

Training, research and application in hydrology and water resources development and management – how to bridge the gap?

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Due to advent of computations facilities and emerging technologies in the field of water sector, the gap between research and its applications is rapidly increasing. Problems and challenges in the field of hydrology and water resources have been discussed. Requirement of hydrological design aids as well as Decision Support Systems; necessity of preparation of standards, manuals, guidelines; strengthening of training and capacity building; importance of web portals and outreach plans; drawing talented young professionals to research institutions; upgradation of infrastructure; significance of crowdsourcing and engaging citizen scientists; integration of research and practice and action points for using emerging technologies are brought out.

Keywords: Capacity building, crowdsourcing, design aids, online training, research and applications, web portal.

As mentioned in the National Water Policy (2012), water, a scarce natural resource, is fundamental to life, livelihood, food security and sustainable development. India has more than 18% of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area. With rapidly growing population and improving living standards, the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day. Due to spatial and temporal variability in precipitation, the country faces the problem of flood and drought syndrome. Overexploitation of groundwater is leading to reduction in river flow, declining groundwater resources, and salt water intrusion in aquifers of the coastal areas. Over canal irrigation in some of the command areas has resulted in water-logging and salinity. The quality of surface and groundwater resources is also deteriorating because of increasing pollutant loads from point and non-point sources. Some major urban areas already face serious water shortages compounded by water pollution crisis, the latter often originating from water-dependent and water impacting agricultural and industrial activities. The climate change impacts are expected to affect populations directly by more frequent extreme events such as floods and droughts, rising sea levels, changes in the seasonal distribution and amount and type of precipitation such as snow and rain, storage components of the water cycle such as glaciers, snow pack and groundwater via recharge.

So far, the data collection, processing, storage and dissemination have not received adequate attention. Low awareness about water scarcity and its life sustaining and economic value results in its mismanagement, wastage, and inefficient use, as also pollution and reduction of flows below minimum ecological needs. In addition, there are inequities in distribution and lack of a unified perspective in planning, management and use of water resources. Further, questions relating to water resources management and usage cut across many economic and social sectors, including agriculture, fisheries, industry, urban development, energy, environment, tourism and public health.

The National Water Policy (2012) mentions that continuing research and advancement in technology shall be promoted to: (i) address issues in the water sector in a scientific manner. Innovations in water resources sector should be encouraged, recognized and awarded; (ii) it is necessary to give adequate grants to the states to update technology, design practices, planning and management practices, preparation of annual water balances and accounts for the site and basin, preparation of hydrologic balances for water systems, benchmarking and performance evaluation; (iii) it needs to be recognized that the field practices in the water sector in advanced countries have been revolutionized by advances in information technology and analytical capabilities. A re-training and quality improvement programme for water planners and managers at all levels in India, both in private and public sectors, needs to be undertaken; (iv) an autonomous centre for research in water policy should also be established to evaluate impacts of policy decisions and to evolve

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policy directives for changing scenario of water resources; (v) to meet the need of the skilled manpower in the water sector, regular training and academic courses in water management should be promoted. The training and academic institutions should be regularly updated by developing infrastructure and promoting applied research, which would help to improve the current procedures of analysis and informed decision making in the concerned departments and by the community. A national campaign for water literacy needs to be started for capacity building of different stakeholders in the water sector.

Need for bridging gap between educational training and real-world applications

India is currently facing numerous challenges in planning, development and management of water resources and a well-trained manpower is required for meeting these challenges to bridge the gap between research and its applications in hydrology and water resources development and management. However, 'water resources' has been a relatively neglected subject for education and training in the developing countries like India. The areas in which a general hydrology course is normally offered in the developing countries like India are usually civil engineering, agricultural engineering, geology and geography. Most of the academic institutions concentrate on scientific education leaving applications of the knowledge to be learnt on job training. However, no amount of training can substitute a well planned and executed education programme, which should enable fresh degree holders to be well trained and skilled professionals at the various levels. Hydrology and water resources include interdisciplinary subjects such as civil engineering, agricultural engineering, atmospheric science, meteorology, geology, geophysics, mathematics, computer science, chemistry, ecology, geo-informatics, etc. Thus, solution of the complex hydrological and water problems involves multidisciplinary approaches. However, at present most of the organizations lack adequate manpower, competence and skills for adopting multidisciplinary approaches and new emerging technologies for solving complex water issues based on the concept of integrated water resources management for sustainable development. The undergraduate education currently gives varying levels of coverage to the water resources subjects in civil and agricultural engineering. Our post-graduate education in hydrology and water resources has also not drawn adequate response. The details of the suggested changes and revisit of the educational curriculum for undergraduate and postgraduate levels as well as the strengthening of the training and capacity building are discussed as follows.

Efforts should be made for providing in-depth knowledge about the basic theories involved in water resources

planning, design and management. Some of the basic courses should be made compulsory; whereas, the advance courses should be electives. Undergraduate students should be exposed to the hydrologic design criteria for various water resources projects and procedures and practices of planning, design and management of water resources projects being followed in India and the world over.

For this purpose, the data requirements and infrastructure facilities required for providing the solutions of the various hydrological and water resources problems should be covered. Specialized courses in hydrology and water resources at undergraduate level should be designed and run at educational institutions for providing in-depth and focused knowledge of the required subjects for hydrologic analyses and water resources planning, development and management. The curricula should be uploaded on their website, so that every university/institution does not have to prepare it from scratch. Adequate infrastructural facilities including placement of well-educated, trained and competent faculty as well as the establishment of required laboratory and computational facilities should be taken up on priority basis. The laboratories should be well equipped with the state-of-art equipment. The students should be imparted field training for observation, processing, analysis, computerization and retrieval of the data. Training in traditional computer programming is not adequate to prepare students studying water resources to deal with available computing technology. There is a critical need to formalize the computing curriculum in water resources education to meet the challenges of the fast growing technology.

Postgraduate education in hydrology and water resources in India is being imparted at a number of academic organizations. The syllabi of the post graduation courses in hydrology and water resources are revised keeping in view past deliberations which later came up as recommendations of national and international organizations but a lot more needs to be done in view of the challenges being faced in the area of hydrology and water resources considering anthropogenic changes to global water and energy cycles, natural periodicity and climate change. Considering the present-day requirements of water resources in the country, there is a need to strengthen the postgraduate level programmes by including some of the advanced level courses such as coastal hydrology, snow and glacier hydrology, arid zone hydrology, forest hydrology, urban hydrology, environmental hydrology and eco-hydrology in addition to the conventional courses of surface water hydrology, groundwater hydrology and watershed management. Furthermore, some courses on the applications of modern tools and soft computing techniques in hydrology and water resources covering geographical information system (GIS); remote sensing, isotopic techniques; laboratory based studies covering soil investigations; hydraulic and hydrological

investigations; water quality, hydrological instrumentation; subjects covering the development and applications of software and use of information technology; operational research and soft computing techniques like artificial neural networks, fuzzy logic, genetic algorithm; basic concepts of artificial intelligence; expert system; integrated flood management, Decision Support Systems (DSSs) and their applications; integrated water resources development and management, are required to be appropriately covered. The postgraduate course should be framed with a six-month or one-year project work, wherein, students are given water resources problems for solving, after reviewing the existing knowledge in the area. It could be a research project or development of software integrating the latest knowledge in the courses leading to integrated planning, development and management of water resources.

Adequately trained manpower is necessary to improve the capabilities of operational organizations at the Centre and in the states with regard to observations as well as primary and secondary processing of hydrological data. Though there is no regular course for technicians training in hydrology, meteorology and other related fields, various organizations like Central Water Commission, India Meteorological Department, Central Ground Water Board, State Irrigation Departments, etc. dealing with subjects related to water resources have created facilities for on-the-job and in-service training of the personnel. However, the training programmes for technicians and observers are highly inadequate. The education and training programmes for the observers and technicians may be taken up by the polytechnic institutes, Industrial Training Institutes (ITIs) and various data collecting organizations such as Central Water Commission (CWC), India Meteorological Department (IMD), Central Ground Water Board (CGWB), Central Water and Power Research Station (CWPRS), Central Pollution Control Board (CPCB) and various state irrigation and water resources organizations.

Strengthening of training and capacity building programmes

Continuing education programmes, summer courses and refresher courses are being organized for providing an overview of the new technologies and their applications in hydrology and water resources. Such programmes are not only being organized by academic institutions like IITs, engineering colleges but also by some of the central and state government organizations such as National Water Academy, Central Water Commission; Rajiv Gandhi National Ground Water Training and Research Institute, Central Ground Water Board; National Institute of Hydrology; Central Water & Power Research Station, India Meteorological Department; Department of

Hydrology, IIT, Roorkee; Department of Water Resources Development and Management, IIT, Roorkee; National Remote Sensing Centre; Water and Land Management Institutes, Technical Teacher Training Institutes, Staff Training and Irrigation Research Institutes in states, etc. Karnataka Engineer Staff Training College at Krishnarajasagar, Engineering Staff College at Nasik and other similar state institutes for training of in-service personnel in various areas of water resources. National Institute of Hydrology, Roorkee has made a remarkable contribution through organization of short duration training workshops and training courses at Roorkee and in various states for transfer of technology with the main emphasis on latest developments in hydrological analyses, design and software applications. The Institute has also organized a number of training programmes for the middle level officers of the central and state organizations who have participated in the World Bank funded Hydrology Project Phase-I and Phase-II. The institute has provided trainings to a large number of participants from central government, state governments and academic organizations under its technological transfer and capacity building programmes. Some of the important areas in which the training programmes have been organized include: observation, processing and analysis of precipitation data; basic hydrology; flood frequency analysis; groundwater modelling; flood routing and flood forecasting; design flood estimation; reservoir operation; urban hydrology; GIS and remote sensing applications; snow and glacier hydrology; water quality modelling; project hydrology; hydrological modelling; applications of soft computing techniques; assessment of impact of climate change on water resources, etc.

For the senior level officers, refresher courses of one or two days duration should be organized on the specialized topics so they can stay updated with recent research. In such courses the officers may be apprised about the latest developments in the computational facilities and the role and applications of information technology. Some of the specialized topics on which refresher courses may be organized for such officers include hydrological design aids, software applications, information technology (IT) applications for data management, applications of GIS and remote sensing techniques, modern tools for hydrological investigations and analysis and social sciences. It would be helpful in making them aware of the existing gaps in the practices being followed and available improved procedures and methodologies for planning, design and management of water resources. It would also be helpful in developing the required infrastructure facilities and well trained man-power for better development and management of water resources. A major problem is that, many of the senior level officers are unable to understand the concerns of stakeholder communities and address them. They are also unable to articulate justifications or correct popular misconceptions because they often simply

dismiss them as 'common people do not understand' without realizing they also have some knowledge gaps in understanding social issues. Often these result in 'miscommunication' on both sides and big projects fail after a lot of money has already been invested. Hence, there should be continuous interaction with the stakeholders through workshops and interaction sessions.

There should be active cooperation among the organizations and institutes who are involved in the applications of the emerging techniques such as GIS and remote sensing, isotopic techniques, hydrological modelling, soft computing techniques, water quality modelling, assessment of impact of climate change, down scaling of GCM and RCM data, development and application of DSS, etc. Similar efforts should be made by the educational and research institutions by providing continuing education and training to the engineers and academicians of the organizations engaged in water resources planning and development. For organization of some of the training programmes faculty should be exchanged for knowledge sharing and capacity building. Some of the international training courses should be organized for the participants from SAARC, African and Afro-Asian countries. Some of the scientists and engineers should be provided opportunities for undergoing trainings in the developed Asian, European and American organizations. As solution for the complex hydrological and water resources problems involves multidisciplinary approaches and presently most of the organizations lack the adequate manpower, competence and skills for adopting the multidisciplinary approaches for solving complex water issues; hence, interdisciplinary trainings should also be imparted to match stakeholder needs and concerns. Such efforts would lead to improvement in the capabilities of operational and research organizations at the centre and in the states in the water resources sector.

Development of HDA, DSS, standards, manuals and guidelines

Development of hydrological design aids (HDA) based on the state-of-art knowledge and long-term data is a prerequisite for planning and designing of water resources projects. User-friendly software and user manuals of the HDA need to be developed and provided to the various concerned organizations and adequate training and capacity building should be carried out so that the user agencies are able to make full use of HDA. Under the World Bank funded Hydrology Project Phase-II, hydrological design aids namely: HDA 1: Assessment of Water Resources Potential – Availability/Yield Assessment; HDA 2: Estimation of Design Flood; and HDA 3: Sedimentation Rate Estimation have been developed by the Central Water Commission and the same are under finalization for dissemination and use by the practitioners. Also,

recently, standards/manuals/guidelines have been developed for small hydro development by the Alternate Hydro Energy Centre, IIT, Roorkee under the sponsorship of the Ministry of New and Renewable Energy, Government of India.

The DSS (P) for integrated water resources development and management and Real Time Decision Support System (RTDSS) developed under the World Bank funded Hydrology Project-II are the recent efforts for bridging the gap between the developed advanced technologies of water resources planning, designing and management and their field applications. Through applications of the DSS (P), the various scenarios for planning of integrated water resources development and management may be generated and analysed by the practitioners and decision makers for taking optimal decisions. RTDSS enables Bhakra Beas Management Board (BBMB) to improve flood management, leading to minimized loss of life and property for those living along the rivers. It can also help authorities in optimization of power generation, encouraging overall development in the region. RTDSS utilizes hydrological rainfall-runoff and hydraulic river routing models to forecast reservoir inflows and floods. The other RTDSS developed for Krishna and Bhima River Basins enables improvement in flood management for the integrated reservoir operation. The RTDSS generates scenarios which can be used for short- and long-term flood management, water planning and reservoir operations. The DSS (P) for integrated water resources development and management and RTDSS developed under the World Bank funded Hydrology Project-II should be further improved and extended in their functionalities as well as wider and cost effective applications.

For formulation of Indian Standards, the Bureau of Indian Standards (BIS) functions through the technical committee structure comprising of division councils, sectional committees, subcommittees and panels. Division councils are set up by Standards Advisory Committee (SAC) in defined areas of industries and technologies for formulation of standards. These include representatives of various interests such as consumers, regulatory and other Government bodies, industry, scientists, technologists, testing organizations and consultants. Standards should be developed for design of various types of hydraulic structures and other important aspects related to hydrology and water resources and these standards should be regularly updated based on the needs and technology advancements for wider dissemination and evolving cost effective solutions.

Creation of web-portals and outreach plans

A web-portal provides a platform where a focused, active and innovative interaction between the R&D institutes and stake holders is carried out. Creation of interactive

web portals and outreach plans are necessary for dissemination of research outcomes. Some among such international initiatives include USGS Geo Data Portal, USGS Water Data, GEO Portal, etc. Some of the river basin organizations like Mekong River Commission (www.mrcmekong.org) and Murray Darling Basin Authority (<http://www.mdba.gov.au/>) provide real time data. The data.gov.in portal of India is a platform for single-point access to datasets published by Ministries/Departments/Organizations of the Government of India. The India-WRIS developed for generation of database and implementation of web enabled water resources information system in India provides a single window solution for comprehensive, authoritative and consistent data and information of India's water resources along with allied natural resources for assessment, monitoring, planning, development and finally Integrated Water Resources Management (IWRM).

Time series data, spatial data and relational data, maps, technical reports, developed software packages, training manuals, hydrological design aids, standards and guidelines, etc. should be made available on the websites for convenient access by users. Social media and internet are the modern communication paradigm and are already being used for knowledge dissemination in various sectors. The Young Hydrologic Society (YHS) has started a LinkedIn group that allows young hydrologists around the world to easily get in touch with their peers. News and information on upcoming conferences and workshops or anything else relevant to this group may be posted at the YHS LinkedIn group. Twitter follows the YHS on [twitter@younghydrology](https://twitter.com/younghydrology) and Facebook also follows the YHS group of Young Hydrologic Society. Researchers and practitioners need to harness the internet in a systematic way to communicate their methodologies, so that the research findings are translated into practice. A structured approach to knowledge translation that harnesses social media and internet would have tangible, practical benefits for researchers and the practitioners. It would also facilitate wider dissemination of the developed methodologies, manuals, standards, guidelines and software packages, etc. for finding out cost effective and reliable solutions to various hydrological and water resources problems.

Online training courses

Massive Open Online Courses (MOOCs) are a revolutionary new concept in higher education, whereby course content is delivered online and free of cost to participants from around the world (<http://www.themooc.net>). MOOC enhances knowledge and skills for tackling complex issues such as resilience, transformation and how sustainable development, ecosystem management, disaster risk reduction and climate change adaptation are linked and can be operationalized. It would benefit disaster manag-

ers and practitioners, climate change adaptation professionals, development planners and project implementers, and policymakers. The Modular Curriculum for Hydrologic Advancement (MOCHA) project which was awarded the 2011 Education and Public Service in Water Resources Award by the US Universities Council for Water Resources (UCOWR) is another such effort towards establishing an online faculty learning community for hydrology education and a modular curriculum based on modern pedagogical standards. The overall objective is to create a continuously evolving core curriculum that overcomes traditional biases and is freely available to, developed, and reviewed by the worldwide hydrologic community through web-portal with support for community-driven curriculum development.

Some of the international universities and R&D institutions are offering various online courses on both free and payment basis. For example, free online courses in hydrology and hydraulics, urban drainage and sewerage and ecological sanitation are offered from UNESCO-IHE. Also, online course on groundwater hydrology from MITOPEN Courseware (Massachusetts Institute of Technology) and the NOAA/COMET/WMO International Basic Hydrologic Sciences Distance Learning Course are being offered. The National Water Academy, Central Water Commission (Pune) in association with COMET & World Meteorological Organisation (WMO) (www.etrp.wmo.int) offers an international distance learning course in basic hydrological sciences for Asian region. More and more similar online courses should be developed and offered by the Indian institutions and organizations so that the Indian students get an opportunity to use rainfall, runoff and watershed data from Indian watersheds. Web conferencing allows conferencing events to be shared with remote locations. These are sometimes referred to as webinars or interactive conferences, online workshops. In general, the service is made possible by internet technologies, particularly on TCP/IP connections. The service allows real-time point-to-point communications as well as multicast communications from one sender to many receivers. It offers data streams of text-based messages, voice and video chat to be shared simultaneously, across geographically dispersed locations. Through applications for web conferencing training events, lectures can be organized.

The Information Technology Research Academy (ITRA) is a national programme to help build a national resource for advancing the quality and quantity of R&D in information and communications technologies and electronics and its applications, in IT and related institutions across India. The current activities for ITRA-Water are: measurement to management, integrated urban flood management, improving groundwater levels and quality. ITRA's project in the areas of 'mobile computing, networking and applications' and 'IT-based innovations in sustainability of water resources' has been launched by

the Ministry of Communications and Information Technology. The initiative is in line with the R&D framework to strike the right balance between basic and applied research and addresses some of the domains, which have been emphasized by the R&D framework such as agriculture, water, energy, etc. so that R&D focus must culminate into transfer of technology and commercialization of research.

The National Programme on Technology Enhanced Learning (NPTEL) is a joint initiative of the IITs and IISc to provide e-learning through online web and video courses in engineering, science and humanities streams. The mission of NPTEL is to enhance the quality of engineering education in the country by providing free online courseware. Online courses are free for all and certification exams are for a nominal fee. Similar online courses should be developed and offered by other Indian institutions and organizations.

Enhancement of incentives for attracting the best talent in research

Presently R&D is not attracting the best talents as a professionals especially in the area of hydrology and water resources in India. The opportunities for career growth in the R&D organizations are lesser than the academic organizations. Professionals should be employed by catching them young and professionally trained as per the job requirements in the desired subject specialization. There is a need for enhancing incentives for attracting the best talent for research and academic organizations. Professional allowances, foreign trainings at prestigious institutions and universities, incentives for providing consultancy services, high profile awards for early career researchers and students may be considered as some of such incentives. The infrastructure as well as the facilities for carrying out R&D need to be restructured. The opportunities for career growth as well as the working atmosphere are required to be improved. Further, integrated water resources development and management is a multi-disciplinary subject; therefore, professionals from the various concerned disciplines need to be engaged for carrying out the R&D activities.

Organization of R&D sessions, brain storming sessions/seminars/symposia/conferences

For scientific interaction to bridge the gap between research and applications in hydrology and water resources development and management, it is necessary to organize R&D sessions, brain storming sessions/seminars/symposia/conferences by bringing together the researchers, academicians, engineers, practitioners and all other stakeholders on regular basis. These scientific interactions facilitate in identifying the critical research needs as

well as development of tools and methodologies for addressing the emergent issues and in demonstrating innovative applications of the latest technologies and act as a catalyst to promote applications of state of art technologies and research findings among the stake holders. Such interactions and activities provide platform for sharing the innovations and pioneering R&D accomplishments and exchanging the expertise and experiences. Such activities also help in learning the latest developments in methodologies, practices and technologies and help in avoiding duplication of the efforts. Collaborative R&D programmes, training and capacity building can also be accomplished through cyber-seminars or e-conferences. These activities also synergize research and capacity building among scientists, policy makers, managers and stakeholders.

Crowdsourcing and engaging citizen scientists

Crowdsourcing is an open call for voluntary assistance from a large group of individuals for studying and tackling complex challenges by carrying out research at large spatial extent and over a long duration of time in ways that professional scientists working alone cannot easily accomplish. Citizen science promotes the public for voluntarily participating in the scientific process by collecting data/information, raising queries, conducting experiments, taking observations, developing low-cost technologies and open-source software, where people can contribute to advancement of scientific knowledge and technology for the benefit of society. CrowdHydrology (<http://www.crowdhydrology.com>) was established in 2010 in the Northeast United States with the goal of using innovative methods to collect spatially distributed hydrologic data and is now expanding to programmes across the entire continent. It is expected that this platform will soon enable to expand even farther, offering global support to those seeking to aid the study of hydrologic data worldwide. The data collected is accessible, free-of-charge to all universities, resource management agencies, and watershed organizations. Spatially and temporally distributed measurements of processes at the watershed scale, come at substantial equipment and personnel cost. Attention needs to be paid on building a crowdsourced database of the required hydrological data.

Murthy *et al.* illustrated capacity building for collecting primary data through crowdsourcing as an example of disaster affected Uttarakhand State (India). A multi-institutional initiative called 'Map the Neighbourhood in Uttarakhand' (MANU) was conceptualized after massive flood devastation in June 2013, with the main objective of collecting primary data on damage through participation of local people (mainly students) using state-of-art tools and technologies of data collection and a mechanism to integrate the same with Bhuvan geo-portal

(www.bhuvan.nrsc.gov.in) in near real-time. Geospatial analysis of crowdsourced points with different themes has been carried out subsequently for providing inputs to restoration planning and for future developmental activities.

Flooded streets (<https://www.mapbox.com/blog/chennai-flood-map>) was a crowdsourced effort to map inundated roads in Chennai using OpenStreetMap data interactivity built using Mapbox GL and was hosted on GitHub. One can zoom into a locality, visualize which streets are reported as flooded and click on a street if you know it is flooded. While bridges collapsed, floodgates opened and people were confined to their homes; citizens came together on social media, viz. Twitter, Facebook, etc. to coordinate efforts to send or seek help with accommodation, food and rescue relief. The people behind the joint effort at Chennai rains.org, widely shared a Google spreadsheet listing helpline numbers, aid offers and requests, rescue requests, volunteer details and accommodation details so that people could fill in details or provide necessary information to volunteers. Sheth and his team at the Ohio Center of Excellence in Knowledge-enabled Computing (Kno.e.sis, Wright State University, USA) are carrying out a new NSF-funded project, Social and Physical Sensing Enabled Decision Support for Disaster Management and Response. They have mobilized to use their technology to monitor and analyse social media and crowdsourcing to support better situational awareness for the Chennai floods.

The various efforts towards crowdsourcing and engaging citizen scientists have proven to be vital in solving different types of hydrological and water resource problems. There is an urgent need for adopting more and more crowdsourcing and engaging citizen scientists for collection, compilation, processing, analysis and dissemination of data/information for finding solutions of the real life hydrological and water resource problems, so that not only the formally trained professional scientists and engineers, but everyone can contribute to science, engineering, and technology through open science and innovation approaches.

Integrating research and practice

Professionals working in R&D and academic organizations like to think that they are making a difference. The demands for service requests from R&D activities are continuing to grow. Scientists must be able to relate the outcome of R&D activities to the user agencies and society in a manner that will cause them to realize the need to do something about it. For solving problems in water sector, user-friendly products, methodologies and tools must be developed and they must be in a form that can be easily understood and used by local officials and field engineers. The researcher should keep developed methodologies and findings crisp and to the point. Brief statements

of research findings in a clear format, and works that integrate findings, are of beneficial use to practitioners. Simple summary statements presenting findings and recommendations for actions should be prepared. The practitioners often do not have the time or desire to read and interpret theoretical discourses and research methodologies. Some of the researchers do honest, sincere, important work, but they do it in isolation. This may reduce the possibility of utilization of their work at the practitioner level. The practitioners must work hard to identify and isolate specific problems, so that researchers can design projects that address the needs of users. If researchers focus on problems pointed out by local engineers as critical, their results are much more likely to be read and used. The Leopold Leadership Program at the Stanford Woods Institute for the Environment is the first formal effort in North America to train mid-career academic environmental researchers to communicate about their science with decision makers outside academia. The Indian Institute of Science (IISc) in association with Gubbi Labs has also setup Research Media Services, which aims to bridge the gap between research institutes and the general public. In addition, practitioners should not be intimidated by academics and rather be willing to work with the research community, seek their advice without believing everything they say. The methodologies and results may be scrutinized and validated by the practitioners. The practitioners should make efforts to find information, methodologies, manuals, design aids, standards, etc. for solving hydrologic and water resource problems. The tailor made solutions may not be expected to career to all the problems and efforts are required to be made for customizing the generic methodologies.

The action points for using emerging technologies are listed as follows:

- Generally, conventional data such as daily stream flow data for major gauging sites and daily/hourly rainfall data are available but river cross-sections, L-sections, topographic data at short contour intervals, reservoir inflow, outflow, land-use data and soil data are not adequately available. Therefore, appropriate instrumentation and automation in data collection for meteorological, hydrological and other related data are required.
- Setting up of suitable manual and automatic data observation networks for hydro-meteorological, hydrological, other related data in the Himalayan and other hilly regions and establishment of data collection network for small catchments for short interval stream flow data and other related data collection should be paid attention.
- Data collection, processing, storage, retrieval and dissemination using the state-of-art knowledge in information technology sector should be encouraged.

- There should be active cooperation among organizations and institutes involved in the applications of emerging techniques such as GIS and remote sensing, isotopic techniques, hydrological modelling, soft computing techniques, water quality modelling, assessment of impact of climate change, down scaling of GCM and RCM data, etc.
- Preparation of standards/guidelines based on advanced techniques and tools for planning, design and operation of water resource projects should be encouraged.
- Applications of emerging techniques such as remote sensing and GIS, isotopic techniques, hydrological modelling and DSS (planning) and DSS (real time) for flood forecasting and early warning, etc. should be encouraged.
- Establishment of a national network of water quality labs, soil water labs, hydrological instrumentation labs and other related labs with state of art instruments as well as well-trained manpower should be taken up.
- Adequate man-power/competence/skills for adopting the multidisciplinary approaches and new emerging technologies for solving complex water issues based on the concept of IWRM for sustainable development needs to be created.
- Online learning programmes such as web portals, e-learning and webinars as well as audio-visual aids including video conferencing facilities should be effectively utilized by the various organizations for training personnel under the distance learning programmes.
- There is a need to further strengthen the India-WRIS developed for generation of database and implementation of web enabled water resource information system with features like, direct link to current and historical hydro-meteorological observations, hydrology tools for online analysis, etc. Also, efforts should be made for development of similar systems for solution of hydrological and water resource problems.
- There is a need for adopting more and more crowd-sourcing and engaging citizen scientists for collection, compilation, processing, analysis and dissemination of data/information for finding solutions of the real life hydrological and water resource problems.

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