSOCIATION II
WORKING GROUP ON
HYDROLOGICAL SERVICES

SEOUL, REPUBLIC OF KOREA
17 TO 19 OCTOBER 2017

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FINAL AGENDA

REGIONAL ASSOCIATION II – ASIA (RA-II Asia)
WORKING GROUP ON HYDROLOGICAL SERVICES (WGHS)

Fourth Session

Han River Flood Control Office
Ministry of Land, Infrastructure and Transport
Seoul
Republic of Korea

17 to 19 October 2017

Tuesday 17 October

Morning Session (09:00 – 12:00, Moderator: Dr. Hwirin KIM)

- Opening of the session and welcome speech by Director General of Han River Flood Control Office
  (Mr. Hajoon PARK, Director General)

- Introduction of participants and adoption of the agenda
  (Dr. Sung KIM)

- Report on activities of the Commission for Hydrology (CHy) as a result of the 15th session of the CHy, December 2016
  (Dr. Paul PILON)

- Report on decisions and recommendations of RA-II, including the RA-II Operating Plan 2016-2019, as a result of the 16th session of RA-II, February 2017
  (Dr. Sung KIM and Dr. Paul PILON)

- Liaison with regional bodies and programs including the ESCAP/WMO Typhoon Committee
  (Ms. Jiyoun SUNG)

- Discussion on application of the Dynamic Water resources Assessment Tool (DWAT) and identification of possible future improvements
  (Dr. Hwirin KIM)

Afternoon session (13:00 – 17:30)

- Discussion on follow-up and implementation of action items as a result of the CHy and RA-II sessions
  (Dr. Sung KIM)

- Pilot Project: Cryosphere Monitoring to understand Trends of Glaciohydrology of High Asia (Dr. Paul PILON)

- Presentation and discussion of work plans for EG-MMI (Coordinater: Dr. Sung KIM)

  - Hydrometric measurements (Dr. Youngsin Roh)
  - Mass movements (sediment disasters and debris flows) (Mr. Sangay Tenzin)
  - Provision of hydrological services (Mr. Xin Zhao)

- Presentation and discussion of work plans for EG-HA (Coordinater: Mr. Muhammad Riaz)

  - Water resources assessment reflecting climate change and variability (Dr. Hwirin KIM)

Welcoming reception by HRFCO (19:30 – 21:00)

- Han River Cruise hosted by Director General of the Han River Flood Control Office

Wednesday 18 October

Morning session (09:00 – 12:00)

- Presentation and discussion of work plans for EG-HA (Coordinater: Mr. Muhammad Riaz)

  - Water-related disaster risk management (Ms. Htay Htay Than)
  - Cryosphere modelling (Dr. Sergei Borshch)
  - Flood forecasting (Mr. Sangay Tenzin)
  - Hydrological drought forecasting and prediction (Mr. Pema Wangdi)

Afternoon session (13:30 – 17:30)

- Field trip to the Gunnam Flood Control Reservoir near DMZ

Reception by KICT (17:30 – 19:30)

- Reception hosted by Director of Hydro Science and Engineering Institute, KICT (Goyang City)

Thursday 19 October

Morning Session (09:00 – 12:00)

- Finalization of the work plans

Afternoon Session (13:30 – 16:00)

- Discussion and adoption of the report of the meeting
- Closing session