Azadi Ka Amrit Mahotsav

Central Water Commission

77 years

IN THE SERVICE OF NATION





Central Water Commission

77 years

IN THE SERVICE OF NATION

NOVEMBER 2022

NEW DELHI

Foreward

CWC came into existence two years before the independence of the country. Its creation was envisioned by Dr. B. R. Ambedkar. The country was grappling with one of the worst famines at that time. Since then CWC has been at the centre stage to provide its services in the implementation of water resources projects in the country as well as in the neighbouring countries and also implementation of international treaties and handling various other facets of the water sector. CWC has always been one of the leading Govt. agencies which put a national perspective into the water sector which was primarily seen as a provincial/State subject.

During the last seven decades, CWC has been intimately associated with planning, investigations, designs and management of various aspects of water resources development including irrigation, hydropower generation, flood control, water management etc. The expertise developed during this period under one roof has made the country self-reliant in this Field and consequently, various complex problems of diverse projects have been tackled successfully. Besides, the expertise developed has also been made available to other developing countries. Also, based on the requirement CWC did the construction of Hydel Projects in Bhutan and Nepal.

As we all know that since Independence, the country invested a sizeable portion of its budgetary resources in the Irrigation infrastructure. The existence of CWC ensured that those investments were well-coordinated and backed by sound engineering interventions. The country achieved many stupendous milestones in terms of infrastructure and achieved 'Atma Nirbharata' in the food supply. Completion of Major hydropower projects also fuelled the economic growth of the concerned areas.

The Design and Research Wing has contributed immensely to the designs and engineering of Concrete and Masonry Dams, Earth & Rockfill Dams, Tunnels, Power Houses, Underground Caverns, Gates, Barrages and Canal Structures. The Dam Safety Organisation was created in 1979 to play a leading role in providing dam safety services and the creation of dam safety cells in the States. We are happily witnessing the formalization of arrangement in the form of the enactment of the Dam Safety Bill in the year 2021.

Considering the growing population and emerging demands, CWC could come up with a National Perspective Plan in the 1980s. This is currently known as river interlinking in common parlance. Recently, its first project, Ken Betwa Link Project has been approved by the Union Cabinet for implementation.

India established various bilateral mechanisms of cooperation for water with neighbouring countries. Such elaborate cooperation mechanisms are not available in other countries in the region or the continent. Also, when it was required, CWC provided its valuable service in defending the interest of the country within the framework of cooperation.

India has one of the most comprehensive sets of planning and design standards for the water resources sector. CWC's role in the development of such standards has also been noteworthy. The Flood Forecasting system initiated by CWC in the 1950s provided a large benefit to the country. The vast data collection network of CWC is relied for the planning and development of major water resources in the country.

Going forward, vigorous and multi-pronged efforts are needed to achieve water security & sustainability for the country which is crucial for food & energy security as well as the overall economic and social development of the country. Big and bold multi-purpose water resources projects in the transboundary basins are the need of the hour. The role of CWC is very important in this context. CWC's success would be closely linked with the water secured and prosperous India.

Acknowledgments

Being Country's pioneer organisation, Central Water Commission has led all endeavours of water resources development and management ever since 1945. Besides, CWC has been enriching the knowledge of water stakeholders through numerous publications and this publication falls in the same league. Content of this publication have been compiled in a very short duration and needless to say that it required a great diligence in managing, synthesising and coordinating with a range of officials.

At the outset, I would like to acknowledge with much appreciation, the support of Hon'ble Union Minister of Jalshakti **Sh. Gajendra Singh Shekhawat jee** and extend my indebtedness for his continuous encouragement to pursue such literary works.

I would like to tender a special gratitude to Hon'ble Minister of State **Sh. Bishweswar Tudu jee and Sh. Prahlad Singh Patel jee** for their valuable guidance, direction and continued interest in bringing out such publications.

I convey my sincere thanks to Sh. Pankaj Kumar, Secretary (DoWR, RD& GR) for continuous motivation and whole hearted support in pursuing any new and innovative work by CWC.

I would also like to take this opportunity to thank my colleagues Sh. J. Chandrashekhar Iyer (Member D&R), Sh. Kushvinder Vohra (Member WP&P) and Sh. P.M Scott (Member RM) who thoroughly reviewed and monitored the respective chapters of this publication.

My special thanks to all my colleagues who have meticulously compiled and contributed chapters/articles for this publication. I would also like to thank Sh. Sameer Chatterjee (Chief Engineer, HRM), Sh. Vijai Saran (Chief Engineer, DSO), Sh. P Dorje Gyamba (Chief Engineer, POMIO), Sh. Rishi Srivastava (Chief Engineer, BPMO), Sh. S.K. Rajan (Director, TC), Sh. Bhupinder Singh (Director- WP&P Coordination Dte.), Shri Deepak Kumar (Director- River Data Compilation, RDC-1 Dte.), Sh. S.S Bakshi (Director- Dam Safety Monitoring, DSM Dte.), Sunil Kumar (Director- Basin Planning, BP-1 Dte.) and Anant Kumar Gupta (Director- PCP Dte.) and all others for their precious contribution for preparation of this publication. Finally, our sincere thanks are to all officials of CWC for their valuable support during the preparation of publication

(Dr. R. K. Gupta)

श्री गजेन्द्र सिंह शेखावत

Shri Gajendra Singh Shekhawat

सत्यमेव जयते

जल शक्ति मंत्री
भारत सरकार

Minister of Jal Shakti
Government of India

Message

On completion of 75 years of independent India, we are celebrating our numerous successes and achieving food self-sufficiency is indeed one of them. Irrigation development has played key role in this direction and Central Water Commission (CWC) led this endeavor from the front. The esteemed organization of CWC came into existence two years before the independence of the country. Ever-since its inception, CWC has been tirelessly rendering valuable services in the entire gamut of water resources development including project preparation, appraisal, monitoring, design & research, flood management etc. Since water is a vehicle for socio-economic development, all these contributions from CWC has definitely proved to be one of the strongest pillars of country's economic prosperity and social well being. Water governance and policy formulation is one of the most crucial responsibilities of Ministry of Jal Shakti and CWC being apex technical organization, always provided the best supports in drafting bills, policies, guidelines and all other related matters.

Water resource is primarily a subject of state list but many times state governments have limited technical and financial capability for planning, designing and executing a multi-purpose water resources project. In such situations, CWC facilitates hand-holding to State Governments by several means including technical consultancy. Needless to say that all iconic structure such as Bhakra Nangal to Hirakud, Sardar Sarovar, Tehri etc. could see light of the day due to immense contribution by CWC throughout. More interestingly, whenever any water dispute arises between various States / stakeholders, CWC is being considered as the most neutral organization for their redressal. CWC has also extended its expertise to neighboring countries in development and management of their water resources which has further strengthened our bilateral relationship.

I would like to congratulate all brilliant officers and staff of the great symphony of Central Water Commission on the occasion of completion of 77 years of successful journey as an apex technical organization in water resources management of the country.

On this occasion, I am glad to know that CWC is releasing a publication highlighting its achievements and proud works of it. It will help all of us to know what an ideal organization could do for the country's water resource development.

(Gajendra Singh Shekhawat)

श्री प्रहलाद सिंह पटेल

Shri Prahlad Singh Patel

जल शक्ति एवं खाद्य प्रसंस्करण उद्योग
राज्य मंत्री
भारत सरकार

Minister of State for Jal Shakti and Food Processing Industries Government of India

Message

Water has always remained close to our hearts – be it in the form of pious rivers or as the ritual water, it always remains as a prime mover for all kinds of development. A large part of the country has been facing huge spatial & temporal variability in rainfall and consequently the cascading events of flood and droughts. Having large agrarian society with deep-rooted sentiments for the land always highlighted the importance of a wide and sustainable network for irrigation. Despite water being s State list subject, need of an over-arching expert technical body at the centre realised when the India was nearing towards its independence from British power. This culminated in the creation of Central Waterways, Irrigation and Navigation Commission (CWINC) in 1945 which is at present Central Water Commission. Gratitude to two visionary men who spearhead the inception and organizational structure of CWC - Dr. Bhimrao Ambedkar and Dr. A N Khosla (founder Chairman of CWINC) who provided CWINC the right orientation and the much needed initial momentum.

Ever since beginning, CWC has been providing exemplary services such as planning, investigations, hydrological observation, project preparation, designs and management of various aspects of water resources development including irrigation, hydropower generation, flood control, water management, inter-state disputes etc. The great achievements of CWC also opens the door for new era of leadership in water resource, and hoping it will sustain its qualitative efforts for the sustainable development and management of water resources in the country.

I am having immense pleasure for wishing Central Water Commission (CWC) for completing its 77 years of nation service. I essentially believe that all officers and staff of Central Water Commission are the torch bearers of the legacy left by the founding fathers of this organization like Dr. B. R. Ambedkar and Dr. A. N. Khosla. I feel extremely delighted and immensely fulfilled to get full support from Central Water Commission as and when required

Best wishes

Jai Hind

(Prahlad Singh Patel)

श्री बिश्वेश्वर टुडु
Shri Bishweswar Tudu

सत्यमेव जयते

जल शक्ति एवं जनजातीय कार्य
राज्य मंत्री
भारत सरकार
Minister of State For
Jal Shakti & Tribal Affairs
Government of India

Message

Sustainable development of water resources and its efficient management is the key to water security and economic growth. Needless to say that increasing population, economic growth, industrialization and urbanization are bound to result in increased and conflicting demands for various purposes. Moreover, the changing trend of climatic patterns has already started affecting the water sector adversely. Therefore, we have to adopt a holistic approach to address existing and upcoming challenges with equal emphasis on development and management of water resources in a sustainable manner. In order to address these challenging and rapidly changing scenario of water resources, country needs a technically competent organisation and Central Water Commission (CWC) fits the bill.

CWC has been contributing sustainably in managing the water resources holistically by means of appropriate project planning, techno-economic appraisal, state-of-the-art design & research, structural & non-structural measures for flood management, hydrological observation network etc. Organized and well planned irrigation development enabled India to join league of very few countries having food self-sufficiency and CWC has played a pivotal role in this endeavor. CWC has contributed significantly in all major and medium irrigation projects in the entire length and breadth of the country.

Nowadays, there is a paradigm shift in the management of water resources approach as more emphasis has been given towards efficient utilization of water resources, demand management, use of nonconventional water resources. It gives me pleasure to acknowledge that CWC is adapting to such changes adequately and fully capacitated to synchronise its functioning as per the needs of the hour.

I wish to extend my greetings to entire fraternity of Central Water Commission for their notable contribution towards building India's water sector and helping millions of Indians for their upliftment and also find it a suitable shoulder to confront new responsibilities and challenges in the upcoming decades.

I wish all the best for the future prospects and its important role in water resources management.

(Bishweswar Tudu)

श्री पंकज कुमार

Sh. Pankaj Kumar

सत्यमेव जयते

सचिव
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
भारत सरकार

Secretary
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Message

Water is essential for sustaining life. With the advancement of human civilization, consumption of water for drinking, hygiene, agriculture and industry has grown manifold. No wonder, water has occupied the central stage in our lives with traditions and folklores abounding around it. Management of water grew in prominence in India to meet the food security needs of a large, growing and primarily agrarian population. The widespread spatial and temporal variation in the precipitation, which often leads to simultaneous occurrence of floods and droughts in various regions, renders the management of water sector even more challenging. The visionary planned and scientific approach towards management of water resources was manifest, particularly in 1950s and 1960s with construction of several large dams as the temples of modern India. The Central Waterways, Irrigation and Navigation Commission (CWINC), set up in 1945, saw a series of changes and became the Central Water Commission (CWC) in 1974.CWC, a premier technical organization of India in the field of water resources, has played a stellar role towards addressing development of India's water resources, against the backdrop of evolving priorities and challenging complexities. During its formative years, CWC made remarkable contribution to the engineering marvels such as Mahanadi River Valley project, Hirakud Dam, Kosi Project, Farakka Barrage Project, Indira Gandhi Canal and Nagarjuna Sagar Dam. CWC prepared the master plans for river basins and played a critical role in resolution of inter-State water disputes, including creation of boards for implementation of awards of tribunals on water sharing. With passage of time, CWC has shouldered new responsibilities and developed expertise in a wider gamut of activities, including flood forecasting, flood management, project appraisal, design flood studies, water availability studies, Glacial Lake-Outburst Flood (GLOF), dam rehabilitation and improvement, reservoir storage monitoring and sedimentation assessment, coastal data collection etc.

Several noteworthy achievements are to the credit of CWC, including the design of Tehri Dam, Sardar Sarovar Project, Polavaram Irrigation Project, technical & financial assistance to neighboring countries, extensive hydro-meteorological observation &flood forecasting network, development of portals like India-WRIS, successful mediation between States for inter-State water disputes, providing solutions for special problems of water resources, reassessment of the water availability in India,progress of the national projects, preparation of the rule levels of various reservoirs, and capacity building through the National Water Academy, Pune. The former and the current leaderships of CWC along with their team of officers deserve accolades for steering CWC towards its rightful place as a premier national institution for management of the country's water resources.

Sh. Pankaj Kumar

डॉ. आर.के गुप्ता

Dr. R.K Gupta

सत्यमेव जयते

अध्यक्ष
केन्द्रीय जल आयोग
Chairman
Central Water Commission

Message

Envisioned by Dr. B. R. Ambedkar, Central Water Commission came into existence two years prior to the independence of the country. As the first Chairman, Dr. A.N. Khosla extended visionary leadership and laid a strong foundation and his legacy has been carried forward till date. Ever Since inception, CWC has been at the centre stage in development and management of every aspect of water resources in the country.

During the last 77 years, CWC has rendered extremely valuable services to the nation in the form of water management, hydrological observation, flood forecasting, project planning, survey & investigations, designs of various water resources projects including irrigation, hydropower generation, flood control. The decades of hard work of indefatigable professionals of CWC contributed to all round growth of the country. As per the recommendation of Famine and Irrigation commissions, the country invested a sizeable portion of its budgetary resources in the Irrigation infrastructure. CWC ensured that those investments were well-coordinated, value for money and backed by sound engineering interventions. The country achieved many stupendous milestones in terms of infrastructure and achieved not only 'Atma Nirbharata' in the food supply but also became a net exporter. Commissioning of major hydropower projects provided much needed clean energy and fuelled to fast economic growth. Services rendered by CWC contributed significantly towards mitigation and adaptation of impact of climate change on water resources. Besides, CWC always played a pivotal role in all gamut of water governance including development of legislations, national water policies, guidelines and extended all requisite support to various parliamentary proceedings on water resources. At times, CWC played key role in resolution of water disputes between several State Governments and put a national perspective into the water sector which was primarily seen as a provincial/State subject. Moreover, CWC has always supported neighbouring and developing countries by extending consultancy services to their water resources projects.

CWC is the architect of national perspective plan 1980 which envisages interlinking of Indian rivers offering multipronged interventions to address temporal and spatial disparity in water availability throughout the country. India has one of the most comprehensive sets of planning and design standards for the water resources sector. CWC's role in the development of such standards and numerous guidelines/norms has also been noteworthy. The Flood Forecasting system initiated by CWC in the 1950s provided a large benefit to the country by protecting countless life and property annually. The vast data collection network of CWC is relied for the planning and development of major water resources in the country.

Indian water sector has been facing numerous challenges with ever growing population, fast economic growth, rapid urbanisation and changing pattern of climate. In such emerging scenario, country needs an impeccable plan of measures and CWC is fully equipped to lead from the front in all endeavours of water management.

(Dr. R.K. Gupta)

जे चंद्रशेखर अय्यर

J. Chandrashekhar Iyer

सत्यमेव जयते

सदस्य (डी & आर)
केन्द्रीय जल आयोग
Member (D & R)
Central Water Commission

Message

India's water resources sector, after independence, had an arduous challenge to create storages and water conveyance system to achieve self-sufficiency in food production. From around 300 dams during independence, the country has witnessed remarkable achievement in dam building and presently the country ranks third in the world with over 5300 existing dams. The Design and Research Wing in Central Water Commission has played a pivotal role in this exponential growth and contributed immensely in the planning, analysis and design engineering of several prestigious water resources as well as hydropower projects and advised the States and public utilities in their implementation.

CWC has been a pioneer and continues to be so, in the design engineering of concrete, masonry, earth & rockfill dams, barrages, canals & tunnels, surface and underground power houses, hydro-mechanical components and other appurtenant structures in water resources and hydropower projects in the country and In the neighbourhood.

CWC has always strived for best practices based on sound judgement and world wide experience and contributed significantly in design standards. Over these years,engineering solutions have been offered to several complex problems encountered during execution of water resources projects and even later during the project operation, making use of the modern computational tools and latest technologies. The knowledge and experience gained in these projects have been regularly disseminated to water sector professionals in various Central and State Government departments including public and private sector agencies to build institutional capacity within the country to address future challenges.

CWC continues to be in the forefront of setting new benchmarks in design engineering and developing new technologies and solutions, including ensuring the safety of the existing dams and associated infrastructure,thereby contributing towards the overall water security of the country.

(J. Chandrashekhar Iyer)

कुशविंदर वोहरा

Kushvinder Vohra

सत्यमेव जयते

सदस्य (डब्ल्यू पी & पी)
केन्द्रीय जल आयोग
Member (W P & P)
Central Water Commission

Message

The cradle for origin of any form of life on this blue planet is water. Across the world, since ages, water has been revered as fundamental for existence and growth. India has around 4% of world's renewable water resources. The mean annual rainfall in the country is 3880 BCM, most of which takes place under the influence of South-West monsoon between June to September. The spatial and temporal variation in rainfall which ranges from less than 100 mm in the western Rajasthan to more than 2,500 mm in North-Eastern areas, often leads to simultaneous occurrence of inundation and droughts in various regions.

After independence, sudden loss of irrigated systems of West Punjab created a threat to food security for vast population of India. Thus, development of Irrigation canals and creation of strategic storages took center stage as means for ensuring food security and mitigating droughts & floods as well. The erstwhile Central Waterways, Irrigation and Navigation Commission (CWINC) established in 1945, was transformed to Central Water and Power Commission in 1951. Since then, the Commission kept evolving and adapting to the needs of the country and reached its present version in 1974, as Central Water Commission.

In its 75 years long journey, CWC has had a long run as a premier technical organization of India in the field of water resources and played stellar role in transforming India into a food and energy surplus country but also made colossal contribution in uplifting of livelihood of millions of Indians and economic growth of India as well. Today, India has storage capacity of 257 BCM and 5300 large dams. The hydro power capacity have shoot up to 46722 MW from 508 MW in 1947.

The Commission presently deals in domains such as River/ Water Management, Basin Planning and Management, Civil / Structural Design of Water Resources Projects, Inter-state / International Conflict Resolution in water related disputes, Flood Forecasting/ Hydrological Observations, Survey & Investigation/ Appraisal /Monitoring of Water Resources Projects and others. It has vital roles in Policy Formulation in water sector and ensuring integrated and sustainable development and management of India's water resources by using state-of-the-art technology and competency and by coordinating all stakeholders.

The new challenges and complexities arise in future with increase in water demand for ensuring food security and drinking water supply to a population of 1.66 billion (expected 2050 population). The water demand from other sectors viz. industrial sector, will also see multifold rise to keep the economic growth trajectory upward. Climate change effects on national level water availability and potential exacerbation of disparities coupled with the increased demands on water, will have double whammy effect. In addition, with increasing stress on water resources, its management is being influenced by the other aspects of socioeconomic and political developments.

CWC will require newer approaches and involvement of trans-disciplinary experts and multiple stakeholders to confront these new challenges. An integrated and comprehensive approach including adequate legal provisions along with appropriate institutional arrangements for implementation of schemes/ programmes and optimum development of multipurpose water resources projects (including interlinking of rivers) needs to be adopted. Further, efforts towards capacity building, increasing participation of masses and innovative methods for ensuring financing of new projects and R&D, needs to be augmented.

(Kushvinder Vohra)

पी. एम. स्कॉट

P. M. Scott

सत्यमेव जयते

सदस्य (आर एम)
केन्द्रीय जल आयोग
Member (R M)
Central Water Commission

Message

Water is precious natural resource for sustaining life and environment. Effective and sustainable management of water resources is vital for ensuring sustainable development. In view of the vital importance of water for human and animal life, for maintaining ecological balance and for economic and developmental activities of all kinds, and considering its increasing scarcity, the planning and management of water resource and its optimal, economical and equitable use has become a matter of the utmost urgency. Management of water resources in India is of paramount importance to sustain a billion plus population. Water management is a composite area with linkage to various sectors of Indian economy including agricultural, industrial, domestic and household, power, environment, fisheries and transportation sector.

Since Independence, the country invested a sizeable portion of its budgetary resources in the Irrigation infrastructure. The existence of CWC ensured that those investments were well-coordinated and backed by sound engineering interventions. The country achieved many stupendous milestones in terms of infrastructure and achieved 'AtmaNirbharata' in the food supply. Completion of major hydropower projects also help fuelled the economic growth of the country.

CWC being a premier technical organisation in the field of water resources since the last 7-8 decades has played crucial role in planning, development & management of water resources projects not only in India but also in the neighbouring Countries emphasising on वसुधैव कुटुम्बकम which means "the world is one family". CWC has also provided technical & financial support to neighbouring countries such as Afghanistan, Nepal and Bhutan. CWC has been intimately associated with investigations, designs and management of various aspects of water resources development including irrigation, hydropower generation, flood control, water management etc.CWC has put in noteworthy contributions to Hirakud Dam, NagarjunaSagar Dam, GandhiSagar Dam, Polavaram Project, Tehri dam, Bansagar Project, SardarSarovar Projects etc.

With time, CWC shouldered new responsibilities and areas of expertise with a wider gamut of activities including flood forecasting, flood management, project appraisal, design flood studies, water availability studies, Glacial Lake Outburst Flood (GLOF), dam rehabilitation and improvement, reservoir storage monitoring and sedimentation assessment, coastal data collection etc.

CWC in recent times have been deeply involved in strengthening and widening of its Flood Forecasting & warning system, Hydro-meteorological stations and is also working in collaboration with Google - for sending forecast warning through Google enabled smart phones. CWC is also monitoring 477 glacial lakes in Indian Himalayan Region and Environmental Flows in River Ganga, to rejuvenate and make Ganga River free of pollution.

Growing competition over finite water resources, compounded by climate change, will have serious implications for India's food security and the country's economic development. CWC will require involvement of trans-disciplinary experts, adequate database for rationalising the decisions, familiarising with up to date technologies to confront these new challenges.Going forward, vigorous and multi-pronged efforts are needed to achieve water security & sustainability for the country which is crucial for food & energy security as well as the overall economic and social development of the country.

(P. M. Scott)

ए के बजाज

A. K. Bajaj

पूर्व अध्यक्ष (2008–2011)
केन्द्रीय जल आयोग
Ex-Chairman (2008-2011)
Central Water Commission

Message

It gives me great pleasure to know that my organisation Central Water Commission has completed 75 years of providing technical expertise support in development of the water sector not only in India but many other countries also and is celebrating the same by bringing out a souvenir on the occasion. I have had the pleasure of spending more than 37 years of my working life with CWC and am now engaged in sharing the technical expertise gained over this period with other State Government and private organisations.

Central Water Commission has come a long way since its beginning 75 years ago and has developed over the years into a premier institution of excellence by assimilating knowledge from all around the world in providing technical expertise and engineering solutions in the water resources sector. India has harnessed its water resources vastly since the decades of the 60s and 70s for meeting the irrigation and drinking water needs of the country and CWC's contribution to the same is well known and documented.

I had the opportunity of heading the organisation for nearly three and a half years and during this time interacted with the vast majority of officers of the Commission all of whom I found to be technically excelling in their respective fields.

I wish Central Water Commission many more years of continued technical excellence in the future for further development of the country's water resources potential.

(A. K. Bajaj)

अश्विन बी. पांडया

Ashwin B. Pandya

Ex-Chairman (2013-2015)
Central Water Commission
and Secretary General
International Commission on
Irrigation and Drainage (ICID)

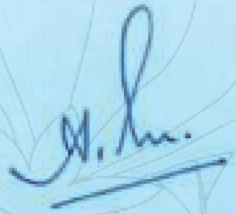
Message

It gives me immense pleasure to note that Central Water Commission is completing 75 years to the service of the nation in the fields of water, energy and food security. Central Water Commission has been an active participant in bringing about a revolutionary change in our water management regime through its unwavering technical and scientific support in the development and management of irrigation, hydropower and multipurpose projects across the country and its immediate neighbourhood. The Commission has transformed itself over time to meet the current challenges in these sectors.

With the climate change effects and ever growing needs of food, fibre and energy, the work of Commission is facing newer challenges in the management of water resources and I am sure that the dynamic leadership of the engineers and scientists has already risen up to the challenges and are delivering to the nation. Central Water Commission being the chair of Indian National Committee on Irrigation and Drainage of ICID, is also actively participating in the knowledge building for agricultural water management across the world.

I take this opportunity to congratulate all the officers and staff of Central Water Commission on this unique occasion and convey best wishes from International Commission on Irrigation and Drainage for greater achievements in working towards a water secure world, free of poverty and hunger through efficient water management.

Best regards



(Ashwin B. Pandya)

एस. के. हलधर

S. K. Haldar

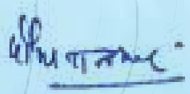
Ex-Chairman (2008-2011)
Central Water Commission
and Chairman
Cauvery Water Management Authority (CWMA)

Message

It gives me immense pleasure to know that Central Water Commission (CWC) is bringing out a Souvenir, highlighting the progress and milestones of achievements in the field of development and management of Water Resources in the country made by CWC during 75 years of its inception since 1945. This is also an occasion to pay homage to the founders and pioneers of the Commission.

Since beginning, CWC has been working for providing quality service to the nation in the field of water resources development and management. 75 years of Journey of ewe is a landmark in the history of economic development of India, of which the irrigation engineers of the country can be proud. Major/ medium irrigation and multipurpose projects have made our country selfrel iant in the field of food production and power. Over the years, ewe has contributed substantially in the fields of water planning, design of hydraulic structures, consultancy services to projects in various states in India as well as foreign countries, Dam Rehabilitation and Improvement Project (DRIP), hydrological observations, inter-state water issues, cooperation in trans-boundary river basins, implementation of PMKSY-AIBP, CADWM and flood forecasting services.

On this occasion, I convey my sincere appreciation to the entire team of this esteemed organisation for their remarkable service to the nation. I am confident that CWC will continue to render yeoman services in the development of water sector in future also.



(S. K. Haldar)

एम. गोपालकृष्णन

M. Gopalakrishnan

Ex-Member
Central Water Commission
and Ex-Secretary General
International Commission on
Irrigation and Drainage (ICID)

Message

It is a matter of delight to see that the Central Water Commission (CWC) would be celebrating its Annual Day this year shortly, on its completing 75 years of significant contributions to country's development agenda.

I consider it as my proud privilege to pen a few words on this occasion. I joined the Central Water Engineering Services (Class I) through the UPSC's CES 1966 and till my retirement in January 2003 had served in its various wings, like the Designs & Research Wing, Water Resources & Planning and River Management Wings, besides the field organisation charged with Investigation, Planning of RVD Projects and Monitoring the wide river net work for data collection and flood forecasting. It was a holistic experience of varied colour, and I am proud to have been part of this great Organisation as a CWES officer for nearly 36 years.

In 70s, when we entered the services, the sciences dealing with water were rather in its infancy stages; be it designs or other aspects of water planning, or site investigations, we had to put considerable intuitiveness to deal with the tasks. In 1977 when the Koyna Earthquake took place, in the absence of computer support, we used to depend entirely on slide rules and calculators. The seismic parameters were rather crudely assessed by simplistic empiricism. We had to imagine different scenarios and obtain the structural behaviour to evolve remedies. In subsequent decades, we marched with the State of Art and contributed to the processes evolving guidelines, based on experiences which are now widely followed. CWC could assist exhaustively in bringing up Codes and Guidelines that could help subsequent generations dealing with water subjects in Centre as well as the States of the Union, with BIS Codes in RVD Sector. The CWC's D& R wing retained its high esteem for its admirable 'Knowledge Base' and sound judgement in problem shooting. CWC retained the privilege of designing admirable water resources development structures nationwide and I feel privileged that, in one form or another, I was able to associate with nearly 180 WRD projects in varied aspects.

What's the one single project contribution of CWC designs that matters so much and make me proud of is Tehri Dam Designs, a mega dam structure that was designed in India by its own inhouse strength. That the ICOLD recognised it as an outstanding dams of the world in one of its congresses subsequently, a decade later is an ample demonstration about Indian Dan Design strength. CWC could raise its stature of India amongst world's dam building nations; and, CWC stood comparable to other national set ups of fame like USBR or US Army Corps of Engineers or the then USSR, to cite a few parallels. The rich and valuable experience that I had in CWC in enhancing my own knowledge base richly was highly beneficial. To say the truth, even after retirement, I was able to be professionally active, retaining the opportunity to spread the gains, globally. As ICID's Secretary General, a post of esteem that I held post retirement for nearly 9 years enabled me in rendering advice in the global arena, and work with GWP, UN-WWDR of UNESCO, etc. My humble thanks to CWC that nurtured my engineering professional skills, earlier.

Ganga Basin Water Studies (GBWS) of CWC around 1985 was the first of its own kind wherein a multi-disciplinary team was tasked with bringing out a Key Document on the entire Ganga Basin Master Plan, a study that can provide a fair insight with augmenting minimum flows in Ganges. The inputs for the studies were from several allied sister fields that matter. In other words, inputs from disciplines like Economy and Statistics etc. were included in multi-specialist's expert team, all within CWC. It is the forerunner to amply demonstrate that that CWC could be inclusive and not just be an engineering focussed set-up that relegates the role of the sister spheres and could be an effective set up for factoring IWRM approach too in the near future.

As is always the case, Central Services in India offer a holistic opportunity for their officers to serve the nation in a non-partisan manner. Water sector central services is no exception. As the services in CWC brings out a professional in water sector with a national outlook in addressing water related challenges, the CWES officers are the best' sought after' professionals, in many water tribunals etc.

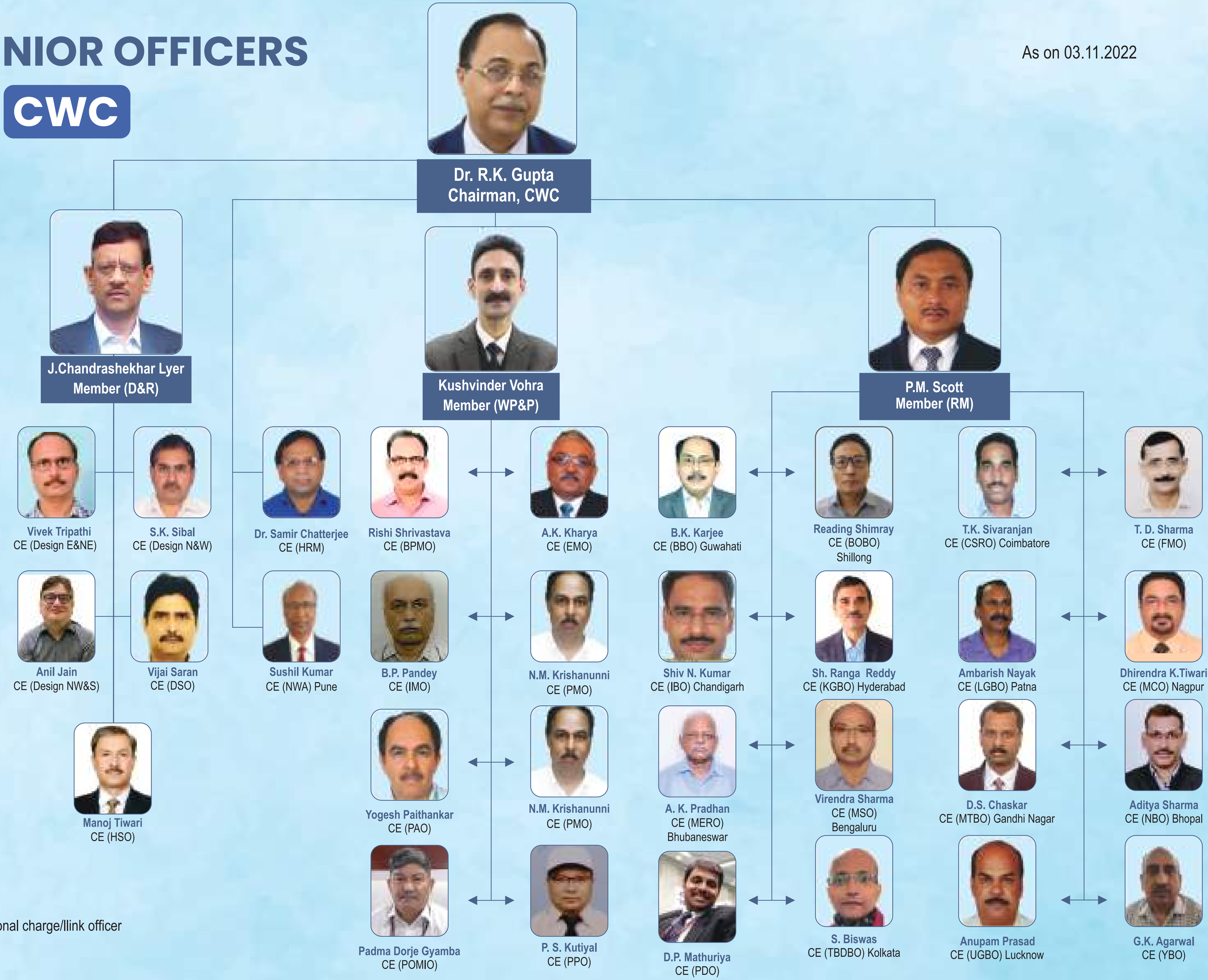
A lot of new challenges in water sector are emerging due to growing water stress and Global Climate Challenges. CWC may be obliged to morph itself to effectively manage water by River Basin approach and IWRM and this might ask such changes as are required to enable Centre in managing water as a resource of high value, more effectively. CWC should regear itself accordingly.

My humble prayers for all the best to this great & august Institution of Excellence on its 75th Annual Day Celebrations. I feel proud of being part of the family CWC and could participate in enhancing contributions to the Nation in Water Sector.

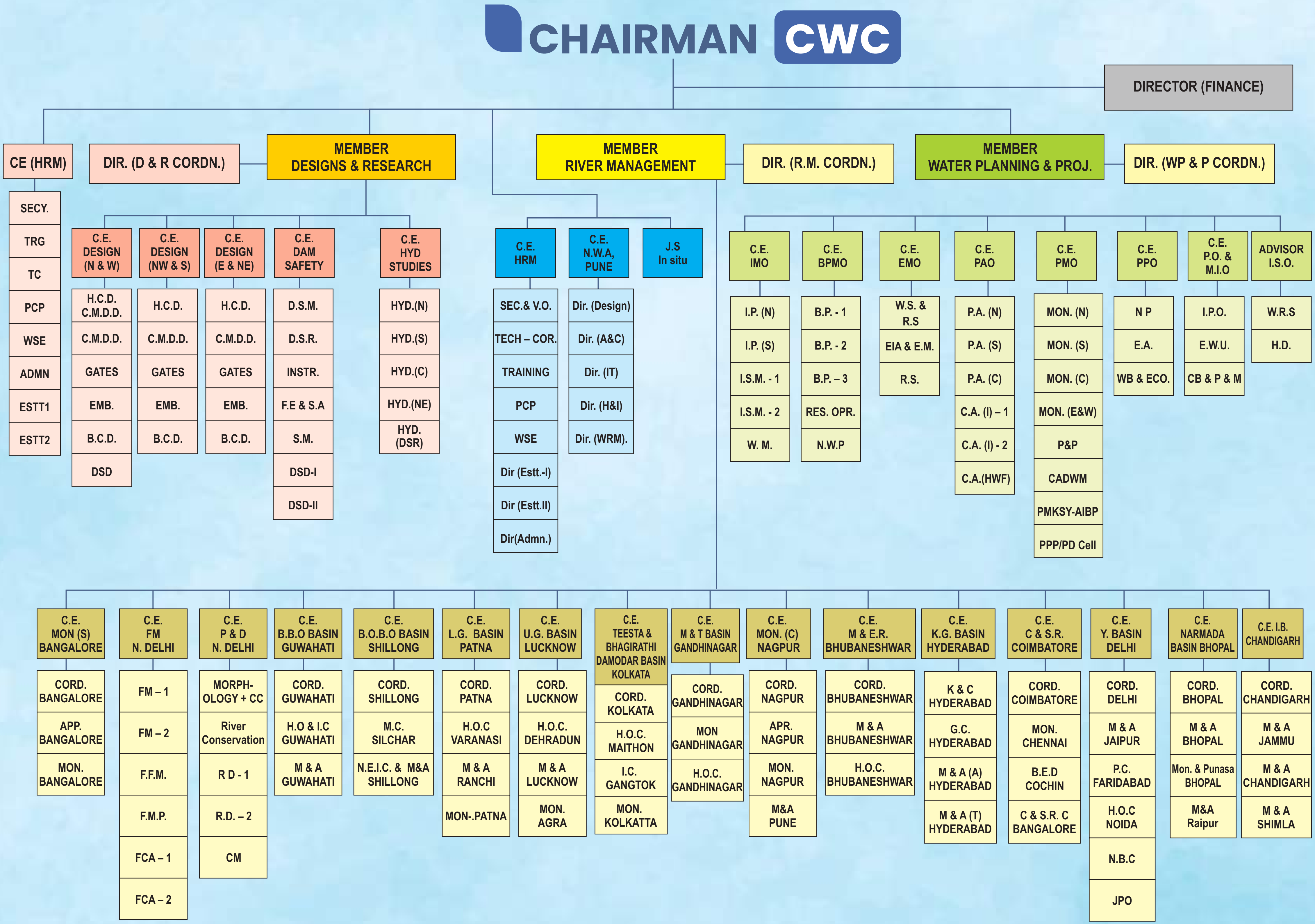
(M. Gopalakrishnan FNAE)

SENIOR OFFICERS of CWC

As on 03.11.2022

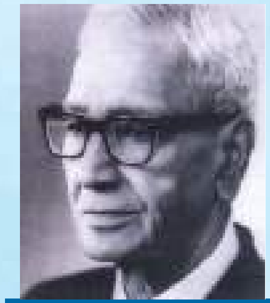


(*) Additional charge/llink officer


CHAIRMAN CWC
DIRECTOR (FINANCE)
CE (HRM)
SECY.
TRG
TC
PCP
WSE
ADMN
ESTT1
ESTT2
DIR. (D & R CORDN.)
MEMBER DESIGNS & RESEARCH
C.E. DESIGN (N & W)
H.C.D. C.M.D.D.
C.M.D.D.
GATES
EMB.
B.C.D.
DSD
C.E. DESIGN (NW & S)
H.C.D.
C.M.D.D.
GATES
EMB.
B.C.D.
C.E. DESIGN (E & NE)
H.C.D.
C.M.D.D.
GATES
EMB.
B.C.D.
C.E. DAM SAFETY
D.S.M.
D.S.R.
INSTR.
F.E & S.A
S.M.
DSD-I
DSD-II
C.E. HYD STUDIES
HYD.(N)
HYD.(S)
HYD.(C)
HYD.(NE)
HYD. (DSR)
MEMBER RIVER MANAGEMENT
DIR. (R.M. CORDN.)
C.E. HRM
SEC.& V.O.
TECH – COR.
TRAINING
PCP
WSE
Dir (Estt.-I)
Dir (Estt.II)
Dir(Admn.)
C.E. N.W.A, PUNE
Dir. (Design)
Dir. (A&C)
Dir. (IT)
Dir. (H&I)
Dir. (WRM).
J.S In situ
MEMBER WATER PLANNING & PROJ.
DIR. (WP & P CORDN.)
C.E. IMO
I.P. (N)
I.P. (S)
I.S.M. - 1
I.S.M. - 2
W. M.
C.E. BPMO
B.P. - 1
B.P. - 2
B.P. – 3
RES. OPR.
N.W.P
C.E. EMO
W.S. & R.S
EIA & E.M.
R.S.
C.E. PAO
P.A. (N)
P.A. (S)
P.A. (C)
C.A. (I) – 1
C.A. (I) - 2
C.A.(HWF)
C.E. PMO
MON. (N)
MON. (S)
MON. (C)
MON. (E&W)
P&P
CADWM
PMKSY-AIBP
PPP/PD Cell
C.E. PPO
N P
E.A.
WB & ECO.
C.E. P.O. & M.I.O
I.P.O.
E.W.U.
CB & P & M
ADVISOR I.S.O.
W.R.S
H.D.
C.E. MON (S) BANGALORE
CORD. BANGALORE
APP. BANGALORE
MON. BANGALORE
C.E. FM N. DELHI
FM – 1
FM – 2
F.F.M.
F.M.P.
FCA – 1
FCA – 2
C.E. P & D N. DELHI
MORPH-OLOGY + CC
River Conservation
R D - 1
R.D. – 2
CM
C.E. B.B.O BASIN GUWAHATI
CORD. GUWAHATI
H.O & I.C GUWAHATI
M & A GUWAHATI
C.E. B.O.B.O BASIN SHILLONG
CORD. SHILLONG
M.C. SILCHAR
N.E.I.C. & M&A SHILLONG
C.E. L.G. BASIN PATNA
CORD. PATNA
H.O.C VARANASI
M & A RANCHI
MON-.PATNA
C.E. U.G. BASIN LUCKNOW
CORD. LUCKNOW
H.O.C. DEHRADUN
M & A LUCKNOW
MON. AGRA
C.E. TEESTA & BHAGIRATHI DAMODAR BASIN KOLKATA
CORD. KOLKATA
H.O.C. MAITHON
I.C. GANGTOK
MON. KOLKATTA
C.E. M & T BASIN GANDHINAGAR
CORD. GANDHINAGAR
MON GANDHINAGAR
H.O.C. GANDHINAGAR
C.E. MON. (C) NAGPUR
CORD. NAGPUR
APR. NAGPUR
MON. NAGPUR
M&A PUNE
C.E. M & E.R. BHUBANESHWAR
CORD. BHUBANESHWAR
M & A BHUBANESHWAR
H.O.C. BHUBANESHWAR
C.E. K.G. BASIN HYDERABAD
K & C HYDERABAD
G.C. HYDERABAD
M & A (A) HYDERABAD
M & A (T) HYDERABAD
C.E. C & S.R. COIMBATORE
CORD. COIMBATORE
MON. CHENNAI
B.E.D COCHIN
C & S.R. C BANGALORE
C.E. Y. BASIN DELHI
CORD. DELHI
M & A JAIPUR
P.C. FARIDABAD
H.O.C NOIDA
N.B.C
JPO
C.E. NARMADA BASIN BHOPAL
CORD. BHOPAL
M & A BHOPAL
Mon. & Punasa BHOPAL
M&A Raipur
C.E. I.B. CHANDIGARH
CORD. CHANDIGARH
M & A JAMMU
M & A CHANDIGARH
M & A SHIMLA

CWC CHAIRMEN

Sh. A.N. Khosla



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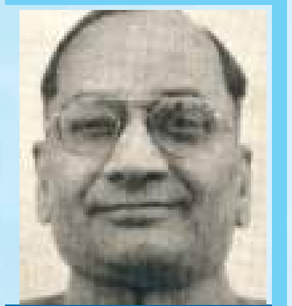
Sh. Kanwar Sain



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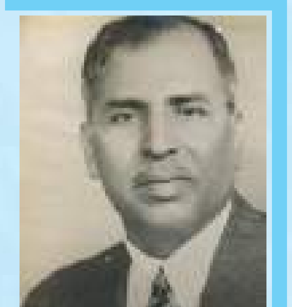
Sh. M. Hayath



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Sh. S.S. Kumar

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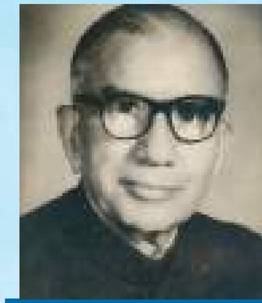
Sh. M.R. Chopra



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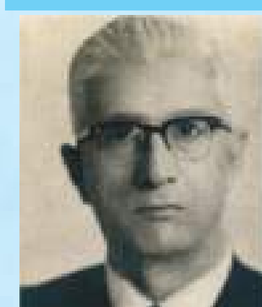
Sh. C.L. Handa

18.08.1966 - 07.12.1966

Sh. D. B. Anand



08.12.1966 - 05.06.1968

Sh. G. A. Narasinh Rao

06.06.1968 - 12.02.1970

Sh. S. K. Jain

29.03.1970 - 16.01.1974

Dr. Y. K. Murthy

25.05.1974 - 31.10.1978

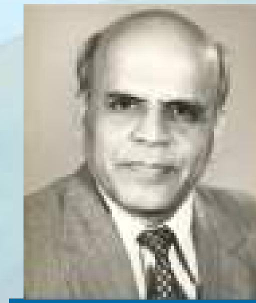
Dr. K. C. Thomas

01.11.1978 - 30.06.1980

Sh. R. Ghosh

01.07.1980 - 30.09.1981

Sh. M.G. Padhye



05.07.1982 - 15.09.1982

Sh. Pritam Singh

05.10.1982 - 31.12.1984

Sh. M.A. Chitale

25.09.1985 - 22.02.1989

Sh. R.B. Shah

01.07.1989 - 28.02.1990

Sh. V.B. Patle

29.03.1990 - 31.07.191

Dr. C.D. Thatte

16.01.1992 - 10.09.1992

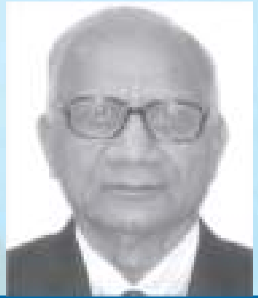
Sh. Z. Hasan

29.04.1998 - 29.06.1998

Sh. A.D. Mohile

31.12.1998 - 31.08.2000

Dr. B.K. Mittal



04.06.2001 - 31.07.2001

Sh. R. Jeyaseelan

27.10.2003 - 30.11.2006

Sh. S.K. Das

01.12.2006 - 31.07.2007

Sh. A.K. Bajaj

02.03.2009 - 31.08.2011

Sh. R.C. Jha

01.09.2011 - 31.07.2012

Sh. A. B. Pandya

05.11.2013 - 31.12.2015

Sh. G.S. Jha

01.01.2016 - 31-01.2017

Sh. Narendra Kumar

02.03.2017 - 31.10.2017

Sh. S.Masood Husain

18.12.2017 - 30-06-19

A. K. Sinha

01.11.2019 - 31.10.2019

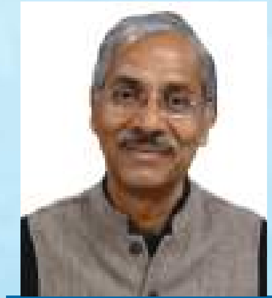
R.K. Jain

01.11.2019 - 31.12.2020

S. K. Haldar

01.01.2021 - 17.11.2021

R. K. Sinha



17.11.2021 - 31.01.2022

Dr. Rakesh Kumar Gupta

01.02.2022 to till date

MANDATE & MISSION

Mandate

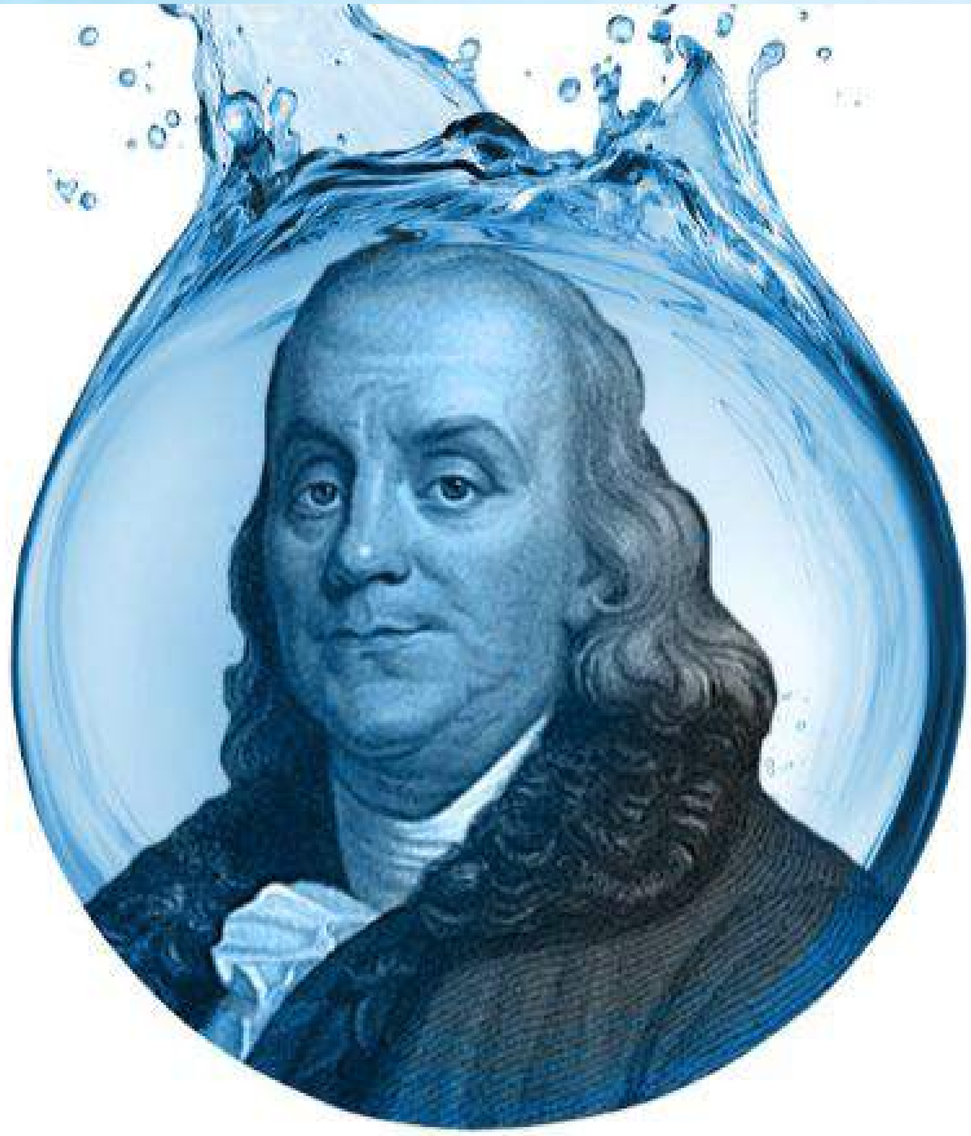
General responsibility of initiating, coordinating and furthering in consultation with the State Governments, concerned, schemes for the control, conservation and utilization of water resources in the respective state for the purpose of flood management, irrigation, drinking water supply and water power generation.

Mission

To Promote Integrated and Sustainable Development and Management of India's Water Resources by using State-of-the-art Technology and Competency and by Coordinating all Stakeholders.

When the well is dry, we know the worth of water

Benjamin Franklin



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- Contribution of Central Water Engineering Service (CWES)
- A Brief Over-View of Water Resources Development in India
- Contribution of CWC During its Formative Years

Evolution of the Central Water Commission

Historically, all major irrigation works in India have been developed with State led initiative. Profit seeking private enterprise had a short-lived tryst with canal irrigation projects in the mid-19th century during the British rule. But when the private irrigation companies ultimately proved to be a failure, it has led to policy decisions that the State would construct irrigation projects through its own agency from public loans raised for the purpose and that political boundaries would not be allowed to come in the way of best possible utilization of river waters for irrigation. Recurrent droughts and floods during the second half of the 19th century underlined the need for taking up protective irrigation works which were not remunerative.

At the beginning of the 20th century, recommendations of the First Irrigation Commission in 1903 gave new impetus to the irrigation works. Actual execution and management of the irrigation works was the responsibility of the provincial/state Government. Govt. of India and Secretary of State had powers of superintendence, direction, and control on all irrigation activities of state public works departments through an Inspector General of Irrigation and a public works secretariat of the Govt. of India. No major irrigation work could be taken up without the sanction of the Secretary of State and loans raised by Govt. of India were treated as advances to the provincial Governments at predetermined rates of interest.

With the implementation of Montagu Chelmsford Reforms in 1921, irrigation became a 'Provincial' but 'Reserved' subject. Provincial Governments could raise loans themselves for financing irrigation works but administrative approval of the Secretary of the State was essential for projects costing more than Rs.50 lakhs.

In 1927, Govt. of India in consultation with the provincial Governments set up the Central Board of Irrigation as a coordinating body between the provinces consisting of Consulting Engineer to the

Govt. of India and the Chief Engineers looking after irrigation in various provinces.

'Provincial Autonomy' was introduced, and irrigation became a transferred subject following the implementation of Government of India Act, 1935. Provincial Governments got overarching powers over 'water supplies, irrigation and canals, drainage and embankments, water storage and water power' and only 'shipping and navigation' were reserved for the centre. However, there was a provision for intervention by the centre in case of inter-provincial/state water disputes.

During the formulation of the post WWII development policy, the newly created Department of Labour which oversaw the subjects of irrigation, electricity, and other related public works, felt constrained by the provisions of the GoI Act, 1935. It felt that the participation of the Central Government was necessary in case of irrigation and hydro-electric projects planned on inter-State rivers. Central Government's financial support was also required for machinery and equipment, and training of technical personnel. Nevertheless, it went ahead with great caution, suggesting that 'although it was necessary that planning to be effective should be on all India basis even for provincial subjects, it is intended to achieve this objective by means of adjustment, agreements and cooperation, with Provincial and State Governments.' The same line of thinking was also reflected in the framing of the new Constitution for independent India which was adopted by the constituent assembly in

1950 with one major departure from the GoI Act, 1935 which placed the regulation and development of inter-State rivers under the control of the Union Government to the extent declared by Parliament by law to be expedient in the public interest.

Dr. B. R. Ambedkar, Member (Labour) in Governor General's Executive Council during 1942-46 was instrumental in evolving a policy framework for water resources sector which had a component of establishment of administrative and technical expert bodies at the Centre.

The Central Board of Irrigation in its 14th meeting held in November 1943, adopted a resolution recommending the setting up of one technical authority charged with the responsibility of collecting the necessary data concerning water supplies, water rights and waterways for the information and use of the Govt. of India and the provincial governments concerned.

Reconstruction Committee of the Governor General's Executive Council in January 1944, decided to appoint a Consulting Engineer for post-war development of Irrigation and Hydro power.

Mr H C Prior, Secretary to the Department of Labour in his note dated 31.08.1944 proposed the setting up of the Waterways, Irrigation and Navigation Commission which was accepted by the Govt. of India on 12.09.1944.

Dr. A N Khosla, an eminent engineer and a great visionary, who would always be remembered with the Haveli project (now in Pakistan) and other projects designed in accordance with Khosla's theory of uplift pressures for structures on sandy foundations, assumed charge as Consulting Engineer and Waterways Commissioner to Govt. of India in February 1945.

9 out of 11 provinces welcomed the proposal for the formation of the new Commission at the centre and the Department of Labour decided to set it up on the basis of that they had concurrence of the majority provinces.

"I visualize that growth of this body in course of time body in course of time, into a very big organisation with its activities spread over the entire length and breadth of India, and its assistance and advice eagerly sought by provinces & states, to the end that the nature resources of any region may be exploited for maximum benefit and unified development"

Dr. B.R. Ambedkar
Member (Labour)
Viceroy's Executive Council
(1942-46)

Central Waterways, Irrigation and Navigation Commission (CWINC) was thus constituted vide Department of Labour resolution dated 05.04.1945 as per which 'The Commission will act generally as a Central fact finding, planning and co-ordinating organisation with authority to undertake construction work. It will be available to advise the Central, Provincial and State Governments in regard to Waterways, Irrigation and Navigation problems throughout the country. The Commission will be a strong technical organisation designed to conduct, where necessary, surveys and investigations with a view to secure planned utilisation of water resources of the country as a whole and, in consultation with the Provincial and State Governments throughout the country, to co-ordinate and press forward schemes for the conservation, control and regulation of water and waterways and further, when so required by the Government of India, to undertake the execution of any such scheme.'

Rai Bahadur Dr. A N Khosla was appointed as the founder Chairman of CWINC and was tasked by Dr. B. R Ambedkar to prepare the proposal for the constitution and functions of the CWINC. The organisation framework of CWINC was accepted by the Govt. of India in September, 1945. On 14.10.1947, the Governor General declared the office of CWINC a permanent organisation.

In 1944, Central Technical Power Board (CTPB) had also been set up with the general responsibility of initiating, co-ordinating and processing the schemes of power generation and its utilisation throughout the country. Following a review in 1948 regarding the organisations and bodies dealing with waterways and Electricity development, the CTPB, the Electrical Commissioner with the Govt. of India and the Consulting Engineer for Waterways and Irrigation were amalgamated with CWINC and the Central Water Power, Irrigation and Navigation Commission (CWPINC) was formed vide Ministry of Works, Mines and Power resolution dated 16.01.1948. This Commission was charged with 'the general responsibility of initiating, co-ordinating and furthering in consultation with the Provincial and State Governments for control, conservation and utilisation of water resources, throughout the country,

Central Water Commission (erstwhile Central Waterways, Irrigation and Navigation Commission) was established on 05.04.1945

Dr. B.R.Ambedkar not only raised tho concept and argued for the necessity of having such a technical body at the Centre but also laid down its objectives, organisational structure and programme

The final proposal for establishment of CWINC was prepared by the then Department of Labour with the help of Rai Bahadur A.N. Khosla, Consulting Engineer to the Govt. of India for Waterways, Irrigation and Navigation

Dr. A.N.Khosla was subsequently appointed as founder Chairman of the CWINC

Dr. A.N. Khosla
(1945-53)

except the Damodar Valley Schemes, for the purposes of waterpower generation, irrigation, navigation and flood control and if so required, the construction of any such schemes on behalf of the Govt. of India.'

As a result of further review, Govt. of India vide Ministry of Natural Resources and Scientific Research Resolution dated 21.04.1951 decided on grounds of economy and efficiency, to amalgamate the CWPINC and Central Electricity Commission into Central Water and Power Commission (CW&PC). CW&PC was charged with 'the general responsibility of initiating, co-ordinating and furthering, in consultation with the State Governments concerned, scheme for the control, conservation and utilisation of water resources, throughout the country, for purposes of flood control, irrigation, navigation and waterpower generation, as well as schemes of thermal power development and also schemes of transmission and utilisation of electric energy throughout the country. The Commission will if so required, also undertake the construction and execution of any such schemes."

With the creation of the Ministry of Irrigation and Power in 1952 CW&PC became its attached office. The Library and Information Bureau of the Central Board of Irrigation was made part of the Commission in April, 1947. To strengthen the research set up of the CW&PC the then existing Central Water and Power Research Station (CWPRS), at Khadakwasla, Central Soil Mechanics Research Station (CSMRS) at New Delhi were merged with it in the year 1954. Both the CWPRS and CSMRS however were delinked from the Commission, in 1978 and 1981 respectively.

Following the bifurcation of the Ministry of Irrigation and Power in the year 1974 into Department of Power under the Ministry of Energy and Department of Irrigation under the Ministry of Agriculture and Irrigation, the CW&PC was also bifurcated and its water wing became the Central Water Commission (CWC) and its power wing became the Central Electricity Authority(CEA).

Central Water Commission continues to be a premier technical organization of India in the field of water resources and is presently functioning as an attached office of the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India.

CONTRIBUTION OF CENTRAL WATER ENGINEERING SERVICE (CWES)

The **Central Water Engineering Service (CWES)** Group 'A' Service was formally constituted in the year 1965, though the cadre had been building since April, 1945 when Central Waterways, Irrigation and Navigation Commission (CWINC) was established on the advice of Dr B.R. Ambedkar, Member (Labour) in the then Viceroy's Executive Council. CWES is the only organized Group 'A' Service at central government dealing with water sector. CWES was mainly constituted with the objective of efficiently manning the various formations of the Government of India (GOI) dealing with water resources development.

Recruitment

CWES officers, belonging to Civil Engineering or Mechanical Engineering streams, are recruited for the Group-A posts by the Union Public Service Commission (UPSC) on the basis of Engineering Services Examination (ESE) or by way of promotion of Group-B officers in the feeder grade.

Training

National Water Academy (NWA), Pune, the in house training institute of Central Water Commission (CWC), conducts induction training program for the directly recruited CWES officers joining at the Assistant Director level. The promotee CWES officers also undergo an orientation course at NWA. These trainings expose CWES officers to various aspects/issues of water sector and enable them with various techno-managerial tools to deal with various challenges in the sector.

Besides, NWA also conducts Mandatory Cadre Training Programs, various types of trainings and capacity building programs for CWES officers at different levels throughout the year. CWES officers are also sent on foreign trainings on regular basis.

Career Progression Framework

According to prevalent recruitment rules for CWES cadre, an officer is expected to put in minimum 4 years of service at Junior Time Scale (JTS) level, and 9 years at Senior Time Scale (STS) level before his or her promotion to the Junior Administrative Grade (JAG) level. During their tenure at JTS and STS level, the officers develop requisite competencies for bigger responsibilities at JAG level. At JAG and above, the officers are required to deliver well defined output. A CWES officer may further be promoted to Senior Administrative Grade (SAG) level &Higher Administrative Grade (HAG) level after putting in a minimum of 17 years and 25 years of Gr. A service respectively subject to other terms and conditions.

Further pay parity with two years junior batch IAS officers, who are on central posting, is also ensured for CWES officers with Non-Functional Upgradation(NFU)

CWES officers play versatile roles, amidst growing challenges, for the development and management of water resources of the country.

In general, 12 key functional domains can be identified for the functioning of CWES officers viz., 1. Basin Planning and Management 2. Water Management 3. River Management 4. Inter-state / International Conflict Resolution in water related disputes 5. Flood Forecasting/ Hydrological Observations 6. Human Resource Management and Administration 7. Hydrology 8. Civil / Structural Design of WR Projects 9. Survey and Investigation of WR projects 10. Appraisal of Water Resources Projects 11. Monitoring of Water Resources Projects 12. Hydro-mechanical Design of Water Resources Projects

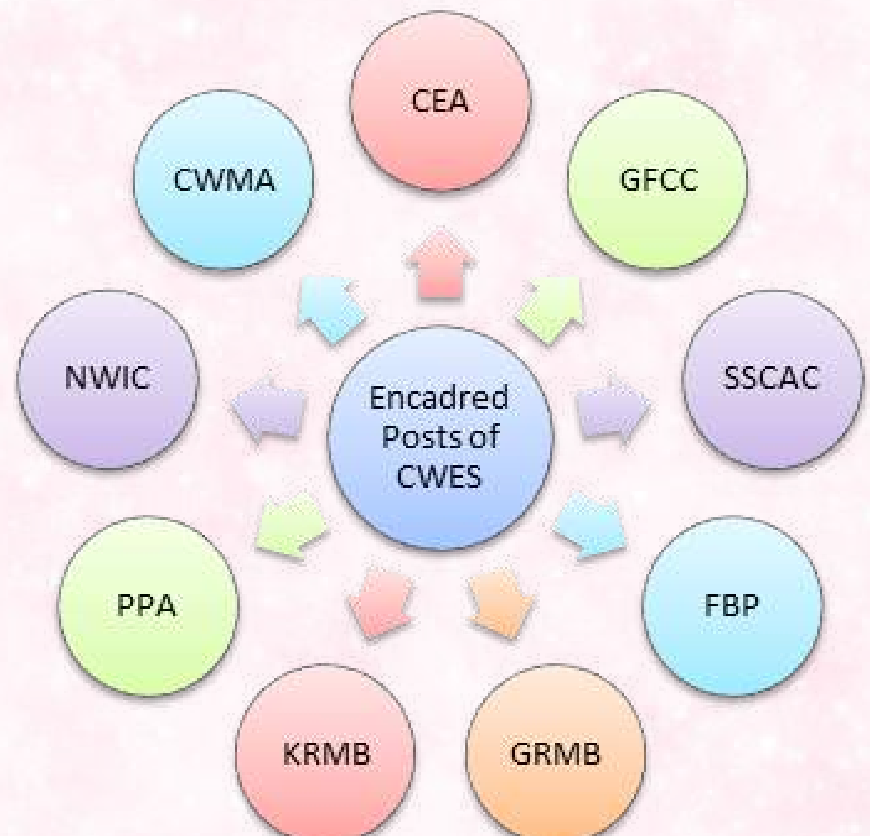
These Functional domains have been assigned with well defined roles/ objectives and activities/ tasks. The groundwork in these domains

Junior Time Scale (JTS)	Assistant Director / Assistant Executive Engineer
Senior Time Scale (STS)	Deputy Director/ Executive Engineer/ Deputy Commissioner (Equivalent to Under Secretary to GOI)
Non Functional Second Grade (NFSG)	Deputy Director/ Executive Engineer/ Deputy Commissioner (Equivalent to Deputy Secretary to GOI)
Junior Administrative Grade (JAG)	Director/ Superintending Engineer/ Senior Joint Commissioner (Equivalent to Director to GOI)
Senior Administrative Grade (SAG)	Chief Engineer/ Commissioner (Equivalent to Joint Secretary to GOI)
Higher Administrative Grade (HAG)	Member, CWC/ Chairman, GFCC/KRMB/ GRMB (Equivalent to Additional Secretary to GOI)
Apex Scale	Chairman, CWC (Equivalent to Secretary to GOI)

prepares CWES officers to play vital roles in Policy Formulation in water sector, Planning for Development & Management of water resources, Designs & Research, River Management etc.

CWES officers head important organisations under the Department of Water Resources, River Development & Ganga Rejuvenation (DoWR, RD & GR),Ministry of Jal Shakti. Majority of the CWES officers are posted in Central Water Commission (CWC), an attached office of the department which promotes "*integrated and sustainable development and management of India's water resources by using state-of-the-art technology and competency and by coordinating all stakeholders.*"

A sizeable no. of posts of CWES are also encadered in other organizations. This includes encadered posts in MoWR, RD & GR, Central Electricity Authority (CEA), Ganga Flood Control Commission (GFCC), Farakka Barrage Project (FBP), Krishna River Management Board (KRMB), Godavari River Management Board (GRMB), Cauvery Water Management Authority (CWMA) etc. Opportunities are also available for CWES officers to steer other organisations e.g. NWDA, CWPRS, CSMRS, NIH, UYRB etc. CWES officers are also deputed on foreign



assignments of planning and execution of Water Resources Projects and other long and short term deputations in international institutions such as Asian Development Bank (ADB). In addition, CWES Gr.'A' officers avail opportunities of serving on important posts in other Govt. departments through Central Staffing Scheme(CSS).

Besides, CWES officers also assume significant roles in other emerging and challenging areas such as National Water Mission, National Mission for Clean Ganga, Inland Waterways, Coastal Management, Interlinking of Rivers etc. It is worthwhile to point out that the Interlinking of Rivers (ILR) programme as adopted by GoI envisaging inter-basin transfer of water from surplus basins to deficit basins was originally formulated by CWES officers as National Perspective Plan (NPP) for Water Resources Development in 1980.

Ever since its constitution as an organized Group 'A' Service, CWES has played a major role in achieving India's water, food and energy security. The cadre has also given few excellent Secretaries to the Govt. of India - Sh. C D Thatte, Sh. M S Reddy, Sh. Z Hasan to name a few, to head the Union Ministry of Water Resources.

CWES officers have played a pivotal role in the development of irrigation potential in the country. CWES officers have been directly associated with many major and medium projects in the country as well as neighboring countries. Some of the notable projects include Tehri, Naptha Jhakri, Srisailam, Farakka Barrage and ongoing national projects such as Polavaram Multipurpose Project. Important projects in neighbouring countries which have been designed by CWES officers include Punatsangchu stage-I&II HEP, Tala HEP, Chukha HEP (Bhutan), Arun-III HEP(Nepal) and Salma dam (Afghan-India Friendship dam). CWES officers are also involved in the investigation and preparation of Detailed Project Reports (DPRs) for Pancheswar Multipurpose Project, Sapta-Kosi and Sun-Kosi Multipurpose Project jointly with Nepal.

India could successfully defend its position in Baglihar and Kishenganga HEP issues in Indus river basin on international stage with the aid and advice of CWES officers. Permanent post of Commissioner for Indus waters as per the provisions of Indus Water Treaty (IWT) is normally headed by an officer belonging to CWES cadre. International treaties for water sharing with neighboring countries such as Mahakali Treaty with Nepal and Ganga waters treaty with Bangladesh are essentially contributions made by CWES officers. CWES officers are invariably involved in other mechanisms of cooperation for the beneficial use of waters and sharing of hydrological information with neighboring countries such as India-China Expert Level Mechanism (ELM), India-Nepal Joint Standing Technical Committee (JSTC), India-Nepal Joint Committee on Inundation and Flood Management (JCIFM), India-Bhutan Joint Group of Experts (JGE) and Joint Technical Team (JTT) on Flood Management etc., Further, CWES officers represent CWC in Technical Committees of various international organizations such as ICID, WMO, ICOLD.

A BRIEF OVER-VIEW OF WATER RESOURCES DEVELOPMENT IN INDIA

Ashwin B Pandya,

Former Chairman Central Water Commission and Secretary General International Commission on Irrigation and Drainage

Introduction

It gives me an immense sense of pride for having been associated and continuing to be associated in a mentorship role with an institution of the stature of Central Water Commission when the Commission is completing 77 years of its distinguished existence.

The journey of Central Water Commission in its various previous forms is synonymous with the development of modern engineered irrigation and electric power in the country and its immediate neighbourhood. The journey of CWC is coterminous with the journey of independent India in seeking food security through water security.

Irrigation was viewed as a means of avoiding droughts and also the floods by way of creating of strategic storages right since 1867. The journey began with establishment of an Inspector General of Irrigation and was later transformed into a Consulting Engineer to the Government in 1923. The irrigation which until then was being looked after by the Crown later on became responsibility of the provinces and principalities with the changes in governance of India. With the provincial autonomy granted in 1937, the irrigation was delegated to the provinces for implementation. In the meanwhile, Central Board of Irrigation and Power was set up in 1927 which was to act as a clearing house for the interstate water problems, promotion and clearance of irrigation and flood control with a mandate to promote research. Central Waterways Irrigation and Navigation Commission came in existence in 1945. The organisation further became Central Water and Power Commission in 1951. Central Water Engineering Service was constituted in 1965 to man the senior positions of the Commission and the Department of Irrigation (presently Ministry of Jal Shakti). Present “avatar” came into existence as Central Water Commission in 1974. However, throughout this journey, the organisation has upheld its technical excellence in all the fields of water management. When one occupies the chair of the Chairman of the Commission and looks at the role of honour in front, it indeed becomes a humbling experience in finding oneself in the company of pioneers and masters.

Role of Central Water Commission in Developmental Efforts

India has come a long way from a land of frequent droughts and floods to a food, fibre and energy surplus country over a period of 75 years. This has been enabled in no small measure by the irrigation systems and hydroelectric projects who have been instrumental in bringing about this achievement. At the dawn of independence, the country found itself with a loss of crucial irrigation systems of West Punjab and consequent threat of food insecurity. CWC provided a confidence and support to the Government of India in deciding that Bhakra Dam complex to be built by the Indian engineers. Since then, we have supported almost every large dam in the country notably Hirakud, Srisailam, Sardar Sarovar just to name a few.There is no underground powerhouse in the country where CWC has not provided its inputs in form of a principal designer or as an expert consultant.

The journey of water resources development and management which has started with the dawn of civilisation is to continue in future as well and role of CWC for the country is likely to be more and more important.

When we began our development, the emphasis was on development of new projects for irrigation as a prime output and hydropower as an added benefit. That was an era of multipurpose projects with large canal networks and major dams. Over the period of time, we have been able to achieve water storages of the order of 250 BCM and 5300 large dams in the country. Our hydropower capacity which was hardly 508 MW at the commencement of the journey in 1947 has gone up to 46512 MW and counting. With the growth in our economy and population, the per capita water availability has also undergone reduction. Improved resilience to the vagaries of nature requires provision of robust infrastructure which can sustain the extremes and provide water and power at all times. These have resulted in new challenges and require newer approaches to tackle them.

When I joined CWC in 1977, it was a period of new developments and there were a large number of projects under design and planning. The country mobilised huge investments through internal resources as well as through external funding from multilateral institutions. We created an impressive asset base by late 1990s as far as peninsular India is concerned.

Challenges Ahead

While creating the impressive asset base, Central Water Commission has faced challenges of planning, development and designing with a great aplomb and have come true to its motto every time. Some of the challenges faced were development of large underground cavities in complex geology of higher Himalayas, setting up and managing flood forecasting systems and upgrading them through telemetry facilities, facing challenges of flood hazard assessment to the projects and evolving standardised methodologies for the risk assessment. In fact, today, in the areas of hydrological analysis and geotechnical designs of water resources projects, the word of Central Water Commission is final. We also acquitted ourselves with great aplomb in international negotiations and transboundary disputes in our immediate neighbourhood by providing sound technical arguments. Baglihar issue is a case in point. One can take pride in the fact that none of the dams designed by CWC have ever failed or found deficient in planning. We do receive brick bats from various quarters while the process is ongoing but eventually, the CWC engineers have proved themselves right.

The challenges of environmental thoughts and priorities which commenced with Brundtland report made the societal priorities undergo changes. With the completion of Bhakra and other projects, we achieved food security by late 70s. In the early period of our development, the focus was on implementation after planning and the technical and technological issues were occupying the minds. The focus of the beneficiary classes was also on acquiring the resource for their economic security from agricultural operations. However, the situation gradually changed as we achieved food security. The advent of resource allocation became a political tool and the societal issues have gained ground in water resources dialogue across the society. Sardar Sarovar project implementation became a landmark event which influenced the conventional paradigms of development by bringing in the social issues of the affected person groups into focus while offering no scientific and economic solutions to the large-scale deprivation faced by the other sections of the society in terms of water resources. The mentality of "Not in My Backyard" started governing the dialogues of development.

Central Water Commission which was conceived as an apex technical body to address the developmental challenges from a science and technology-based approach is now facing new challenges in terms of a lead player for the national development. This does not mean that the original challenges have gone away. Rather, they have become more complex to address as new constraints are added in form of social and political influences. It is quite apt to discuss the new challenges being faced by the commission after having steered the country through a long and arduous path of original development.

Having dealt with the achievements, it is time to focus on the challenges being faced by the organisation as it stands on the cross roads of developmental ideologies and time. A few challenges that come to mind are described below.

Water resources management has no longer remained purely an engineering endeavour to provide adequate water to the beneficiaries. The management is being influenced by the other aspects of socio-economic and political developments. Increasingly, the economic outputs being generated from the given resource with equal emphasis on equity is coming into focus. This requires the organisation to think in terms of water economics and social reactions to the resource development and distribution. The engineering judgement has to be integrated with the socio economic reactions of the society. Government to which the Commission is a principal and lead advisor in the matters pertaining to water is increasingly troubled by the winds of socio-political change. CWC should be able to provide the guidance in this direction while not losing the sight of the underlying principles of science and technology. This will require inter-disciplinary awareness in the officers of the issues at hand and preparation of adequate database for rationalising the decisions.

The traditional mode of operation of the Commission has been that of a technical government department delivering the goals set for the organisation in a silent manner. However, increasingly the water resources field is getting influenced by advocacies of various hues and intents. Many of the intents are not founded on a sound knowledge base of Indian Hydrology and geotechnical/ topographical context. However, in the modern day age of information explosion, the frequent and insistent reporting leads to acceptance of such advisories which may not be sustainable for the country in future. A cacophony of such advocacy has already led the formation of favourable opinions and acceptance of the ideology at mass scale including in the Governance structures. Unless such ideologies are countered with equal vigour, the water resources field is likely to surrender many of the hard earned achievements. Commission has to take up countering of such ideologies and spread equally aggressively relevant information so that the development dialogue does not get hijacked by the lobbies. This requires devotion of adequate knowledge resources and outreach.

Climate change effects are upon us and coupled with the increased demands on water, has a double whammy effect. With already increased frequency of extreme events, ensuring the water delivery through efficient and dynamic conservation policies for the major reservoirs of the country is the need of the hour. Also, predicting flooding events in unexpected medium and small sized basins especially from the catchments draining into the reservoirs is a challenge as the present paradigm of having ground based observations in real time is not feasible. These areas are requiring investigations and developments. The issues are likely to be further aggravated in interstate context where the cascade of reservoirs owned and operated by different agencies are involved. Central Water Commission need to bring about a national water conservation policy and guidelines for engaging the stakeholders with the issue. Other impacts of climate change on national level water availability and potential exacerbation of disparities are also needed to be worked out in quantitative terms and impacts assessed with relation to utilisation patterns. This study can evolve into a national water strategy in the context of climate change and can become a useful support to the government for decision making.

Constitutionally, even though the Entry 56 providing leverage to the federal government, historically, the government has not exercised the lever to its full capacity. There have been water disputes amongst various sub regions in the past and will be in future. Of late, the viciousness of the disputes have increased and consequently the role of judiciary has gone up exponentially in view of reluctance of parties to resolve the issues with internal discussions. Central Water Commission will have to rise to the challenge of providing a scientific basis to the disputes and disambiguate the arguments in their fundamental context to the judiciary either through informal or formal means. Recent case of determination of environmental flow provisions in Ganga is a case in point. It is, therefore, necessary that the organisation gears up for such calls of duty in future as well.

The Commission also has to act as a disambiguating agency against the half cooked solutions masquerading as panacea in the field of water resources. Many of the solutions in this class are becoming a bottleneck in implementing scientific solutions and are serving as tools to the interested groups to thwart the long-term solutions. This is especially true in the context of solutions advocated for the climate change effects on water.

A key element of informed decision making is the ability to analytically examine the technical and managerial issues at hand. It is necessary that the ability of the Commission in applying latest analytical techniques in-house in every sphere of its operation is a must. Being a human intensive activity, the nurturing of expertise in every field of operation for retaining and developing the analytical capabilities is a prime requirement.

The country has created impressive assets in the water conservation and distribution sector. Value of such an asset base is not adequately recognised at the beneficiaries level especially the state governments. Assuring the health of these assets is vital in water security for the country. CWC has already taken a pioneering step by getting the legislation on dam safety enacted and now we have a national act for dam safety. Implementing the act through the labyrinths of federal-state equations will be herculean task. The field poses considerable technical challenges in evolving standards of safety and rehabilitation as apart from the original designs. There are many unexplored areas in material behaviour, construction techniques and new materials developed in other fields but having potential for application in the asset management field. The lead will have to be taken by CWC for assessing and promoting relevant solutions. Having got the attention of the government on dam safety, the next task is to attack the issues prevailing in distribution networks and improving their performance.

Summing Up

In conclusion, the Central Water Commission has provided yeomen service to the nation in the water resources field and will continue to provide in future also. The open work culture and capacity to take challenges has made the organisation stand its ground. The engineers of Central Water Commission have been creating the expertise and are continuing to provide such expertise even post their retirement as well. This has left an indelible mark of Central Water Commission personnel on the water resources field. It is in the interest of nation that the organisation continues to stand its ground in future as well with the equal vigour and continue to support the water resources development of the country.

The need for a strong technical expert body at the centre was felt in the post WWII reconstruction period which led to the constitution of Central Waterways, Irrigation and Navigation Commission (CWINC) in April, 1945 which is the precursor to the present day Central Water Commission (CWC).

The partition of India in 1947 dealt a severe blow to its predominantly agricultural economy. India lost 31 per cent of the irrigated area and some of the most impressive irrigation projects in the Indus basin with extensive canal systems to Pakistan. It has resulted in a deficit of four million tonnes of food grains in 1947. In the aftermath of WWII, the world was also passing through a food crisis and India had no option but to make heavy investments in irrigation to increase food production.

Systematic planning for Irrigation Development was initiated with Five Year Plans. CWC, as an apex technical organization in the field of water resources development and management has been intimately associated with planning, investigations, designs, and management of various aspects of water resources projects. The expertise developed under one roof has made the country self-reliant and consequently various complex problems in the planning, designs and implementation of diverse projects have been tackled successfully.

The Formative Years

Multi-purpose river development on a regional basis with a view to provide simultaneously for irrigation, hydro-power generation, flood control, navigation, domestic water supply, fish culture etc., was already an accepted policy of the Govt. of India at the time of constitution of CWINC. Damodar and Sone River Valley Projects, the Mahanadi (the Hirakud Project), Bhakra-Nangal Project and other projects on the rivers Kosi, Chambal, Tungabhadra were under consideration of the then Department of Labour. Dr. B. R. Ambedkar, Member (Labour) in Viceroy's Executive Council, in the first Conference on Damodar Valley Project held at Calcutta on 03.01.1944 said that *"Our policy for water resource development must be multi-purpose policy so as to include all possible uses of water"*. The Damodar valley, Hirakud Dam and the Kosi projects were undertaken essentially for flood control but were made multi-purpose schemes to maximise the benefit.

It was upon Dr. B. R. Ambedkar's insistence, Rai Bahadur Dr. A.N. Khosla, Chief Engineer in the Punjab province and in charge of Bhakra Dam and other projects, took over as Chairman, CWINC, with just one orderly and one stenographer. He then set out to prepare an organisational structure and framework which was accepted in September 1945. From a modest beginning with a total initial staff strength of 205,the Commission has since grown into a large organisation. To start with it had seven sections, each under a Director to deal with:

- Irrigation
- Waterways
- Navigation
- Hydrology
- Designs
- Publications and Statistics and
- Research.

GOVERNMENT OF INDIA
CENTRAL WATERWAYS IRRIGATION AND NAVIGATION COMMISSION

MAHANADI VALLEY DEVELOPMENT
HIRAKUD DAM PROJECT

VOLUME I—REPORT

JUNE 1947

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Hirakud Project: A Dream Comes True

Facts About The Hirakud Dam

Features of The Project

Financial Control

Control Board

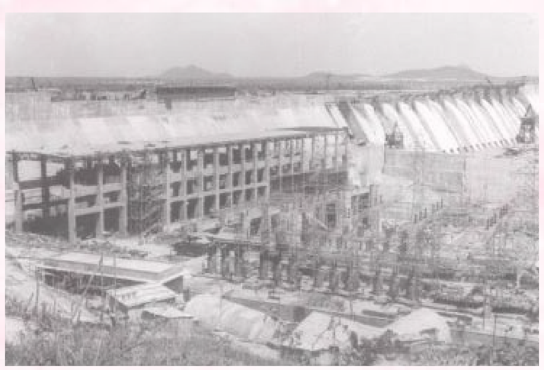


Fig. 1 Hirakud Dam Project was the first Multipurpose Project in India. Completed in 1957, it provides irrigation to 2.51 la ha. Length of the dam (including dykes) is 25.5 Km (Water Resources Development in India, 1997, CWC)

Due to recurrent floods, provincial Government of Orissa approached Dr. B. R. Ambedkar, the Member (Labour) to consider the taming of the Mahanadi on lines of the Damodar Valley Project. In the Cuttack Conference held on 08.11.1945 under the Chairmanship of Dr. B. R. Ambedkar, it was agreed that the potentialities of the Mahanadi river for unified multi-purpose development should be thoroughly and expeditiously investigated. In line with the decisions of the Cuttack Conference, the Surveys and Investigations were undertaken by CWINC under the leadership of Dr. A.N. Khosla. A Project Report on unified development of Mahanadi valley was prepared by CWINC.

Hirakud Dam Project

During 1948-49, Central Water Power, Irrigation and Navigation Commission (CWPINC) was entrusted with the construction of the Hirakud Dam Project, on behalf of the Government of Orissa, at an estimated cost of Rs. 47.81 crores. It has also undertaken the construction of a combined road-rail bridge on the Mahanadi at Sambalpur on the National Highway from Bombay to Calcutta which facilitated the construction of the Hirakud Dam and works connected therewith. The project was formally inaugurated on 13.01.1957.

Kosi Project

The problem of Kosi river, known as 'Sorrow of Bihar' due to huge shifting of its course from east to west and associated flooding was also referred to CWINC. After conducting detailed investigations, in 1950, it formulated a proposal for a multipurpose project including storage dam at Barakshetra(Nepal). However, this was not agreed upon due to economic and financial considerations at that time. Further, a project was conceived in 1953 to construct barrage and embankment on both sides of the rivers and canal system for irrigation in India and Nepal. Agreement between the Government of India and the Government of Nepal on the Kosi Project was made on 25.04.54. Work on embankments

Fig. 2 Dr A N Khosla, Chairman, CWINC with Mr. J L Savage, US expert and other engineers surveying the site of the proposed dam on the Kosi

was started in January 1955 and was completed by 1958. Since major portions of embankments were completed in 1957, flood control benefit started to accrue. Afterwards, the construction of Hanumanagar barrage was taken up in 1959 and was completed in 1963. The project provided flood control benefits, irrigation and hydropower to both the countries and is a fine example of international cooperation between the two countries.

Kakrapara Weir

When the need for harnessing the Tapi waters was felt, CWINC took up investigation in 1946-47 and framed project proposals at the request of the erstwhile Bombay and the Central Provinces and Berar State. Subsequently on ad-hoc committee of experts appointed by the Govt. of India in 1948 under the Chairmanship of Dr. A. N. Khosla recommended that the lower Tapi basin should be developed first. Kakarpara weir in the

Fig. 3 Kakrapara Weir (NWRWS&K Dept., Govt. of Gujarat)

upstream Surat city with canals on both banks commanding area was taken up for execution by the Commission. Investigations for a suitable storage site upstream for securing assured supplies for irrigation and effective flood control were continued and ultimately the later day Central Water & Power Commission (CW&PC) selected Ukai site and formulated a detailed proposal in 1955.

Early Water Disputes Referred to the Commission

Apart from the construction and investigations of projects directly entrusted, the Commission had as one of its important functions to facilitate progress, resolve disputes, etc regarding projects under construction or investigation by different Provincial and State Governments and give technical advice when requested so to do. Among the very first problems referred to the Commission were the Tungabhadra water dispute between Madras province, Mysore and Hyderabad States, and the sharing of the Machkund power between Orissa and Madras provinces which were successfully resolved.

Early Basin Wise Plans

Under the leadership of Dr. A N Khosla, the Commission formulated many river valley projects which were subsequently included in the five year plans. Several important projects were planned and executed with the collaboration of the Commission thereby saving precious foreign exchange required for engaging foreign consultants. From 1954 to 1959, CW&PC undertook the preparation of draft master plans for various river basins. Skeleton basin wide plans were initiated for the major rivers like the Narmada, Tapi, Yamuna, Ganga, Brahmaputra and the Punjab rivers in collaboration with the States concerned. A report was submitted on the Nandikonda (Nagarjuna Sagar) and the Krishna-Pennar projects.

Execution of Multipurpose Projects through Control Boards

Another important event in the early years was the decision to have the Bhakra Dam built by Indian engineers. A major feature of the Bhakra dam construction was that it was done exclusively with departmental labour without involvement of contractors with all labour having been recruited, trained, and supervised and paid directly by engineer officers of the Punjab Government. To avoid procedural delays in according sanctions, purchase of materials, appointments etc. Bhakra Control Board was set up to supervise and monitor the progress of the Project. Bhakra Control Board was chaired by Governor of Punjab and Chairman, CW&PC was one of its members. Simultaneously a Consulting Board was set up with the Chairman of the CW&PC as Chairman and experts in various fields of dam design and construction as Members.

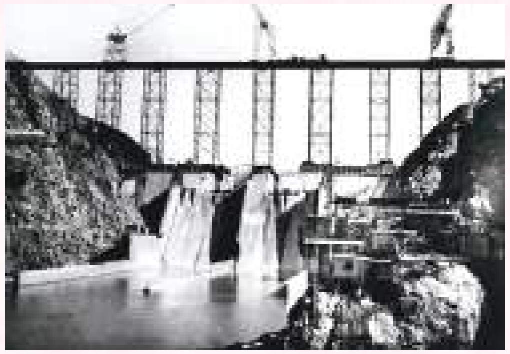



Fig. 4 View of Bhakra dam under Construction in 1959 and at near completion in 1962 (PIB)

On the pattern of Bhakra Control Board, Control Boards for other major projects viz., Chambal Project, Nagarjuna Sagar Project were organised for quick decision making, speedy and efficient execution of works.

Chambal Valley Development Project is remarkable symbol of inter-state cooperation in water resources development between the States of Rajasthan and Madhya Pradesh. Chambal Control Board was constituted in April, 1955 by Govt. of India following the decision of the inter-state conference in March, 1955 to ensure efficient, economical and expeditious execution of the Chambal Valley Development project. The then Deputy Minister for Irrigation and Power, Govt. of India was the chairman of the board which also had representation from Ministry of Finance, CW&PC and the States of Madhya Pradesh and Rajasthan.

CW&PC played significant role in the development of Nagarjunasagar dam which stands as the largest masonry structure in the world and the most remarkable engineering feats of the modern India. Dr. K. L. Rao, guided the construction activity of the project in the capacity of Member (Designs), CW&PC and later as Union Minister for Irrigation and Power, Govt. of India. Also, Chairman, CW&PC was one of the members of control board headed by the Chief Minister of Andhra Pradesh.


Fig. 5 Workers swarm over scaffolding to erect Nagarjuna sagar Dam (National Geographic, May 1963) Nagarjuna Sagar Dam Project after completion (Bhagirath, Publications Division, GoI)

Farakka Barrage Project

After Independence, Govt. of West Bengal was concerned about reviving the discharge through the Hooghly River primarily for keeping the Calcutta Port alive. Immediately after partition, in accordance with the recommendation of the Central Board of Transport, Govt. of West Bengal were asked to undertake investigations in connection with the Ganga Barrage project. However, progress was slow and the task was transferred to CWPINC in July, 1949. After thorough study and consultation, a barrage at Farakka, feeder canal from Farakka to Bhagirathi below Jangipur barrage and other ancillary works were proposed. The Farakka Project was approved in 1960. For various reasons, the actual work on the barrage did not start before 1963-64. The Farakka Barrage Project Authority was set up with the mandate to execute and thereafter operate and maintain the Farakka Barrage Project Complex comprising of Farakka Barrage, Jangipur Barrage, Feeder Canal, Navigation Lock and associated structures. The Barrage comprises of 112 nos. of Gates (108 Nos. main Gates and 4 Nos. Fish Lock Gates) and 11 Nos. Head Regulator Gates for diversion of approximately 40,000 cusec (1035 cumec) of discharge into the Feeder Canal. The barrage is founded on fine sand in the seismic zone and required a considerable amount of design studies.

Fig. 6 Farakka Barrage plays a significant role in regulation of water to Bangladesh as per Indo-Bangladesh Treaty-1996

Fig. 7 Greening the Desert : Indira Gandhi Nahar Project (India Today)

All the technical problems relating to the construction were tackled by Indian Engineers adopting unique construction techniques. The project construction commenced in 1961 and the project was commissioned and dedicated to the Nation in May 1975. It also paved the way for navigation facility from Kolkata to Ganga and the rail and road bridges built over the barrage established the much- needed direct road and rail links between Kolkata and North Bengal & Assam.

Rajasthan Canal Project

Dr. Kanwar Sain took over from Dr. A. N. Khosla in June, 1953 as the second Chairman of CW&PC. Before joining the Commission as Chief Designing Engineer, he was the Chief Engineer and Secretary of Bikaner State and ensured its active participation in Bhakra Nangal project. He was engaged in setting up a world class Design & Research wing in CW&PC on similar lines of United States of Bureau of Reclamation (USBR). He also worked as Chief Engineer of Hirakud Dam project and was a key man in the conception of Damodar valley projects. He played a significant in the conceptualization of the Rajasthan Canal Project (now Indira Gandhi Nahar Project -IGNP.

At an inter-State conference held on the 07.11.1958, it was decided to set up a 'Committee of Direction' and a 'Rajasthan Canal Board' to ensure efficient, economical and early execution of the Rajasthan Canal Project, including all connected works in Punjab and Rajasthan and the colonisation of the area covered by the Project.

Early Role in Hydropower Projects

The first systematic Hydro-electric Survey of India was undertaken by CW&PC during 1953-59. Over the years, CW&PC has carried out detailed surveys & investigations and has been associated either fully or partially in the designs of multiple projects. The Planning & Investigation unit was responsible for progress of water resources projects in the remote areas where no other organisations was

Fig. 8 Recommissioning of Thimphu Mini Hydropower in 2018 to commemorate diplomatic ties with India

available for taking up work. Projects like Loktak in Manipur, Salal in Jammu & Kashmir, Bairasiul in Himachal Pradesh, Gumti in Tripura, Legyap in Sikkim have been investigated and largely constructed by CW&PC officers who also worked in the construction of hydroelectric projects executed by NHPC.

Cooperation with Neighbouring Countries

In the neighbouring kingdoms of Bhutan and Sikkim (which became part of India in 1975), the Commission has played a notable role by investigating a series of micro hydel schemes for utilisation of the waterpower resources.

In Bhutan CWC has also executed two micro hydel schemes to supply power to the State capitals of Thimpu and Paro. India started providing support to Bhutan from 1955 onwards by way of hydro-meteorological data collection, topographical surveys and geological investigations leading to DPRs of major, medium and mini hydropower projects. A permanent office viz. Bhutan Investigation Division (BID) of the CW&PC was created in Bhutan in 1961 which played an active and important role in the success of this cooperation between two countries.

Fig. 9 Trishuli Hydropower Station, Nepal

Trishuli Hydropower Station, one of the earliest hydropower projects in Nepal, was investigated, designed and executed by CW&PC. It was commissioned in 1967 with financial assistance from Government of India and is the 4th largest hydropower plant in Nepal. The joint effort of India and Nepal for the project contributed to the growing bond of Indo-Nepal friendship.

International Cooperation

India has also played an active part in the development work of Lower Mekong Basin which was organised as an international venture. India was associated with the preliminary planning studies of the basin and was associated with the Tonle Sap project on the mainstream and the Prek Thonot project on its tributary in Cambodia. In the former, India's assistance consisted of detailed investigation, field and laboratory studies, hydraulic model studies and preparation of design reports and cost estimate by CW&PC. As a part of Tonie Sap investigations, a Soil Mechanics & Concrete Testing Laboratory was established in Cambodia. Dr. Kanwar sain worked for 9 years as United Nations' expert for the Mekong Development Project.

Project Planning & Examination

All the major and medium irrigation and hydropower projects formulated by the States have been examined in the CW&PC before their approval by the Planning Commission. In the first five year plan, there were about 267 major and medium schemes under implementation, of which 27 were major projects. Several important projects included in the first plan which include Nagarjunasagar (AP), Kosi (Bihar), Chambal (Rajasthan & MP), Harike Barrage (Punjab), Tungabhadra (Karnataka and AP), Bhadra and Ghatprabha (Karnataka), Kakrapara (Gujarat), Lower Bhawani (Tamil Nadu), Matatila (UP), Mayurakshi (WB). Simultaneously, minor irrigation schemes were also undertaken with financial assistance from Government. In the second five year plan, 195 major and medium projects were taken up, of which 25 were major schemes. Some important schemes of second plan were Indira Gandhi Canal (Rajasthan), Gandak (Bihar & Uttar Pradesh), Tawa (Madhya Pradesh), Parambikulam Aliyar (Tamil Nadu), Kabini (Karnataka), Kansabati (West Bengal), Kadana (Gujarat), Ukai (Gujarat), Broach-Narmada (Gujarat), Koyna – Purna – Girna – Mula – Khadakvasla (Maharashtra).

As it was not always possible for every State to have its own design or research organisation, CW&PC filled the gap in drawing up plans to ensure economical and efficient work through a central designs unit. To avoid the delays in procurement of investigation equipment after sanction of the estimate for investigation, CW&PC also facilitated the procurement process and assisted various States by procuring and supplying various equipment. Further, it was responsible for the broader aspect of collection, collation, planning for the water resources utilization in the country and acted as the brain trust for the Ministry of Water Resources and the Planning Commission.

Data Collection

During the formative years most of the planning was aimed at meeting the immediate problems but steps were simultaneously taken for collecting and collating data of rainfall, stream flows, and seismic data affecting river valley projects and power stations. A network of gauging stations and seismographs was established at key points and other necessary investigations were initiated on all the major rivers of India.

Flood Management

The disastrous floods in the year 1954 and 1956 focussed the attention of the country on the need for tackling the flood problem on a scientific and sustained basis. CW&PC was called upon to take up the coordinating functions pertaining to the planning of flood control works. Based on the recommendations of a high level committee on floods constituted by Govt. of India in 1957, flood forecasting as non-structural measure of flood control was initiated by the CW&PC in November 1958 by setting up a forecasting station at Old Delhi Bridge, for the national capital, on the river Yamuna. Later, CW&PC was charged with the responsibility of issuing flood forecasting services in other inter-State and flood prone basins.

Such achievements in the formative years after independence are comparable to the best in the world and the Central Water Commission can justly be proud of its origins and valuable service that it has rendered to the nation.

Indira Sagar Dam, Madhya Pradesh (1992)

A BRIEF HISTORY OF

CENTRAL WATER COMMISSION

1945

Constituted by the then Government on the advice of Dr R.R. Ambedkar (Member Irrigation) as Central Waterways, Irrigation and Navigation Commission (CWINC)

1947

CWINC was declared a Permanent organisation

1948

Reorganized as Central Water-Power, irrigation and Navigation Commission (CWPINC)

1951

Central Electricity Commission and the Central Water-Power, Irrigation and Navigation Commission were merged to create Central Water and Power Commission (CWPC)

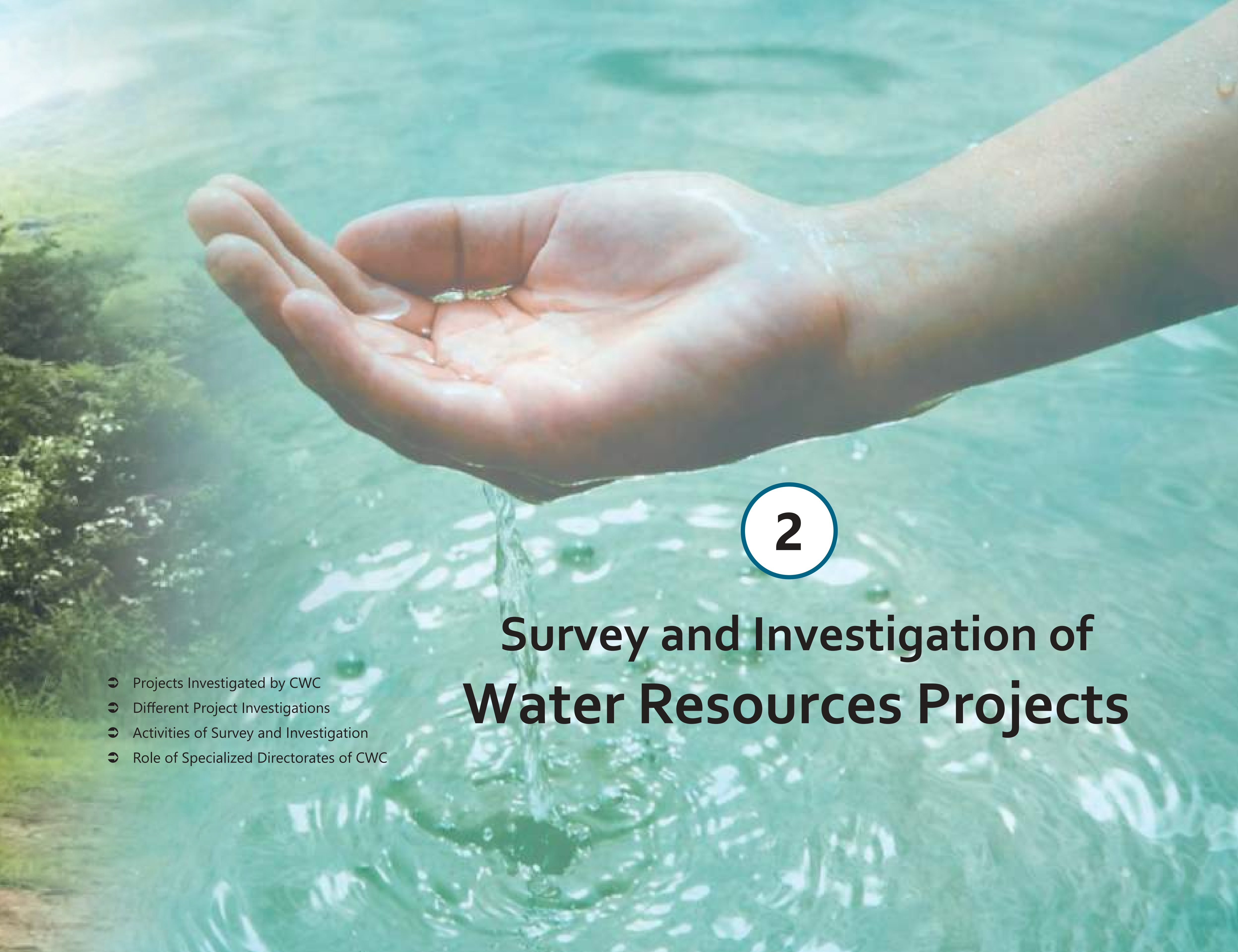
1952 — CWPC became "Attached Office." of Ministry of Irrigation and Power

1974 — CWPC was bifurcated into two organisations Central Electricity Autriority (CEA) Central Water Commission (CWC)

1978 — CWPRS was delinked from CWC

1981 — CSMRS was delinked from CWC

1994 — Establishment of Regional Offices in Major River Basins



2

Survey and Investigation of Water Resources Projects

- Projects Investigated by CWC
- Different Project Investigations
- Activities of Survey and Investigation
- Role of Specialized Directorates of CWC

Survey and Investigation of Water Resources Projects

Surveys and Investigations is very crucial for planning design and execution of Water Resources/River valley projects as it provides critically required field data. A project can be designed optimally and economically, only if necessary field data as per relevant specified standards is available. Such field data also helps in efficient execution, Operation and maintenance as well.

Central Water Commission has since long been active in the field of survey and investigation of Water Resources /River valley projects. Survey and investigation work of a large number of water resources / river valley projects in India and abroad have been successfully completed by CWC.

Besides undertaking survey and investigation work, CWC continues to be involved in this field in other ways by organizing number of training programmes conducted by NWA, CWC for CWC officers as well as for various State Government Departments for preparation of Draft Project Report (DPR) in which concerned officers of CWC guide and train the participating officers from State Government Departments in the aspects related to survey and investigations and preparation of DPR's.

Further, whereas requirements of Survey and investigations work of a Water Resources Development Project are outlined in various BIS codes, a comprehensive guideline for "Preparation of Detailed Project Report of Irrigation and Multipurpose Projects" has been prepared by MoJS/ CWC which is widely used by various project authorities for preparing the DPR.

Stage of Project Investigation

The different stages of project for which investigations are carried out are :

a) Pre-Feasibility Stage

b) Feasibility Stage

c) Detailed Investigation (DPR) Stage

d) Construction Stage

a) Pre-Feasibility Stage

It is more of a desk study with limited field checks. Based on the 1:50000 or 1:25000 scale Survey of India toposheets, possible sites are marked. These sites are examined wherein topography, broad geological aspects in terms of locating the project components are looked into.

b) Feasibility Stage

After selecting the site during Pre-feasibility stage, intensive field traverses are under taken. Detailed survey like contour plans and sections in 1: 1 000 to 1 :5000 scale are prepared for various important structures such as dam, tunnels, powerhouse, etc. One or two alternate axis are probed for detailed geophysical survey and a few drill holes to ascertain depth and quality of bed rock besides carrying out broad geological mapping & collection of regional geological information. The Hydrometeorological data collection is also started during this stage. Based on this data, lay-out of the project is prepared and its techno-economic viability is established.

c) Detailed Investigation (DPR) Stage

At DPR stage investigation, topographical survey of river and grid survey of Dam-axis / Barrage axis, detailed hydrological studies, Geological and Geotechnical investigation, construction material investigation, survey for submergence area including rehabilitation and resettlement, EIA studies, irrigation planning, power potential studies etc for preparation of DPR are undertaken.

d) Construction Stage

Large scale foundation grade mapping for dam, progressive 3D geological logging are carried out during this stage. Foundation grade geotechnical mapping of earth & rockfill dam is done on 1:500 scale. For Concrete Dam, Power House Excavation, Tunnel Excavations etc foundation grade geotechnical mapping and geological logging is done on 1:100 scale. by preliminary field traverses

Survey and Investigation work done by CWC

CWC has done pioneering work for survey and investigation of Water resources / river valley project in India and abroad. CWC generally take up the investigation of any project sponsored by any State Govt., PSU or MJS etc. At present five organizations namely; Barak & Other Basin Organization Shillong, Brahmaputra Basin Organization Guwahati, Indus Basin Organization Chandigarh, Teesta & Bhagirathi Damodar Basin Organization Kolkata and Yamuna Basin Organization, New Delhi are involved in survey and investigation works.

Use of modern techniques such as remote sensing, satellite imageries, aerial photography by unmanned aerial vehicles e.g. drones, DGPS have been included for cutting short the time required in topographical surveys, site selection etc.

Role of specialized Directorates of CWC

After signing MOA with concerned State Govt./ Agency, the topographical survey & investigation geological surface mapping of the project is carried out in the field by the field units of CWC. The proposed layout of the project and detailed investigation plans is finalized in consultation with specialized agencies such as CSMRS, CWPRS, GSI and concerned Design Directorates of CWC. The design of the project is then carried out on the basis of results of investigation by specialized Directorates of CWC viz

i) Design flood, water availability is finalized by Hydrology Directorate.

ii) Civil and Hydromechanical design is carried out by Hydel Civil Design Directorate, Concrete and Masonry Dam Design Directorate, Embankment Directorate, Barrage and Canal Design Directorate, Gates Design Directorate as per requirement.

iii) Irrigation Planning is finalized by Irrigation Planning Directorates

iv) Cost and BC Ratio is finalized by Cost Directorate etc.

Projects Investigated by CWC

CWC (CWINC/CW&PC) since its inception in 1945 have completed survey and investigation and DPR of many water resources projects in the country and in neighboring countries. DPR of more than 200 projects have been successfully completed by CWC. Many of them have been executed by the concerned project authorities. Some of the important project investigated by CWC are:

1. Hirakud Multipurpose Project, Odisha,
2. Bansagar Multipurpose Project, MP,

3. Iduki Multipurpose Project, Kerla,
4. Ukai Dam Project in Gujrat,
5. Baglihar HE Project in J&K,
6. Ujh Multipurpose Project, J&k
7. Salal H.E Project in J&K,
8. Dulhasti HE Project in J&K,
9. Kirthai HE Project, J&K
10. Tawi Barrage, J&K
11. Chandil Multipurpose Project, Jharkhand,
12. Indrawati Irrigation Project, Odisha,
13. Bargi Project in MP,
14. Rajghat Dam Project, MP/UP,
15. Indirasagar Project, MP,
16. Teesta Multipurpose Project in Sikkim,
17. Rangit HE Project in Sikkim,
18. Kolodyne HE Project in Mizoram,
19. Seesri HE Project in Arunachal Pradesh,
20. Lakhya Dam Project, Karnataka etc.
21. Ayodhya Barrage Project, UP
22. Kameng HE Project, Arunachal Pradesh
23. Balpahari Multipurpose Project, DVC, Jharkhand
24. Lower Lagyup HE Project, East Sikkim
25. Vasudhara Project, Andaman & Nicobar
26. Dudh Sagar Multipurpose Project, Dadar & Nagar Haveli
27. Masani Barrage, Haryana
28. Punasa Reservoir Project, Maharashtra
29. Rongai Valley Irr. Project, Meghalaya
30. Juri Dam Project, Tripura
31. T-Surang Irrigation Project, Nagaland
32. Myntdu Leshka HEP(Stage II), Meghalaya

Some of the international project investigated by CWC are:

1. Chukha HE Project in Bhutan,
2. Salma Dam Project in Afghanistan,
3. Pancheshwar Multipurpose Project, Nepal
4. Punatsangchu -I & II, Bhutan
5. Sankosh Multipurpose Project

Name of Project	Benefits Envisages
Hirakud Multipurpose Project, Odisha,	347.5 MW, 7.5 mha Irrigation
Bansagar Multipurpose Project, MP,	425 MW, 4.93 lha (2.49 in MP, 1.5 in UP and 0.94 in Bihar)
Iduki Multipurpose Project, Kerala,	780 MW, Irrigation
Ukai Dam Project in Gujrat,	300 MW, 372700 ha
Baglihar HE Project in J&K,	900 MW
Ujh Multipurpose Project, J&k	196 MW, 31380 ha
Salal H.E Project in J&K,	690 MW
Dulhasti HE Project in J&K,	390 MW
Kirthai HE Project, J&K	930 MW
Tawi Barrage, J&K	35000 Acre

Name of Project	Benefits Envisages
Chandil Multipurpose Project, Jharkhand,	8 mw, 63300 HA
Indrawati Irrigation Project, Odisha,	30877 HA
Bargi Project in MP,	Dam to Irr. 665000 acres Land and to generate 66.50 MW Power
Rajghat Dam Project, MP/UP,	45 mw, irrigation to 1.38 lakh ha in U.P. and 1.21 lakh ha. In M.P.
Indirasagar Project, MP,	1000 mw, 1.32 Lha
Teesta Stage -IV in Sikkim,	595 MW
Rangit Stage-IV HE Project in Sikkim,	120 MW
Kolodyne HE Project in Mizoram,	120 MW
Seesri HE Project in Arunachal Pradesh,	222 MW, 3000 ha
Ayodhya Barrage Project, UP	20000 ha
Kameng HE Project, Arunachal Pradesh	600 MW
Balpahari Multipurpose Project, DVC, Jharkhand	20 MW, 42000 Acre
Lower Lagyup HE Project, East Sikkim	12 MW
Vasudhara Project, Andaman & Nicobar	Conc. Gravity dam to generate 100 KW Power and to irr.100 Ha.

Name of Project	Benefits Envisages
Dudh Sagar Multipurpose Project, Dadar & Nagar Haveli	Rolled earth fill dam to Generate 30 MW power & to Irr.area of 1619 Ha
Masani Barrage, Haryana	Barraghe with earthen Embankment for storing 13800 HM Water
Punasa Reservoir Project, Maharashtra	Straight gravity type dam to generate 832000 KW Power & to Irr. 62000 Acres land
Rongai Valley Irr. Project, Meghalaya	3490 ha
Juri Dam Project, Tripura	2057 ha
T-Surang Irrigation Project, Nagaland	1755 ha
Myntdu Leshka HEP(Stage II), Meghalaya	280 MW
Deopani Multipurpose Project, Arunachal Pradesh	4 MW, 5000 ha
Suntaley Hydro-Electric Project, East Sikkim	40 MW
Sankh Stage -II, Jharkhand	316 MW
Chukha HE Project in Bhutan,	
Salma Dam Project in Afghanistan,	
Pancheshwar Multipurpose Project, Nepal	
Punatsangchu -I & II, Bhutan	
Sankosh Multipurpose Project	

S&I Works at Tlawng HEP, Mizoram

Geological Survey of India Field Visit to Tlawng Hydro-electric Project in Mizoram State to finalize the Dam Axis Location

Drilling work at mid of the dam axis at Tlawng HEP, Mizoram to obtain the depth at which rock strata is avilable

Drilling work at Tlawng HEP

Core logged samples for analysis as part of subsurface investigation

S&I Woks in Jammu & Kashmir

Joint Visit of CWC,CEA and JKSPDC to Ujh Multipurpose Project in 2016 for finalization of components of Ujh Multipurpose Project, J&K.

Topographic Survey work at Barinium HE Project to study the terrain at the project location.

Drifting works at Kirthi Hydro-electric project, Stage-II as a part of investigation process.

Crossing arrangement for field work at Kirthai HE Project, Stage-II

Collection of soil sample from Borrow Area of Haora Dam Project in West Tripura with CSMRS officials.

Breaking of Rocks collected from quarry site for lab testing for Construction Material for Haora and Champaicherra Dam Projects, West Tripura.

Taking Cross-section of Dam axis and other axis across the river at Haora Dam project with GSI officials.

Demarcation of Land at Haora and Champaicherra Dam Project.

S&I Works at Katakhal Irrigation Project, Assam

Survey using drone at Katakhal Irrigation Project in Assam State.

Core logged samples for analysis as part of subsurface investigation at Katakhal Irrigation.

Diamond Core Drilling at Katakhal Irrigation Project as a part of subsurface investigation.

Topographical Survey at Katakhal Irrigation Project at Assam State.

3

Design of Water Resources Project

- Concrete and Masonry Dam Design
- Embankment Design
- Hydel Civil Design
- Barrage and Canal Design
- Gates Design
- Landmark Projects in India in which CWC has Contributed Significantly
- Diversion Projects (Barrages)
- Technical Support Provided by CWC to Tackle Special Problems of Water Resources Projects
- International Cooperation by CWC towards the Design of Water Resources Project in the Neighbouring Countries

Design of Water Resources Project

Since its inception in April, 1945 as Central Waterways, Irrigation and Navigation Commission (CWINC), Central Water Commission has always been at the forefront of design of Water Resources Projects. Immediately after independence, many important technical issues were entrusted to CWC (then CWINC / CW&PC) which were carried out by adopting State of the Art Technology available at that time. Hirakund Dam and Kosi (Hanumannagar) Barrage are such two projects. A number of draft master plans of various river basins of India were also adopted employing latest Technology. CWC also provided technical inputs to all the iconic water resources projects of that time such as Bhakra Dam, Nagarjunsagar Dam, Farakka Barrage etc.

At present, CWC is considered Apex organization in the field of water resources. The design units under D&R wing of CWC are extensively using various state-of-the-art software, based on the advance Finite Element Analyses and computer-aided programs for design of water resources projects. The designs are further corroborated with the physical model studies before their execution in the field.

The design of Water resources projects is done in CWC through Design Directorates specialised in specific engineering fields such as:

1.0 Concrete & Masonry Dam Design

2.0 Embankment Design

3.0 Hydel civil Design

4.0 Barrage and Canal Design

5.0 Gates Design

CWC has to its credit vast experience in dealing with engineering challenges in tunneling particularly in tough geological terrains of Himalayas. The organization is also prompt in catching up with modern practices like that of TBM when it designs or examines water resource and hydropower projects.

Concrete and Masonry Dam Design

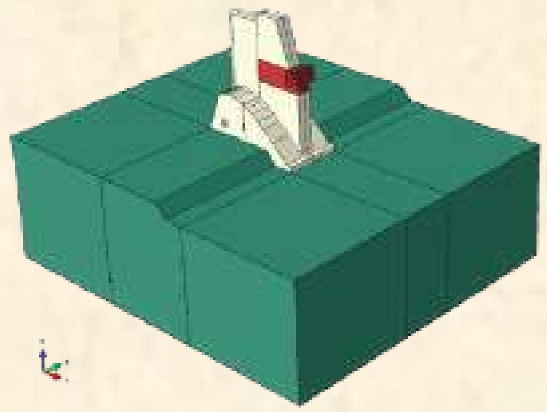


Fig. 1 Model of Spillway & Pier of Dam with foundation

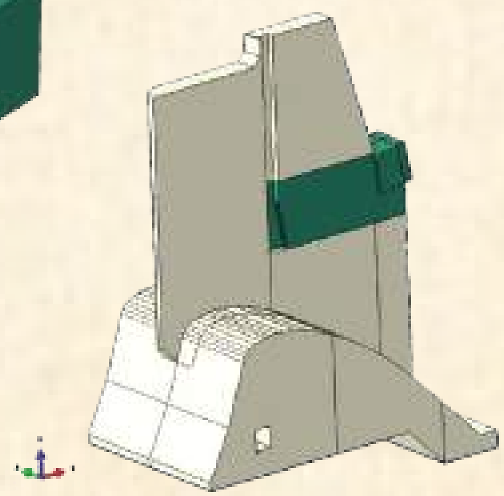


Fig. 2 Model of Spillway & Pier of Dam

Concrete and Masonry dam designs includes designs of overflow and non-overflow blocks of dam, including spillway, energy dissipation arrangement, diversion tunnel, stability analysis (static + dynamic), coffer dams, cut-off walls, grouting and other components like control room spillway bridge, etc.

Latest softwares are being used for carrying out the analysis. HEC-HMS software is used for flood routing analysis. Stability Analysis of concrete dam section is performed on different FEM softwares like ABAQUS, FLAC 3D etc. Tail-water curves are derived using HEC-RAS software. STAAD PRO softwares is utilized for design of spillway bridges, Dam Control Room etc. Other softwares which are extensively used are AutoCAD, AutoCAD 3D Civil, GIS softwares, MS Excel etc.

Embankment Design

Embankment Dam design includes design of components such as spillway, diversion arrangement, free-board calculations, filter, stability analysis (Static & Dynamic), seepage analysis, foundation treatment etc for earthen dams. For Stability and Seepage analysis softwares such as Slide2 (Roc Science) or Geo Studio is used. Latest software such as GTS-NX of Midas is also used for complicated analyses. Other softwares such as AutoCAD, MS-Excel are also extensively utilized.

Hydel Civil Design

Hydel Civil design includes design of components such as Trash Rack & Intake, Desilting chamber, Head Race Tunnel (HRT)/Irrigation Tunnel, Surge Shaft/Chamber, Pressure Shaft/Penstock, Powerhouse alongwith Downstream Surge Chamber (both surface as well as underground) etc.

Tunnel Design

Underground tunnels and caverns are analysed and designed using softwares like RS2 (Rocscience), UDEC and 3DEC. Slope stability analysis is carried out using SLIDE2 software. Transient analysis for hydraulic design of Surge Shaft/Chamber is carried out in WHAMO (US Army Corps) & HAMMER (Bentley). Machine hall units and penstock bifurcations/Wye

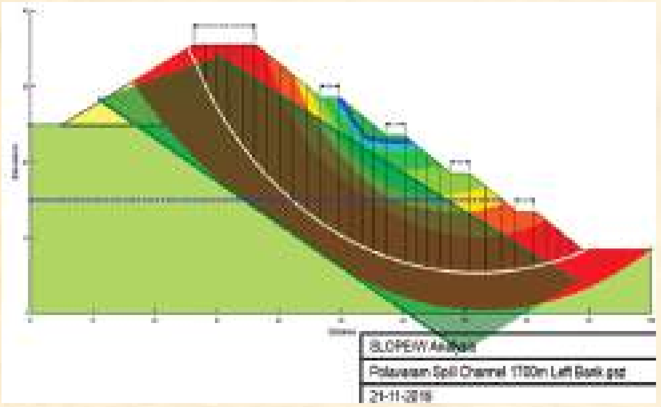


Fig. 3 Slope stability analysis carried out for Spill Channel left bank of Polavaram Irrigation Project, AP.

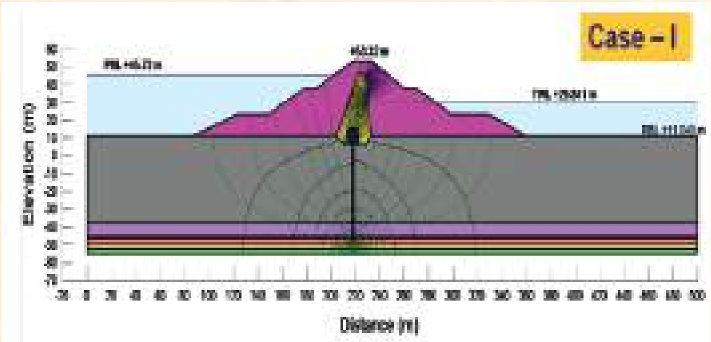


Fig. 4 Seepage analysis carried out for Earth Core Rock-fill Dam Gap-II of Polavaram Irr. Project, AP.

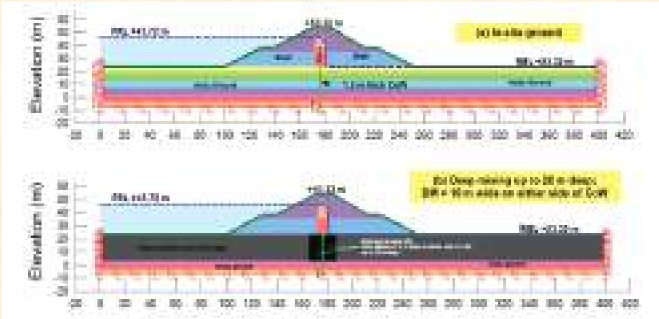


Fig. 5 Numerical model for simulation of foundation improvement using Stone Columns and Deep Soil Mixing of Earth-Cum-Rockfill dam at Gap-I of Polavaram Irrigation Project, AP

piece are analysed in FEM softwares like ABAQUS & ANSYS. Structural analysis of machine hall and transformer hall is carried out using STAAD Pro (Bentley). Other softwares which are extensively used are AutoCAD, AutoCAD 3D Civil, GIS softwares, MS Excel etc.

In Hydro Power Projects, most of the times, tunnels in various forms contribute to larger share of the project components thus requires larger attention in planning and design of them. Tunnels are generally in the form of Head Race Tunnel (HRT), Pressure Shafts, Tail Race Tunnel (TRT), Diversion Tunnel (DT), Main Access Tunnel (MAT) and Construction Adits etc.

Underground Structures Design

In Hydro Power Projects, underground structures are in the form of caverns and shafts viz machine hall, Transformer hall, surge chambers, valve chambers, de-silting chambers, surge shaft/pressure shaft, etc.

Fig. 6 Central gullet tunnel excavation in diversion tunnel of Arun III HEP (900MW), Nepal; Mucking after blasting in tunnel

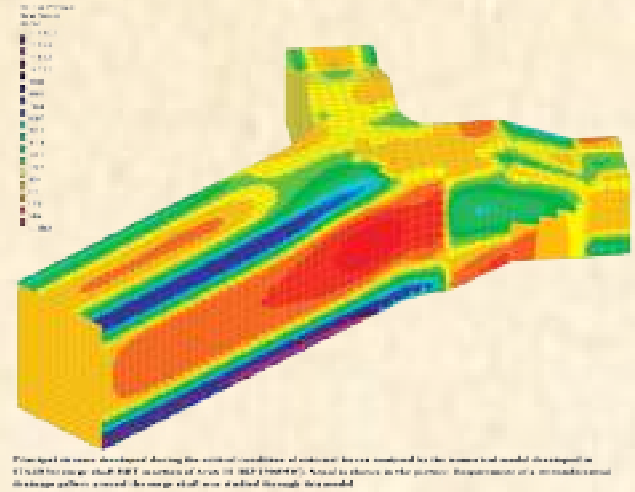


Fig. 7 Model of tunnel in RS2 to check adequacy of rock cover and distance between tunnels for Thana Plaun HEP (151MW), Himachal Pradesh

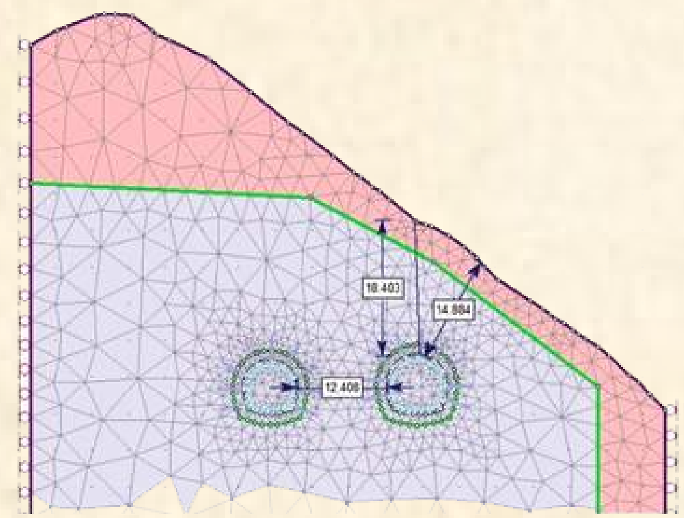


Fig. 8 Adequacy of concrete lining checked for HRT-Surge Shaft junction of Arun III HEP (900MW), Nepal by developing a model by plate elements in STAAD

Giganticity, geological uncertainty and constructional restrictions of these structures make their planning, design and construction cumbersome. CWC has a novel history of handling engineering challenges in this field. In addition to principles of International guidelines, IS codes and conventional practices in the form of rule-of-thumb, CWC uses state-of-art methods in planning, analysis and design of these structures to arrive at techno- economically sound design of these underground structures.

Increasing requirement of longer spans and increasing heights of underground structures for big hydro power projects, generally, pose various challenges before the designers especially in Himalayan Geology. To deal with such challenges, CWC generally analyses such underground structures using latest software viz. Unwedge 2, Swedge2, RS2, Staad Pro etc. to foresee all the possible failure mechanism and uses state-of- art design practices to arrive at optimum design parameters.

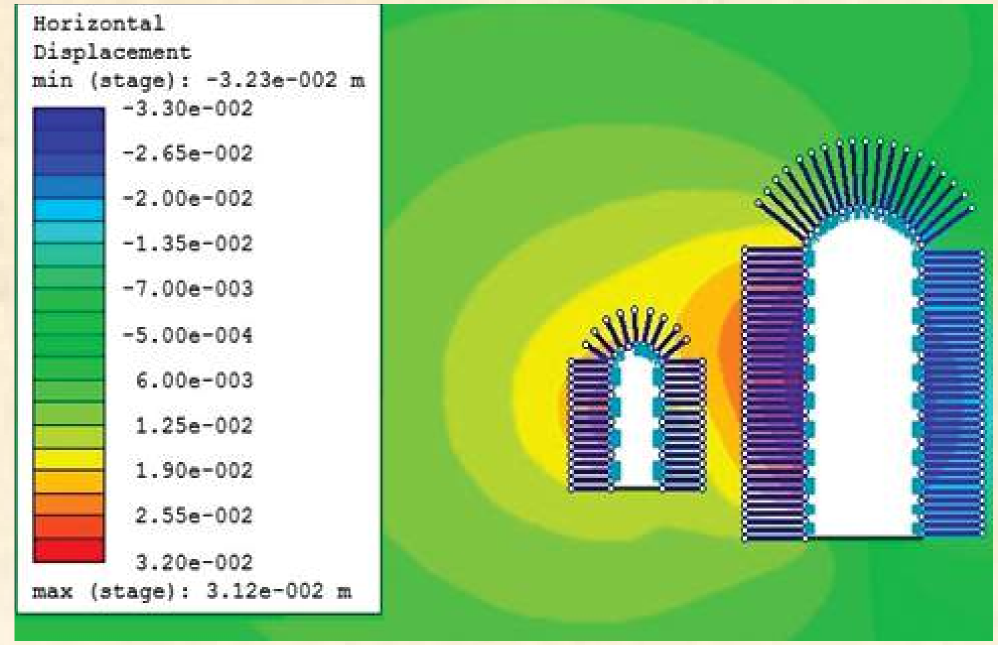


Fig. 10 Portion of Unit 3 in powerhouse of Salma Multipurpose Dam, Afghanistan modeled and analysed in STAAD

Fig. 9 Excavated crown of powerhouse cavern of Arun III HEP (900MW), Nepal in January 2020 (left). Spot bolts installed immediately after excavation are visible; Rock support system of the powerhouse cavern as envisaged (right)

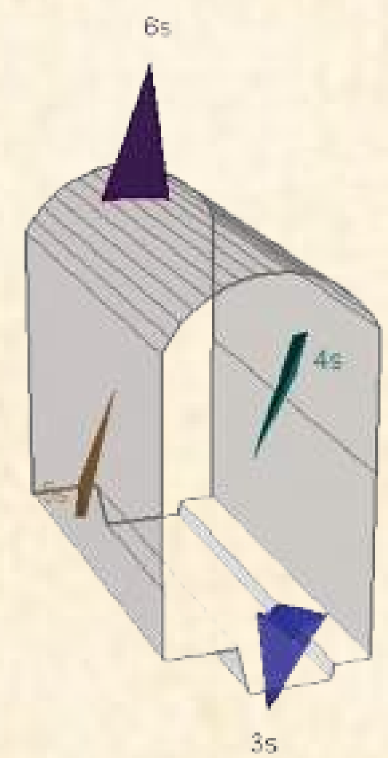


Fig. 11 Model in Unwedge2 developed to finalise orientation of powerhouse cavern in Thana Plaun HEP (151MW), Himachal Pradesh

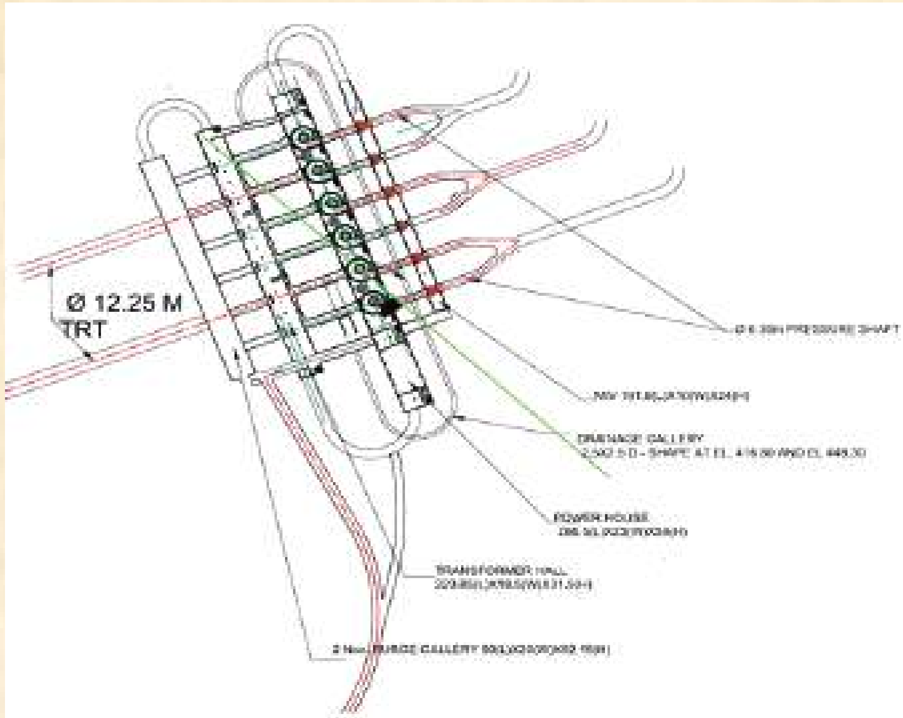


Fig. 12 Critical issue of placement of Pancheshwar powerhouse complex (MIV chamber, Powerhouse cavern, Transformer Cavern and Tail Race Surge Chamber) was studied modeling in RS2.

Barrage and Canal Design

Barrage and canal Design Directorates deals with design of barrages and canals. Barrages are diversion structures which are predominantly utilized in lower reaches of river where due to flat nature of topography, storage is not desirable. CWC has vast experience in design of barrages. A number of iconic barrages such as Farakka Barrage (terminal barrage at Ganga having 108 gates and length of 2304 mtrs.), Prakasham Barrage at Krishna, Dowleshwaram Barrage at Godavari, Hathnikund Barrage at Yamuna etc have been designed by CWC. One of the typical features of Barrages is that these can be founded over permeable foundation and sub-surface flow may be allowed to pass beneath the barrages

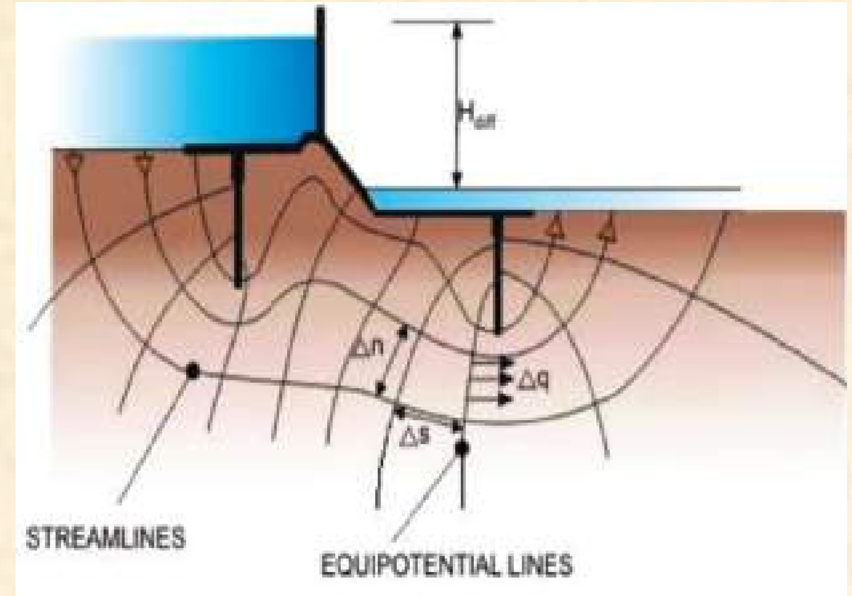


Fig. 13 Subsurface flow beneath barrage

provided that uplift is suitably taken care of and safe exit gradient is not exceeded.

Sir A.N. Khosla, the founding chairman of CWC propounded the seepage analysis theory, which is still being used for sub-surface hydraulic design of barrages. Presently, for complicated hydraulic analyses, FEM is adopted. For surface hydraulics, HEC RAS is typically adopted in addition to model studies. For complicated surface hydraulic analyses, Computational Fluid Dynamics (CFD) is also being used.

For structural design of barrages, Winkler's analysis of beams resting on elastic foundation has been traditionally adopted. Presently, FEM softwares such as Ideas, ANSYS, GTS NX MidasCivil etc are used. For many simpler structural components, excel spreadsheets developed in-house as well as softwares such as STAAD are used.

Presently, a number of Barrages have been constructed in upper reaches of the rivers for hydropower generation. These Barrages are typically high head barrages and are planned where geology is not suitable for storage dams. Design of such barrages is challenging as their design involves issues of Soil-Structure interaction, sub-surface hydraulics etc.

Many issues of Canal design (for fresh design / verification / troubleshooting etc.) are addressed in CWC. For Canal alignment planning, GIS softwares such as ArcGIS and QGIS is adopted in addition with AutoCAD Civil 3D. for hydraulic analyses of complicated problems of canal flow, HEAC RAS or MIKE is generally used. Many cross communication (Bridges etc) and Cross drainage (Aqueduct, Syphon, Level crossing etc) structures which are part of Canal network design are

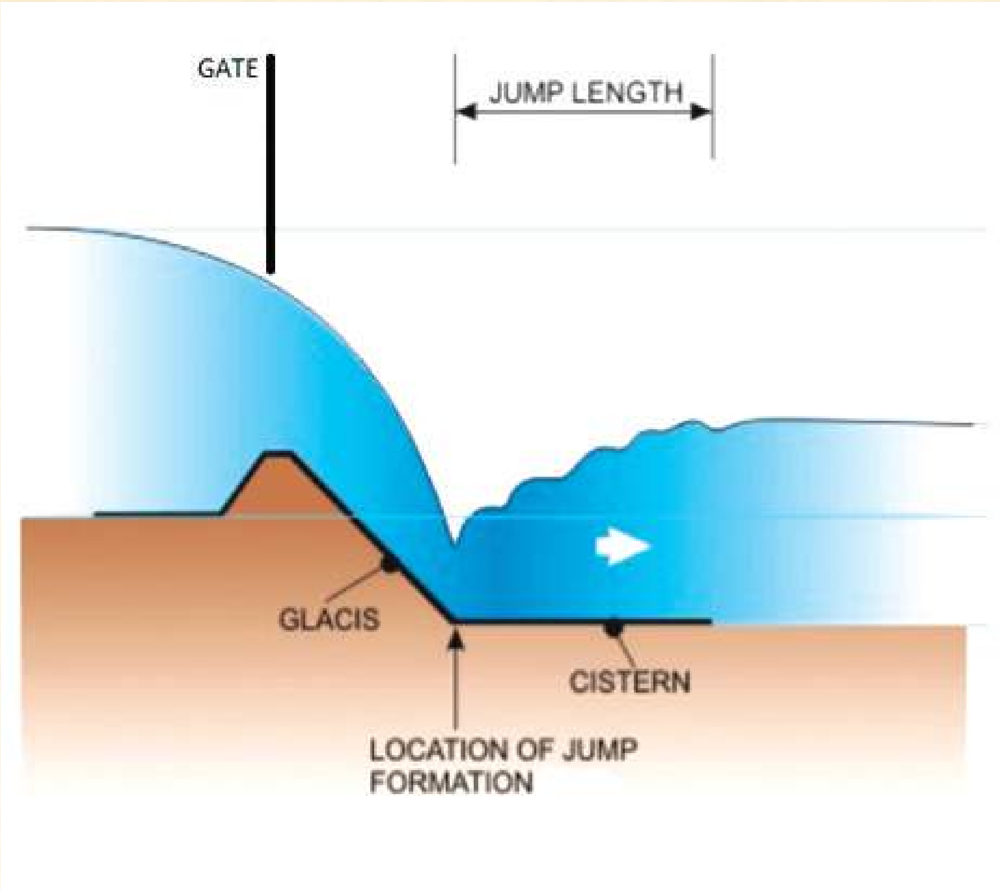


Fig. 14 Energy Dissipation arrangement in Barrage

also handled through application of softwares such as STAAD, Ansys, Ideas, MidasCivil etc.

Unlined Canal design has traditionally been done in India through

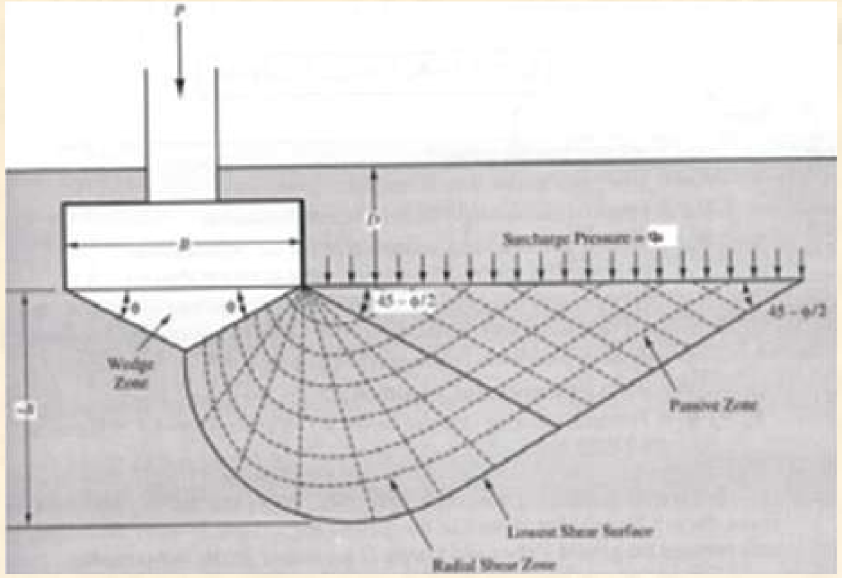


Fig. 15 Foundation failure Mechanism

Lacey's Regime Theory or Kennedy's Critical Velocity Ratio Theory. Both of these theories are empirical / semi-empirical in nature and have been developed through experiments in Indian conditions.

Recognizing the need for water conservation as well as to address the issues of land acquisition for irrigation canals, CWC has published a manual on Piped Irrigation network to promote piped irrigation and for standardization of its design.

Gates Design

Design of Hydro mechanical component of water resources projects such as Hydraulic Gates along with their hoisting mechanisms, Valves, Gantry

Crane, Trash Rack etc is very critical and niche area of design of Hydraulic Structures. The design is not only interdisciplinary involving civil as well as mechanical design approaches but is also critical as hydromechanical component failure is generally sudden and catastrophic. A number of such design issues are handled in CWC.

The structural design of hydro mechanical components is carried out using standard practices with the help of standard softwares viz STAAD as well as FEM approach ABAQUS, FLAC, PLAXIS etc. in line with the BIS (latest) standards. For hydraulic design Computational Fluid Dynamics (CFD) is also being used.

Fig. 16 Edukki Dam

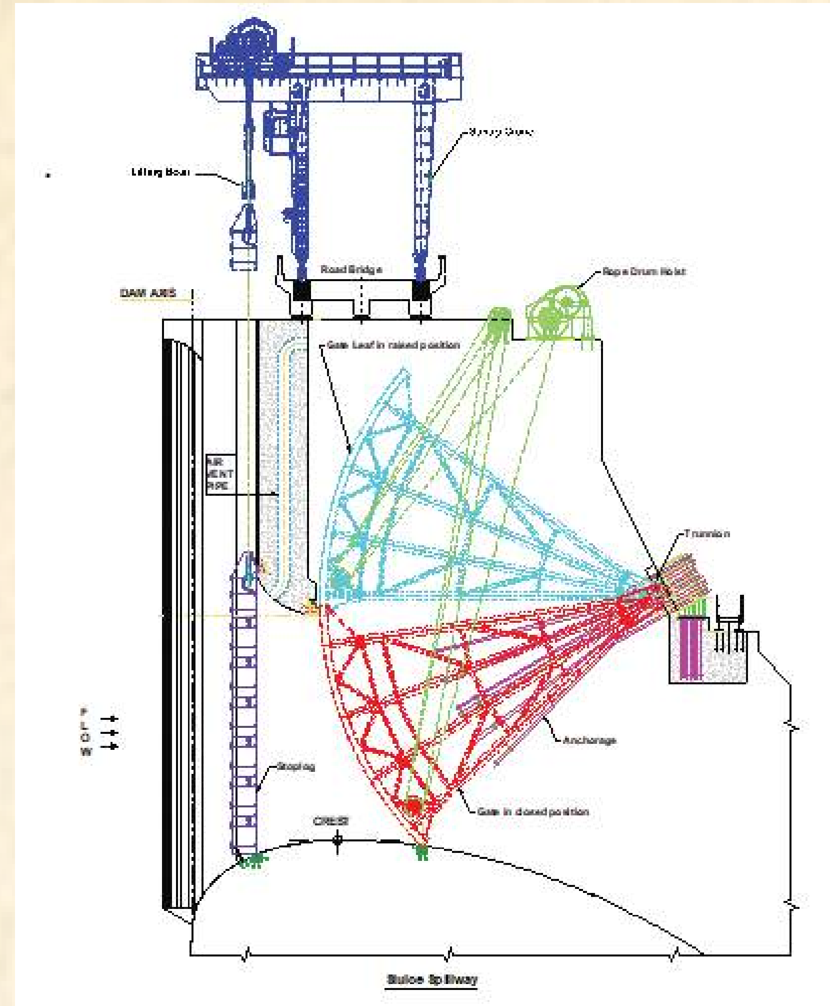


Fig. 17 Typical Hydro-mechanical components arrangement for Gated Spillway of a Dam

Landmark Projects in India where CWC has Contributed Significantly

Nagarjun Sagar Dam MPP, Telangana (1955): CWC has rendered technical support, right from the project formulation upto commissioning.

Hirakund Dam MPP, Odisha (1956): First major multipurpose project- CWC has been associated from planning to commissioning of the project.

Gandhi Sagar Dam MPP, Madhya Pradesh (1960): 2nd largest dam in India after Hirakud Dam was Planned and designed by CWC.

Rana Pratap Sagar Dam, Rajasthan (1970): CWC was the design consultant to the project.

Mahi Baja Sagar Project, Rajasthan (1983): CWC has rendered technical support to the project.

Rajghat MPP, Uttar Pradesh (2000): CWC was the design consultant of the project. Executive committee of Betwa River Board is headed by chairman, CWC.

Nathpa Jhakri Hydel Project, Himachal Pradesh (2004): CWC was principal consultant for Civil and Hydro-mechanical works, has firmed up hydrology and seismic design parameters and has also rendered advice on various technical issues post construction.

Bansagar Dam Project, Madhya Pradesh (2006): An important interstate project providing irrigation to MP, UP and Bihar. CWC has Rendered design consultancy and also provided technical assistance to various technical issues/special problems during construction.

Tehri Dam Project, Uttrakhand (2006): CWC has been associated with the planning and design of various components of the Project. The design engineering for dam, Chute Spillways, Shaft Spillways, Intermediate Level Outlets, etc. was done by CWC.

Koteshwar Dam, Uttrakhand (2011): It is part of Tehri H.E. complex. CWC has provided design support to the project.

Sardar Sarovar MPP, Gujarat (2017): CWC has provided Planning & design consultancy of Power houses and Garudeshwar Weir.

Polavaram Irrigation Project, Andhra Pradesh: (Under construction) CWC approves the design for Civil and Hydro-Mechanical works.

Kamsarat Nallah Water Supply Scheme A & N: CWC has provided construction stage design consultancy.

Kelo irrigation Project, Chhattisgarh: CWC has provided design consultancy to the project.

Diversion Projects (Barrages)

Farakka Barrage Project, W.B. (1975): is an important diversion project crucial for implementing international water treaty between India and Bangladesh. The Barrage is 2305 m long and comprises of 112 numbers of gates. It provides water to Calcutta port and is the only rail link between North East and rest of India.

Farraka Barrage (1975): Head regulator comprises of 11 numbers of gates for diversion of approx. 40,000 cusec of discharge into 38.3 km long feeder canal.

Wazirabad Barrage, Delhi: CWC has provided construction stage design consultancy to this project.

Hasdeo Barrage, Chattisgarh: CWC has provided construction stage design consultancy to this project.

Dolaithabi Barrage, Manipur: CWC has provided construction stage design consultancy to this project.

Anandpur Barrage, Odisha: CWC has provided construction stage design consultancy to this project.

Mahanadi Birupa Barrage, Odisha: CWC has provided construction stage design consultancy to this project.

Hathni Kund Barrage Project, Haryana is an important diversion structure for sharing Yamuna waters between Haryana and Uttar Pradesh. CWC has provided design consultancy to the project and is also providing technical assistance in post construction stage as well.

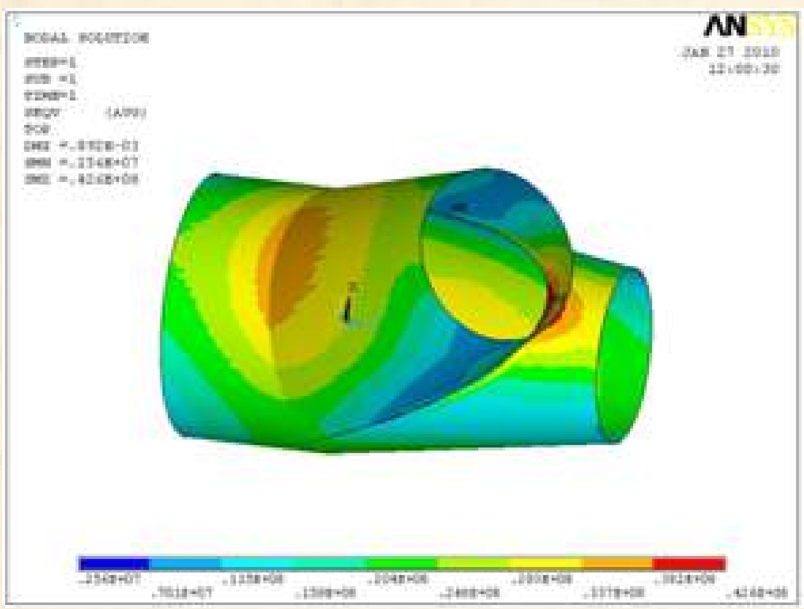
Gumani Barrage, Jharkhand: CWC has provided construction stage design consultancy to this project.

Kharkai Barrage, Jharkhand: CWC has provided construction stage design consultancy to this project.

Technical Support Provided by CWC to Tackle Special Problems of Water Resources Projects

Garada Dam Rajasthan: CWC provided technical assistance for rehabilitation of its breached portion.

Subernarekha MPP, Odisha: Repeated Slope Failure of main canal was resolved successfully by CWC.



Srisailam Left bank H.E Project, Andhra Pradesh: CWC provided technical guidance to analyse and successfully repair the sickle plate to restore operation of Power House.

Sikasar Dam Chhatisgarh: CWC provided design and drawing for rehabilitation of eroded spillway.

International Coperation by CWC towards the Design of Water Resources Project in the Neighboring Countries

Punatsangchu-I H.E. Project, Bhutan (1200 MW): CWC is the design consultant to this ongoing project.

Punatsangchu-II H.E. Project (1020 MW), Bhutan: CWC is the design consultant to this ongoing project.

Underground Power House-Machine Hall Punatsangchu-I H.E. Project (1200 MW), Bhutan: CWC is the design consultant to this ongoing project.

First Highway Tunnel in Bhutan-Punatsangchu-II H.E. Project, Bhutan (1020 MW): CWC is the design consultant to this ongoing project.

Dam-Tala H.E. Project (1020 MW) Bhutan: CWC has provided design consultancy to this project.

Chhukha H.E. Project, Bhutan: CWC has provided construction stage design consultancy. Technical assistance post construction is also being provided.

Underground Powerhouse-Tala H.E. Project (1020 MW) Bhutan: CWC has provided design consultancy to this project.

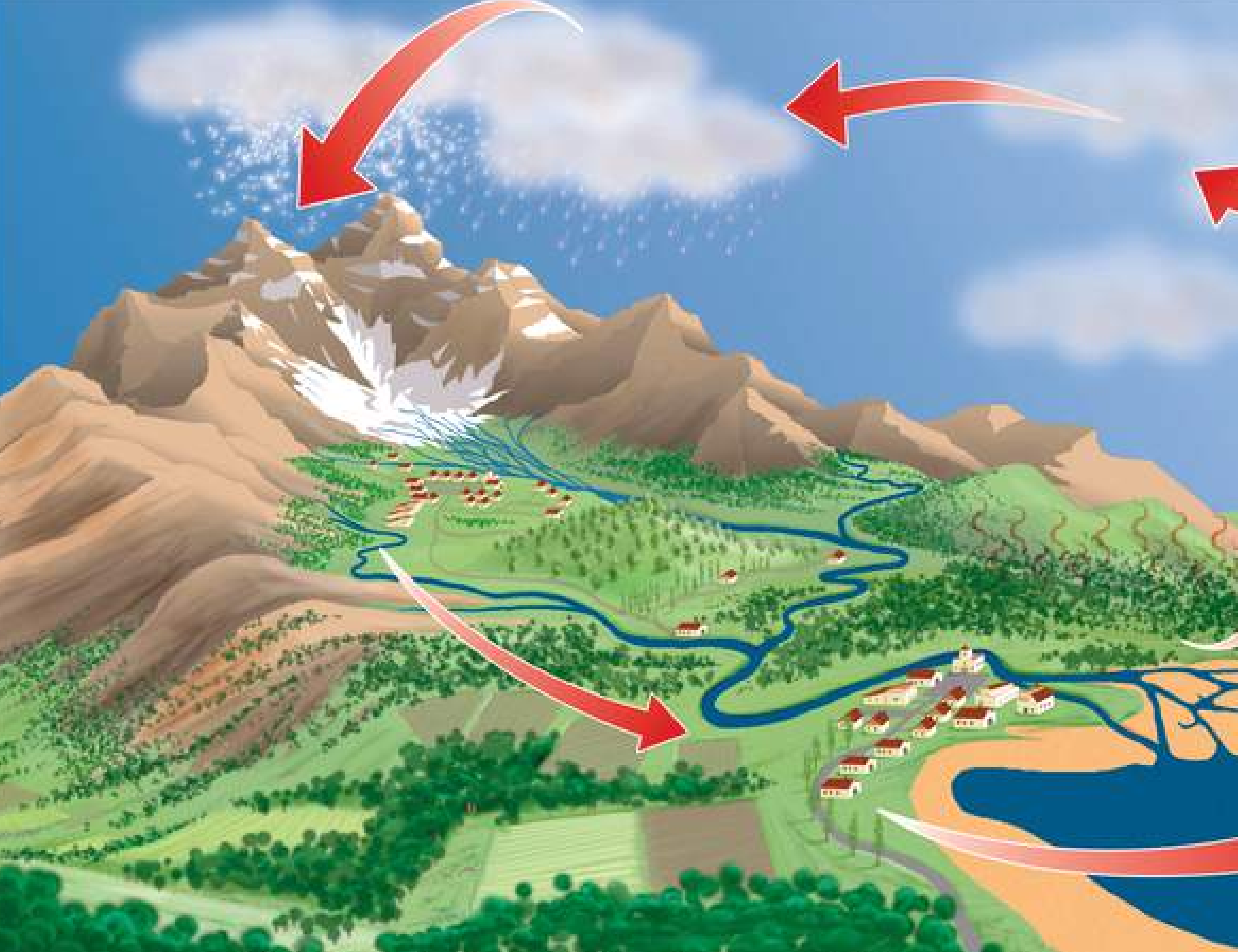
Arun III (900 MW) HE Project, Nepal: CWC is providing design consultancy as Retainer Consultant and is actively providing technical support on design and engineering issues.

Baglihar H.E. Project, J&K: The experts lead by Central Water Commission successfully presented their case before Neutral Expert appointed by World Bank under provisions of Indus Water Treaty.

Salma Dam Project, Afghanistan: (Also known as Afghanistan-India Friendship Dam). CWC has provided planning, design and also provided technical support during constructionof Dam.

Kishanganga H.E. Project, J&K: CWC provided institutional support and its nominated officers were in the core team of Officers which successfully defended the Project before Court of Arbitration under provisions of Indus Water Treaty.

Nagarjuna Sagar Dam, Andhra Pradesh (1967)



4 Hydrological Studies

Hydrological Studies

WATER AVAILABILITY STUDY

One of the most important aspects of in the planning of water resources development project is to assess the availability of water and its time distribution. The estimation of total quantity of available water and its availability on long term as well as short term basis are major factors contributing to the success of any water resources project. Thus, it is necessary to plan the projects in such a way that desired quantity of water is available with certain reliability. In India, normal practice is to plan an irrigation project with 75% dependable flows. Hydropower and drinking water supply schemes are planned for 90% and 100% dependable flows.

The Water Availability Studies are carried out to assess the quantity of water available in a river at a particular location using daily/ten daily/ monthly average discharge/rainfall data of desired quality and quantity depending on the type of proposed water resources project. Some of the important projects for which the water availability study has been carried out by CWC in the recent past are, Kaleswaram Project, Telangana, Upper Bhadra Project, Karnatka, Damanganag-Godavari Link, Damanganaga-Vaitarana-Godavari Link, Demwe, Subansiri Upper, Kalai-I, Kalai-II and Hutong-II HE Projects, Arunachal Pradesh, Tilaiya Dam, Jharkhand, Devasiri HE Project, Uttarakhand, Barinium HE Project, J&K, Indrapuri barrage Project, Bihar, Eastern Rajasthan Canal Project, Ken Betwa Link, Par-Tapi-Narmada Link etc.

Methodology

There are number of methodologies for Water Availability Estimate and a particular methodology is adopted depending upon the availability of input data. The most common methodologies adopted are:

- Rainfall-Runoff regression
- Runoff-Runoff regression
- Yield correction method

Water Availability by Yield Correction Method

When project catchment has rain fed catchment, permanent snow cover catchment and extended snow cover catchment during the winter. In such scenarios there will be different yield at different locations of a basin. If the observed discharge data at two G&D site in the same region is available then the yield model should be prepared at one G&D site and yield parameters assumed in the yield model should to tested on the other G&D site. With tested yield parameters, the yield at proposed diversion site can be estimated and water availability series can be computed using the following formula:

10 daily discharge series at proposed diversion site = 10 daily observed discharge series at G&D site x (computed average annual yield at proposed diversion site / observed average annual yield at G&D site) x (catchment area at proposed diversion site / catchment area at G&D Site)

Input Data Required

For developing yield model at desired locations of a river reach in a basin the following input data are essential:

- Catchment area map
- Hypsometric details of catchment
- Elevation of Permanent snowline
- Transitional snow zone
- Catchment representative rainfall
- Observed long term discharge at minimum two locations in the same basin
- Upstream diversion
- Any other consumptive/non-consumptive use

Case Study: Kameng Basin, Arunachal Pradesh

The river Kameng is one of the right bank tributary of Brahmaputra river. It joins the Brahmaputra river about 11 km upstream of Tejpur town. The drainage area of Kameng river lies approximately between longitudes 92º 00′ 00″ to 93º 20′ 55″ E and latitudes 26º 38′ 00″ to 28º 59′ 50″ N. The river Kameng drains about an area of 12,500 km^2. A catchment area plan of Kameng river showing locations of Bhalukpong G&D site, Bichom G&D site, Pachuk-I HE project location and catchment area of different sub-basins is shown below.

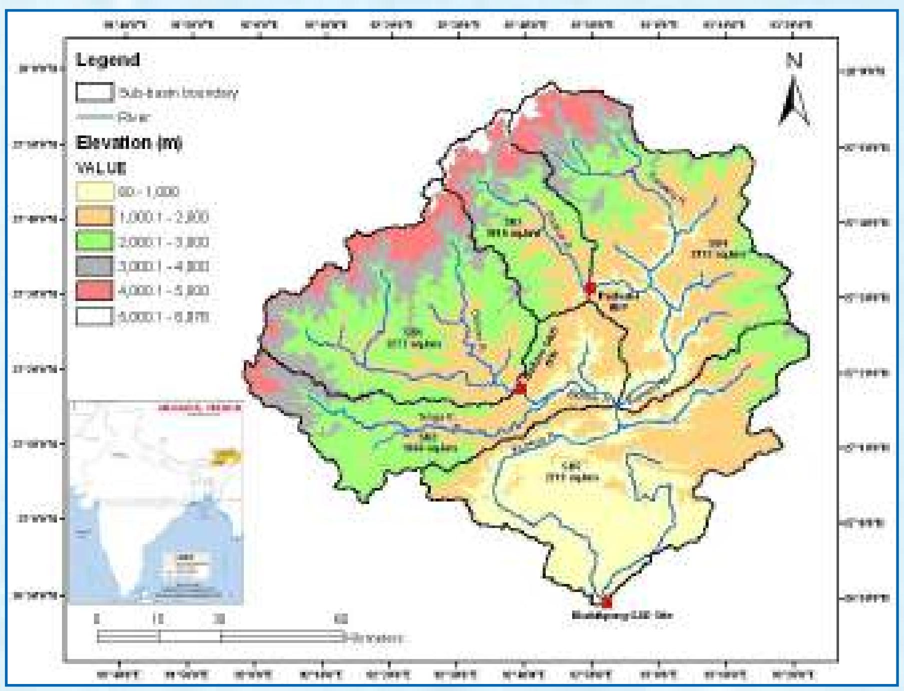


Fig. 1 Catchment area plan of Kameng river at Bhalukpong G&D site

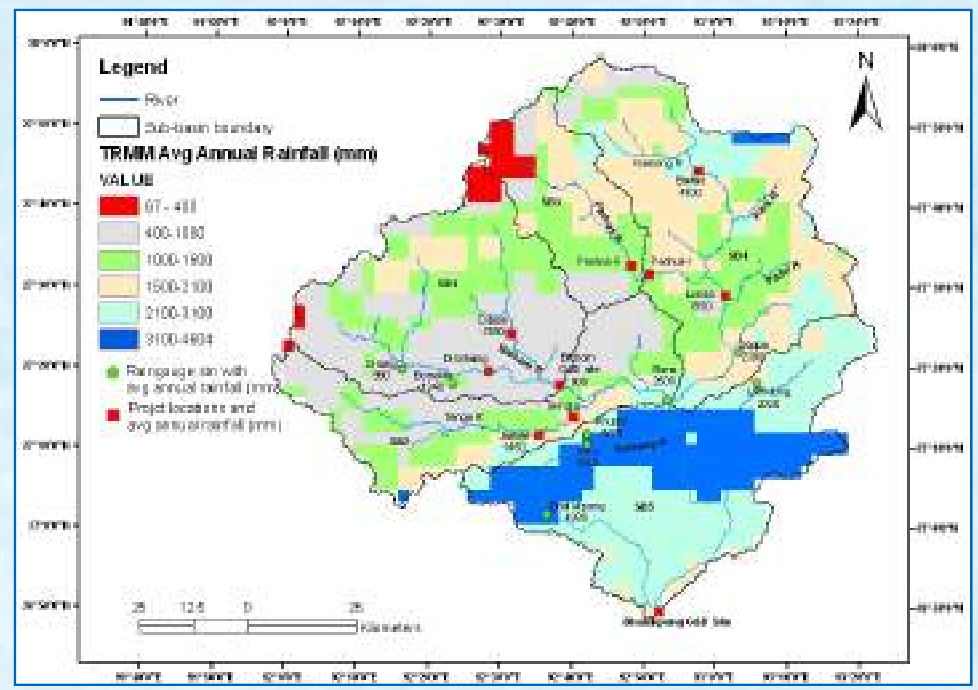


Fig. 2 12 years average annual TRMM rainfall pattern of Kameng basin

Yield Model for Bhalukpong G&D Site

The observed discharge data at Bhalukpong G&D site is available from the year 1990-91 to 2009-10.The catchment area of Kameng river at Bhalukpong G&D site is about 10450 km^2. The permanent snow line in the Kameng basin is at elevation 5000 m. After consistency check of discharge data the yield model was prepared for Bhalukpong G&D site.

Yield Model at Bhalukpong G&D Site of Kameng River

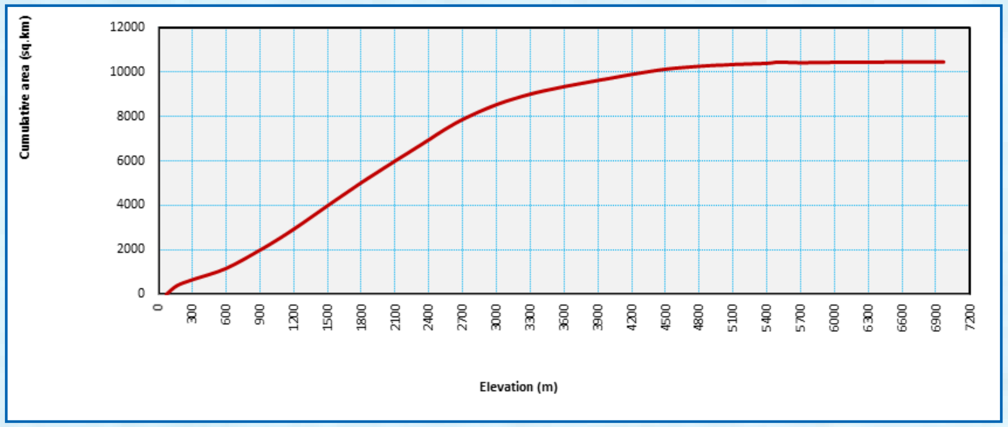


Fig. 3 Hypsometric Curve at Bhalukpong G&D Site

Catchment	Catchment Area (sq.km)	Annual Rainfall (mm)	Snowmelt during six months @ 5 mm/day	Runoff from rainfall (MCM)	Snow melt runoff (MCM)	Observed average annual yield (mm) at Bhalukpong for the period (1993-2010)
Permanent snow cover	136		912.5		124.10	
SB1 and SB2 excluding permanent snow cover	3915.8	1440		5074.88		
SB3 and SB4 excluding permanent snow cover	3679.2	2400		7947.07		
SB5	2719	3914		9577.95		
Area between EL 3000m-5000m	1778	1548			2752.34	
Total				22599.90	2876.44	
Average annual runoff from rainfall and snowmelt (MCM)				25476.34		
Total Catchment Area (sq.km)				10450.00		
Average annual yield (mm)				2437.93		2437.89

Testing of Yield Model of Bhalukpong G&D Site at Bichom G&D Site

For testing of yield model hypsometric curve was also developed at Bichom G&D site and area in different elevation band was computed.

Catchment	Catchment Area (sq.km)	Annual Rainfall (mm)	Snowmelt during six months @ 5 mm/day	Runoff from rainfall (MCM)	Snow melt runoff (MCM)	Observed average annual yield (mm) at Bichom for the period 1969-70 to 1981-82
Permanent Snow cover	23.45		912.5		21.40	
SB1 excluding permanent snow cover	2253.55	1515		3072.72		
Area between EL 3000m-5000m	766	1548			1185.77	
Total				3072.72	1207.17	
Average annual runoff from rainfall and snow melt (MCM)				4279.88		
Total Catchment Area (sq.km)				2277.00		
Average annual yield (mm)				1879.61		1878.00

Computation of Yield at Proposed Pachuk-I HE Project Diversion Site

Catchment	Catchment Area (sq.km)	Annual Rainfall (mm)	Snowmelt during six months @ 5 mm/day	Runoff from rainfall (MCM)	Snow melt runoff (MCM)
Permanent Snow cover	42		912.5		38.33
SB3 excluding permanent snow cover catchment	974	2030		1779.50	
Area between EL 3000m-5000m	296	1548			458.208
Total				1779.50	496.53
Average annual runoff (MCM)				2276.03	
Total Catchment Area (sq.km)				1016.00	
Average annual yield (mm)				2240.19	

10 Daily Discharge Series at Pachuk-I HE Project Diversion Site

10 daily discharge series at Pachuk-I diversion site = 10 daily observed discharge series at Bichom G&D site x (computed average annual yield at Pachuk-I / observed average annual yield at Bichom G&D site) x (catchment area at Pacuk-I diversion site / catchment area at Bichom G&D Site)

DESIGN FLOOD ANALYSIS

Design flood is defined as the flood hydrograph or the instantaneous peak discharge adopted for the design of a river headwork or control structure, after accounting the economic and hydrological factors. Design flood analysis is one of the most important component of hydrological studies for any river valley project or any structure being planned across a stream. In case of river valley project the discharging capacity of surplussing arrangements viz. spillways and sluices etc is decided on the basis of design flood. Depending upon the gross storage and hydraulic head design flood for river valley is adopted as PMF, SPF and 100 year return period flood. Since, design flood is a dynamic process, hence, estimated design flood is also reviewed from time to time.

Central Water Commission had carried out design flood studies for almost all major river valley projects in country and also some of the major projects of Bhutan, Nepal, Afghanistan and Myanmar. Under DRIP Phase-I the design flood of more than 200 river valley projects were reviewed by CWC. Further, under DRIP Phase-II and III design flood of more than 650 projects are likely to be reviewed out of which the design flood review of about 195 projects have already been completed. For design flood studies, CWC is using softwares like ARC-GIS for estimation of physiographic parameters of the project catchment and HEC-HMS for hydrological modelling.

Some of the important dams for which design flood review study has been carried out are Mahi Bajaj Sagar, Ranapratap Sagar and Jawahar Sagar dams of Rajasthan, Gandhi Sagar Dam of Madhya Pradesh, Ukai and Kadana dams of Gujarat, Nizam Sagar and Singur dams of Telangana, Kalagarh Dam of Uttar Pradesh, Vaigai dam of Tamilnadu, Idamalayar dam of Kerala, Tenughat dam of Jharkhand, Maithon Dam of DVC, Ravi Shankar Dam of Chhatisgarh, Umium Dam of Meghalaya, Imphal barrage of Manipur, Balimela dam of Orissa etc.

CWC in association with IMD has published the PMP Atlas of Ganga, Brahmaputra, Mahanadi and other east flowing rivers, Godavari, Cauvery, Narmada and west flowing rivers of western Ghats during the year 2014-15. These PMP Atlases are a ready reckoners for estimating the design storm depths for design flood computations. CWC has also published Manual on Estimation of Design Flood and 22 Flood Estimation Reports.

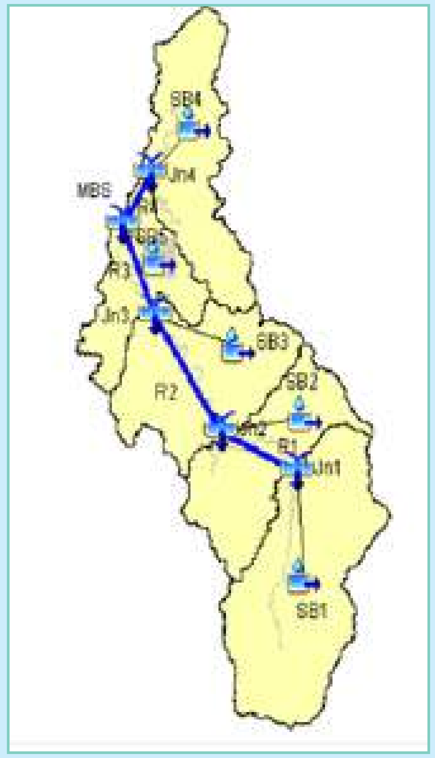
Methodology for Design Flood Estimation

The design flood is estimated either by hydro-meteorological approach or flood frequency analysis. In flood frequency analysis the Instantaneous annual flood peaks are used to estimate the design flood of desired return period by fitting appropriate probability distribution.

In case of hydro-meteorological approach, design flood is esimated

Fig. 4 Mahi Bajaj Sagar Dam, Rajasthan

Lumped model



Quasi-distributed model

either by lumped modelling or quasi-distributed hydrological modelling.

Further, in case of hydro-meteorological approach the design storm and unit hydrograph are two essential inputs. The design storm depths for the project catchment are arrived either by transposition of historical storms and applying the suitable correction factor to transposed depths or adopting the grid values from the relevant PMP Atlases.

Case Study: Design Flood for Kadana Dam

Kadana dam ($23^0$18’22” N and $73^0$49’33” E) is an earthen cum masonry dam built across Mahi River in Mahisagar district of Gujarat in 1989. The dam is about 66 m high with its top at EL 131.40 m. The reservoir with FRL at EL 127.7 m has a live and gross storage capacity of 1203.25 and 1249.26 million cubic meter respectively. The catchment area of Mahi river at dam site is 25520 sq.km. As per IS:11223 the criteria of selection of inflow design flood for safety of dam, Kadana dam qualifies for Probable Maximum Flood (PMF) as its design flood**.**

Physigraphic Parameters

The physiographic parameters of the Mahi catchment at Kadana dam site have been estimated by GIS processing of SRTM DEM.

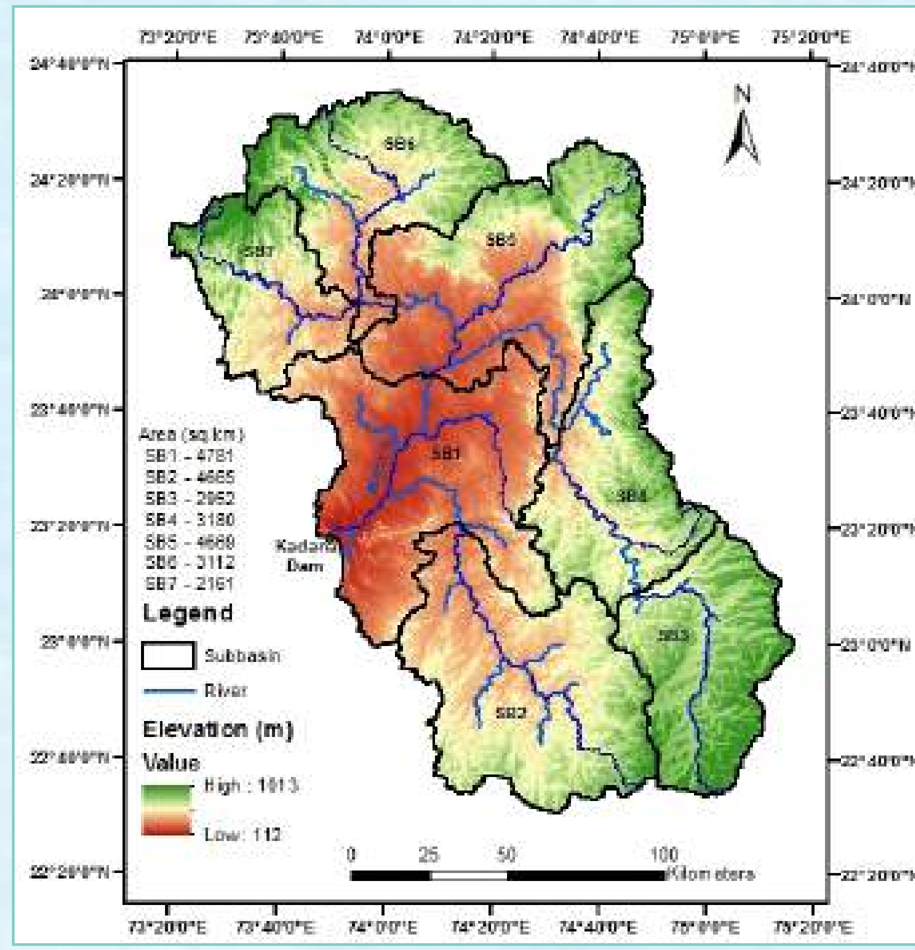


Fig. 5 Catchment area Plan

Unit Hydrographs

The Clark unit hydrographs for the sub-catchments have been developed using HEC-HMS software.

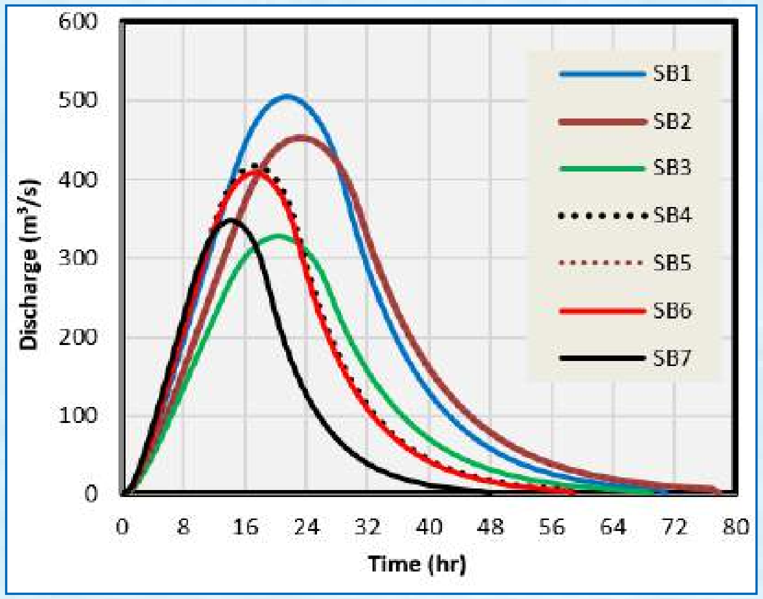


Fig. 6: Clark UH of Sub-catchments

Storm Analysis

The two day storm of 27th-28th July 1927 with storm centre at Dakor (latitude 22.75 degree, longitude 73.15 degree) recorded two day depth 997 mm at storm centre and its corresponding one day storm on 28th July, 1927 has a recorded peak of 540 mm has been transposed in the project catchment to get the maximised depth.

The MAF of 1.29 has been multiplied with the corresponding transposed depths to get the PMP depths.

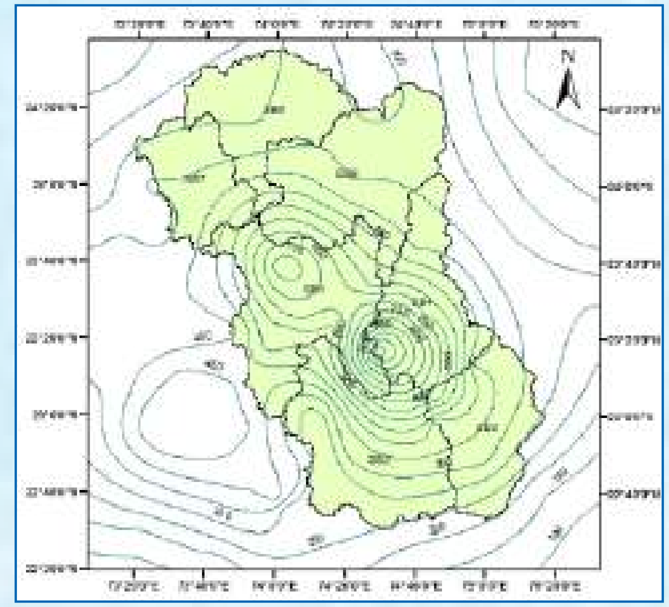


Fig. 7: 27-28 July 1927 Dakor storm after transposition and rotation in project catchment

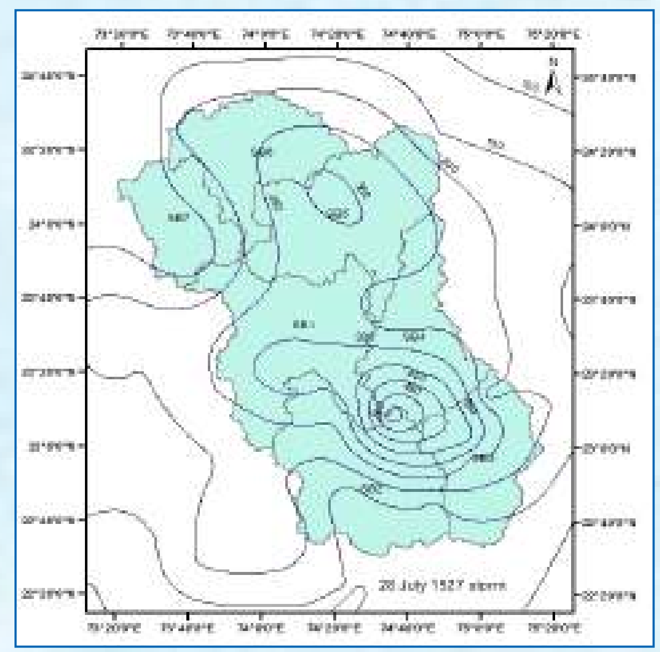


Fig. 8: 28 July 1927 Dakor storm after transposition and rotation in project catchment

HEC-HMS Model Set Up for Design Flood Computation

The HEC-HMS Model has been prepared consisting of sub-catchments, junctions and channel routing reaches. The input parameters viz hourly distributed rainfall, Muskigum routing parameters, base flow etc have been inputted in the model.

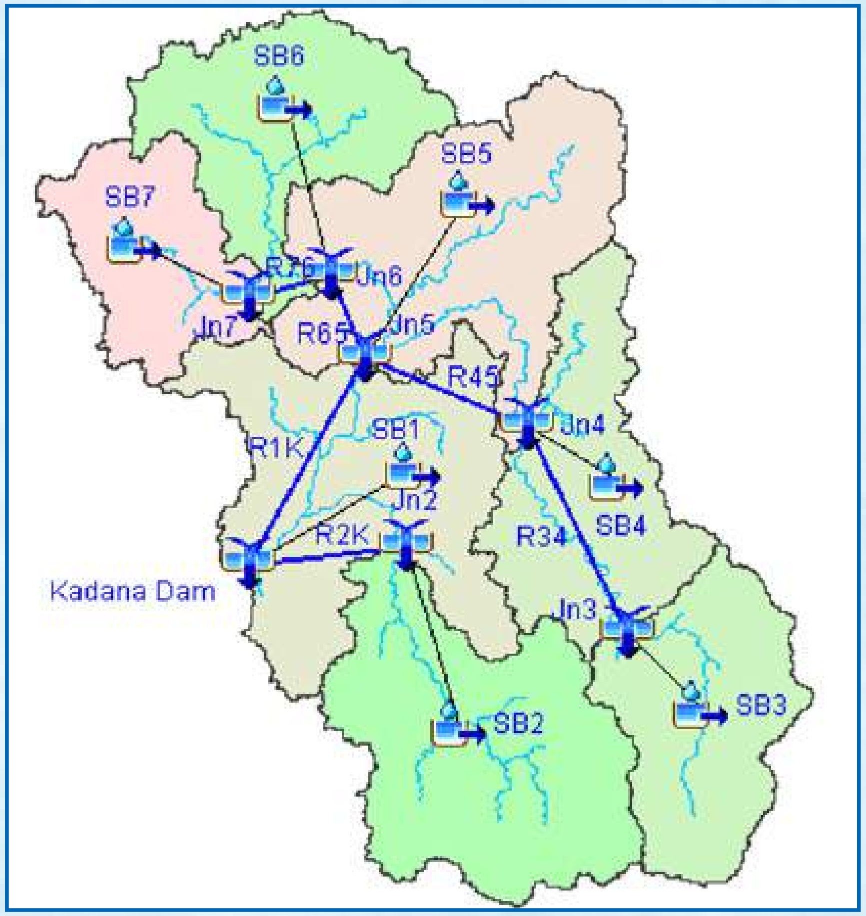


Fig. 9 HEC-HMS Model set up

Study Outcome

Through detailed simulation using quasi distributed hydrological model set up on HEC-HMS, the Probable Maximum Flood (PMF) for Kadana dam has been estimated as 56695 m^3/s.

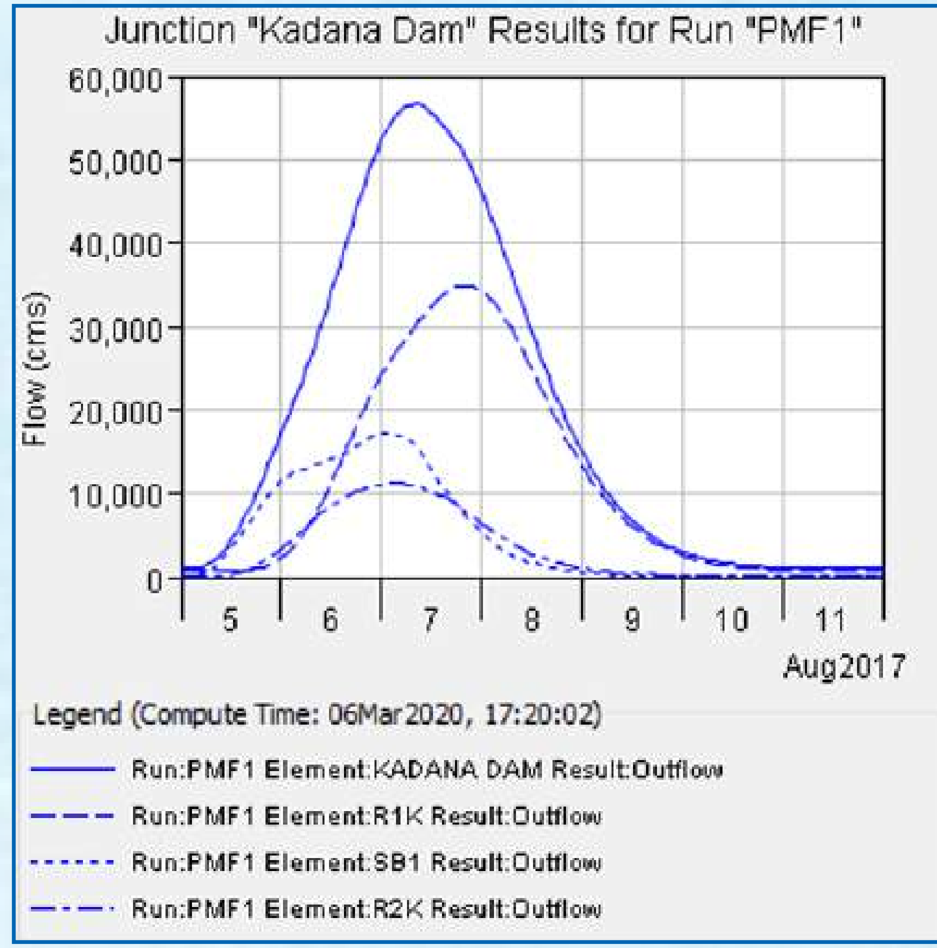


Fig. 10 Simulation plot of HEC-HMS

RESERVOIR ROUTING STUDY

Reservoir routing is used to determine the peak-flow attenuation that a hydrograph undergoes as it enters a reservoir or other type of storage. Reservoir routing is also required to estimate the available free board during occurrence of design flood. Central Water Commission had carried out a number of reservoir routing study in past. Some of the important studies are reservoir routing studies for Mulla Periyar Dam, Vaigai Dam, Gandhi Sagar Dam, Maithan Dam etc.

Methodology for Reservoir Routing

- Collect Elevation-Area-Capacity data of reservoir and salient features of the project
- Collect inflow hydrograph and spillway/sluices rating curve data
- Set up a reservoir routing model on any hydrological model or use EXCEL
- Using appropriate method carry out routing computations

Reservoir Routing Study for Gandhi Sagar Dam

Using the input data a reservoir routing model set up was developed on HEC-HMS.

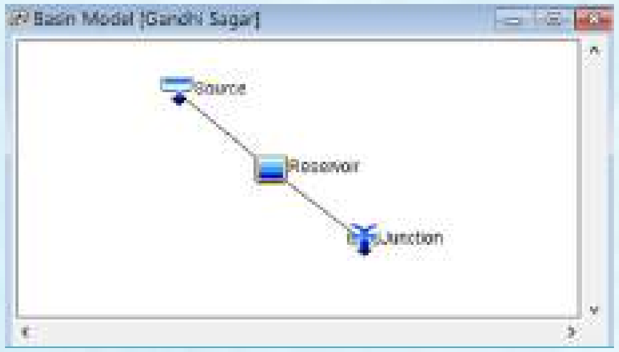


Fig. 11 HEC-HMS Model set up

Inflow Hydrograph

Inflow hydrograph of September 2019 flood was used for reservoir routing.

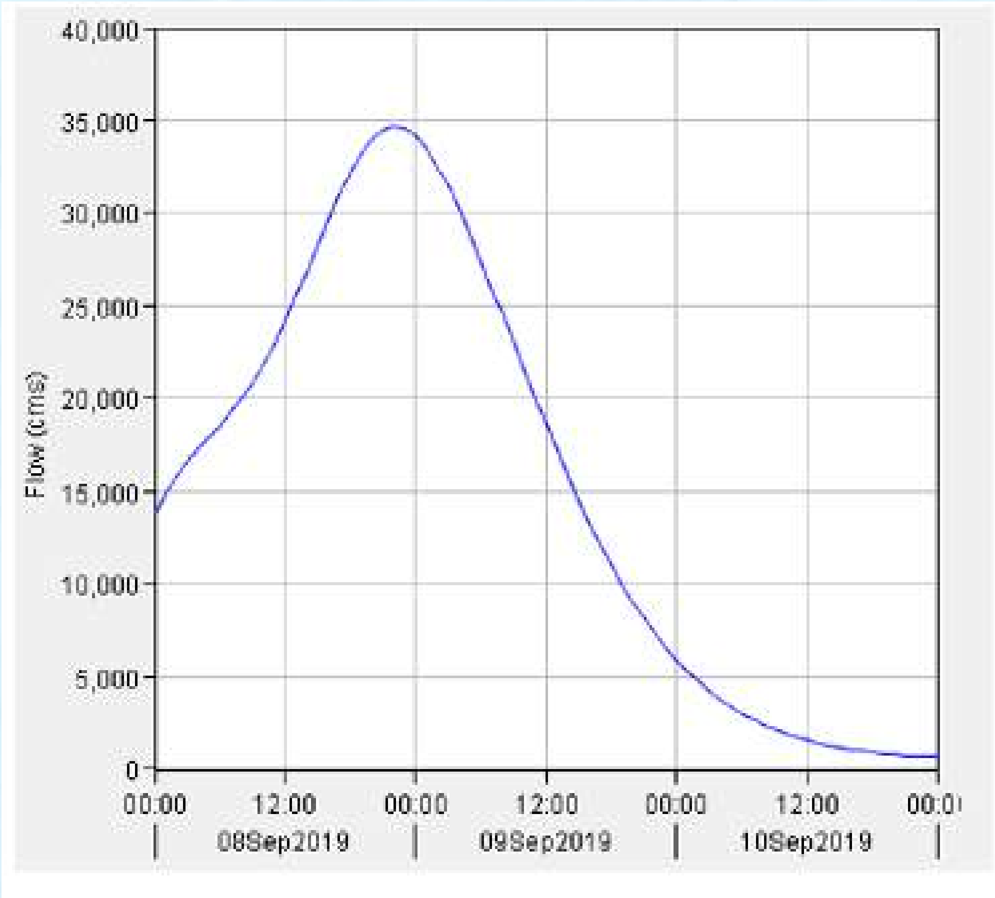


Fig. 12 Inflow hydrograph

Reservoir Routing Output

Reservoir routing output consisting of inflow hydrograph, outflow hydrograph through spillway and water level attained in the reservoir is given below:

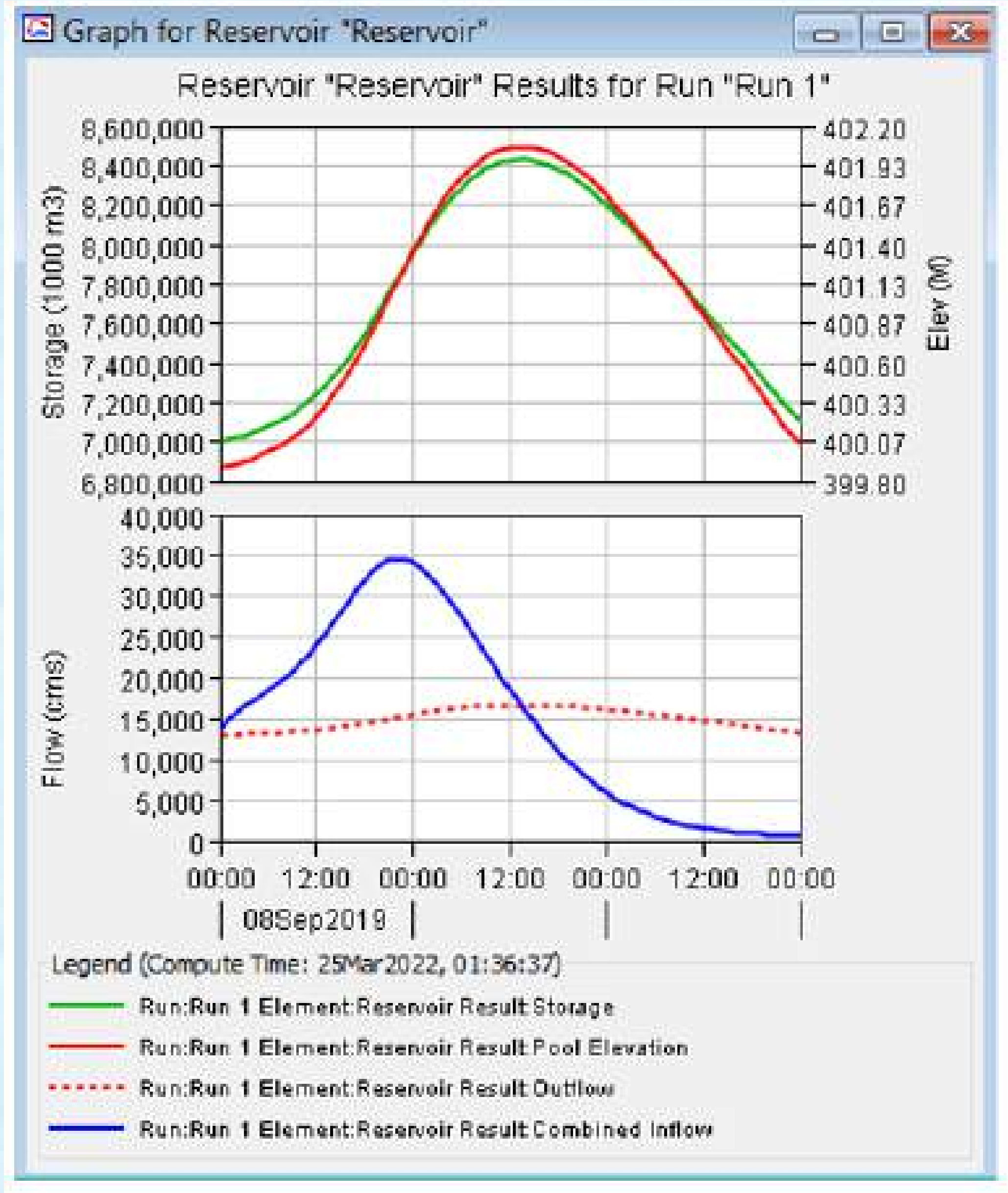


Fig. 13 Reservoir routing plots

RESERVOIR SEDIMENTATION STUDY

Reservoir sedimentation is a complex process that varies with watershed sediment production, rate of transportation, and mode of deposition. Reservoir sediment depends on the river regime, reservoir geometry and operation, flocculation potential, density currents, and possible land use changes over the life expectancy of the reservoir. Sediments carried into a reservoir may deposit throughout its full length, thus gradually raising the bed elevation and causing aggradations. The coarser particles are deposited first, building up an underwater delta near the upstream end of the reservoir, the configuration and progression of which depend on the regime of flow and the variation of water levels in the reservoir. This delta causes a rise of the original river bed and, in addition to the reduction of the active storage. It also causes an increase of water level during floods, which may lead to the submergence of the riverside land.

Sediment deposition, by itself, is inevitable. Therefore, sufficient provision of space should be made in a reservoir for the accumulation of silt load so that its functioning does not get impaired during its useful life. This necessitates the estimation of the sediment load likely to get accumulated over time.

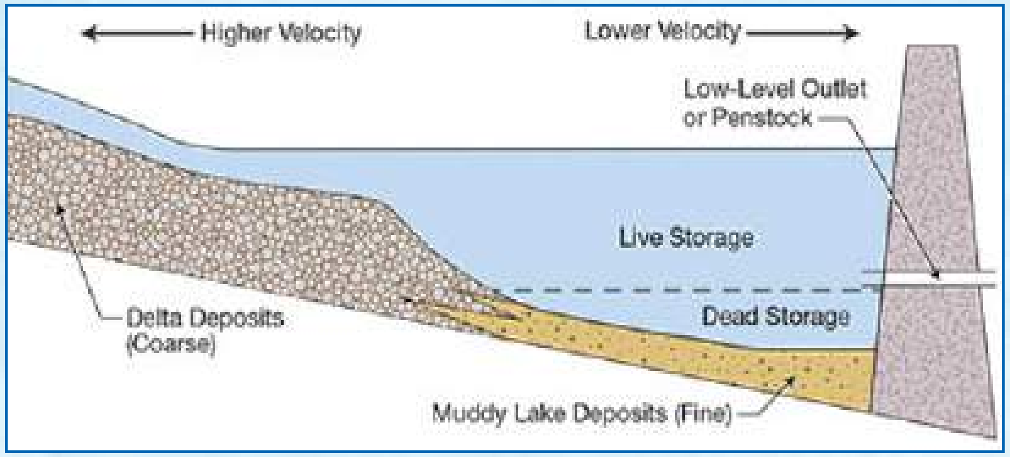


Fig. 14 Reservoir sedimentation schematic

(Source: Morris G.L. and J. Fan, Reservoir Sedimentation Manual)

The reservoir sedimentation study is an integral part of Hydrological Study. Such studies are being carried out by CWC using the conventional approach as well as modelling approach. In conventional approach, total sediment volume deposited into the reservoir at different time intervals is estimated using Brune’s median curve.

The deposited sediment into reservoir, causes the bed level near the dam to rise and the raised bed level is termed as new zero elevation (NZE) which is estimated using Empirical Area Reduction method. It is, therefore, necessary to assess the revised areas and capacities at various reservoir elevations, such that the assessment can be useful to pre-plan necessary future changes in reservoir operation, if any. Reservoir sedimentation study also helps in fixing the live storage of the reservoir and location of outlets to withdraw water from it for downstream uses.

Through reservoir sedimentation modelling approach, it is possible to optimise the reservoir operation for sediment control.

Case Study of Demwe Reservoir

Demwe Lower Hydroelectric Project is a run-of-the-river scheme planned across Lohit river, near Parasuram Kund/ Brahma Kund in Lohit district of Arunachal Pradesh. The project envisages construction of 174 m high concrete gravity dam above deepest foundation level. The Full Reservoir Level (FRL) and MDDL are proposed at EL 424.5 m and EL 400 m respectively. The intake invert level is proposed at EL 381 m. The reservoir will extend about 26 km upstream of the dam. There are 12 sluice spillway gates of size 8.6 m x 11 m, apart from a surface spillway. The gross storage of the reservoir at FRL is 518.59 MCM. The dead storage up to MDDL is 274.18 MCM.

Approach and Methodology

The 26 km reach of the reservoir upstream of the proposed dam has been represented in HEC-RAS model set up by the cross sections. For quasi-unsteady flow set up the average monthly flow has been worked out on the basis of 17 years 10 mean daily flow data. A graded total sediment load inflow including suspended and bed load of 0.1 Ha-m/sq.km./year has been adopted. The bed load has been taken 15% of the suspended sediment load. Using the appropriate transport function and fall velocity method the reservoir sediment modeling has been carried out to estimate the reservoir bed profile for the different points of time.

Fine, medium and coarse fraction has been adopted corresponding to particle size less than 0.075 mm, 0.075 to 0.2 mm and greater than 0.2 mm respectively. The time series of stage has been used as the downstream boundary of the HEC-RAS model setup for different cases of the simulation.

Sediment Gradation Curve

For non monsoon the gradation curve has been prepared taking 18, 26 and 56 percent of the total sediment as coarse, medium and fine respectively. For the monsoon (June-September) gradation curve the coarse, medium and fine fractions have been taken 38, 35 and 27 percent respectively.

Cases Studied

The bed profile and other sediment related parameters has been calculated for i) Operating the reservoir at FRL of 424.5 m always; ii) Operating at FRL of EL 424.5 m during the non-monsoon and at EL 412.5 m during the monsoon period (June to September every year); iii) Operating at FRL of EL 424.5 m during the non-monsoon and at EL 400 m during the monsoon period; (iv) Operating at FRL of EL 424.5 m

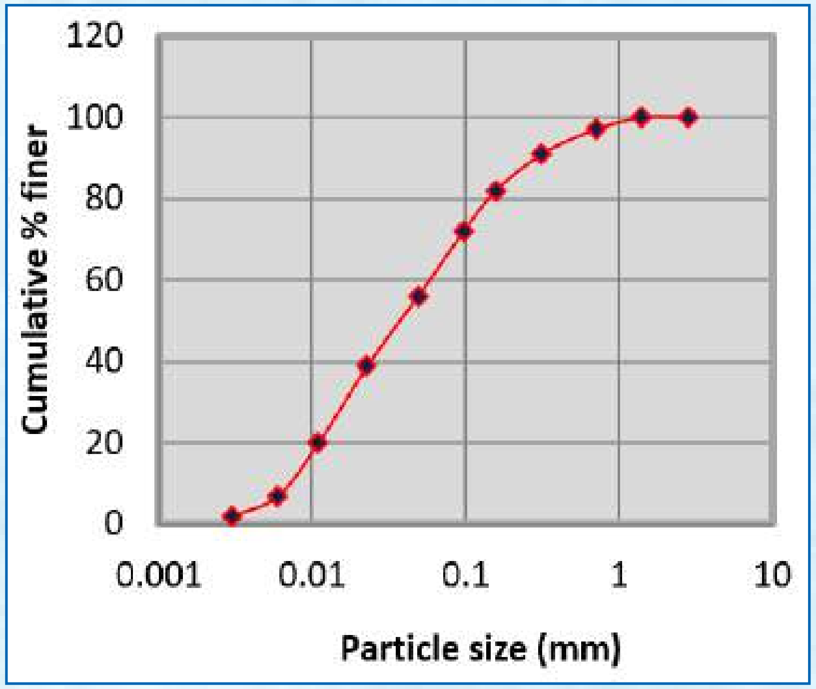


Fig. 15 Sediment Gradation Curve for non-monsoon period

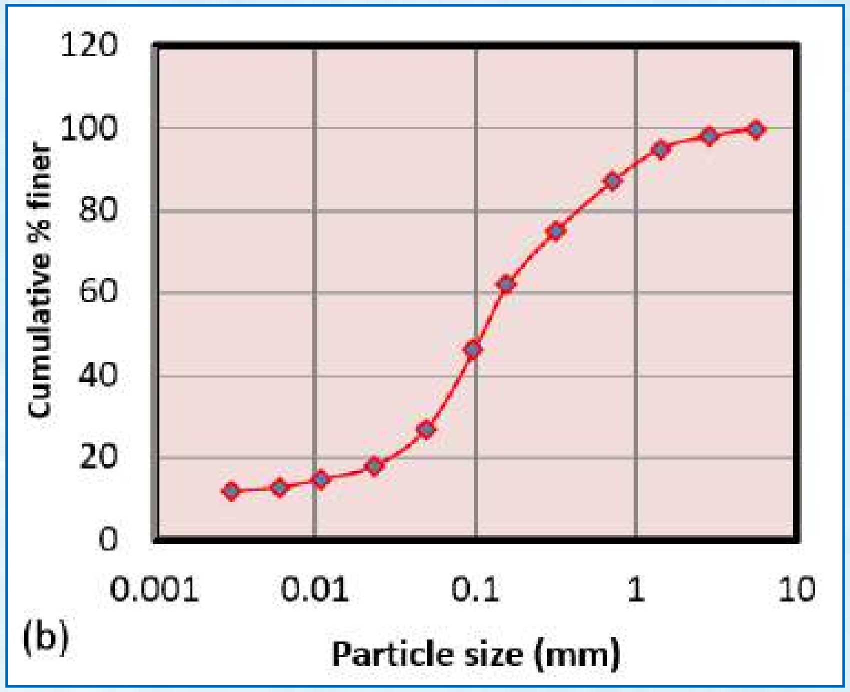


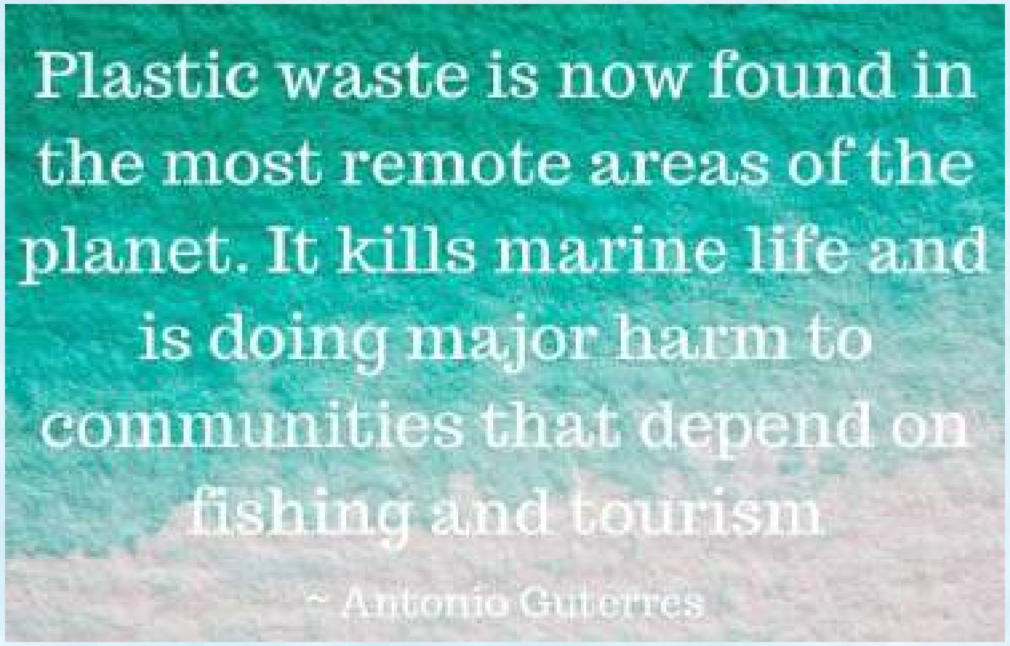
Fig. 16 Sediment Gradation Curve for monsoon period

during the non-monsoon and at EL 412.5 m during the monsoon period along with flushing in June up to EL 365 m every year. For all the above four operating conditions of the reservoir bed profile has reported after 5, 10, 30 and 70 years. The reservoir capacity has also been estimated at the above mentioned points of time.

Study Outcome

In order to get an idea of the best option of the reservoir operation the invert level of reservoir bed after 70 years for all the four cases has been compared as shown below:

The Live storage (MCM) between EL 400 m and 424.5 m after 70 years of the simulation has been estimated as 77, 88, 109 and 100 MCM respectively for Case-i, ii, iii and iv respectively. From the reservoir sedimentation simulation, it has been found that the reservoir operating condition corresponding to EL 424.5 m (FRL) in non-monsoon, EL 412.25 m in monsoon and flushing up to EL 365 m every year, could be the better option for the sediment management as well as optimal power generation aspect.



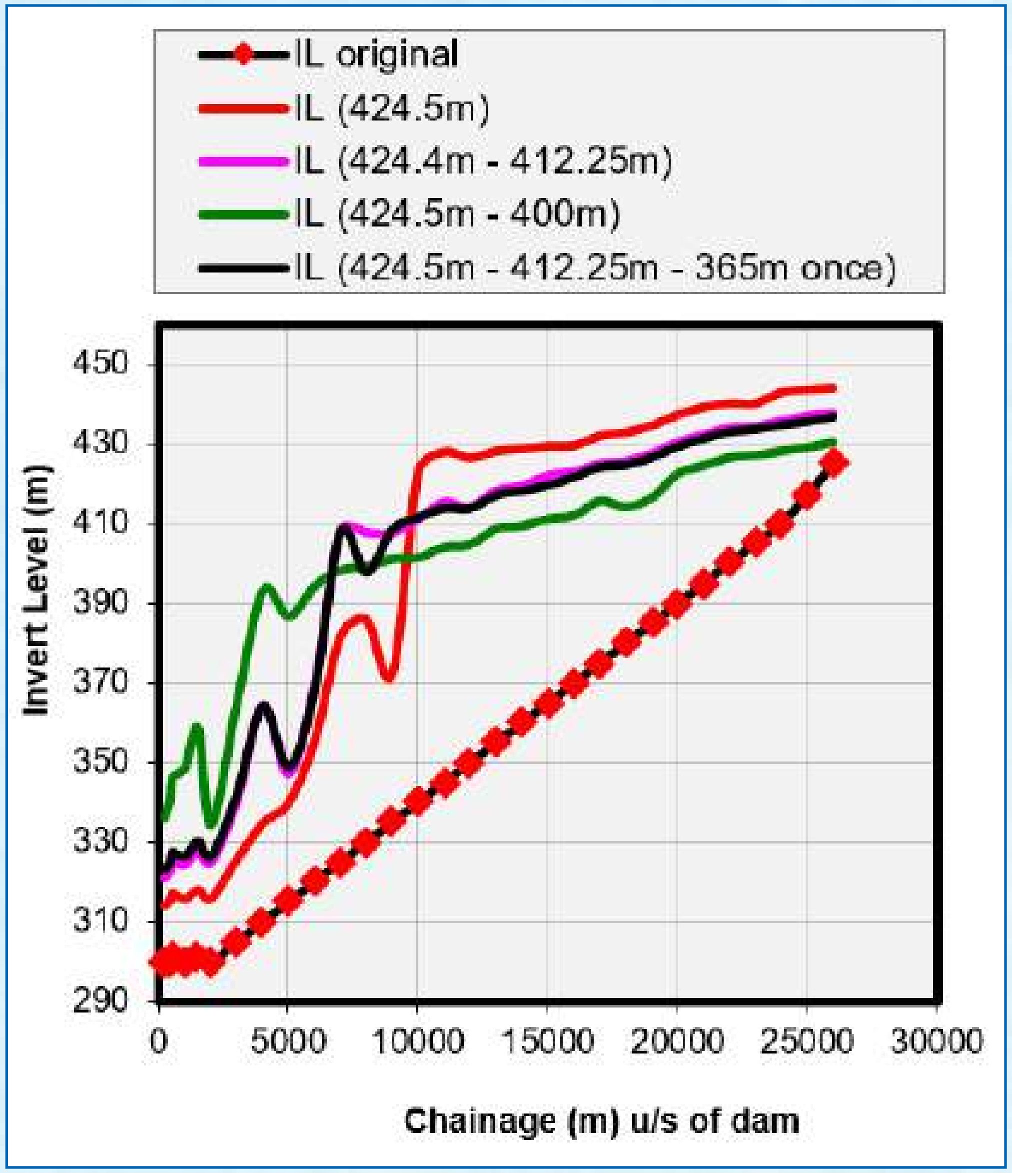


Fig. 17 Comparison plot of reservoir invert level after 70 years of sedimentation for different operating conditions of reservoir

TAIL WATER RATING CURVE STUDY

Rating curve is required to estimate the water level at a particular location of river reach corresponding to different discharges. It is used for designing the stilling basin and other energy dissipation arrangements of River Valley Projects. Central Water Commission had carried out a number of rating curve study in past. Some of the important studies are rating curve studies for Punatsangchhu Hydroelectric Project-I and II, Bhutan, Ayodhya Barrage Project, Uttar Pradesh, Bhur, Bhuswa, Khuntishot, Biramati, Khudia, Barakattha, Sonadubi Projects of Jharkhand.

Methodology for Rating Curve

- Collect surveyed river cross sections
- Set up a hydro-dynamic model

Fig. 18 HEC-RAS Model set up

- Calibrate the model using the stage discharge data
- Make a discharge series and run steady flow profile on any hydro-dynamic model
- Using the steady flow profile simulation results prepare the rating curve at desired location

Tail Water Rating Curve for Ayodhya Barrage

Using the surveyed river cross sections of river near proposed barrage location the hydro-dynamic model was set up.

Model Calibration

Model calibration is essential to estimate the parameters for running the rating curve simulations.

Using the stage discharge data of nearby G&D site the model was calibrated. From model calibration Manning's n has been found as 0.025.

Observed discharge	Observed stage of river	Simulated stage for Manning's n 0.025
(cumec)	(m)	(m)
16413	93.37	93.31
18103	93.56	93.55
19423	93.72	93.7

Rating Curve at Desired Location

Using the calibrated model the rating curve was computed for the discharge series.

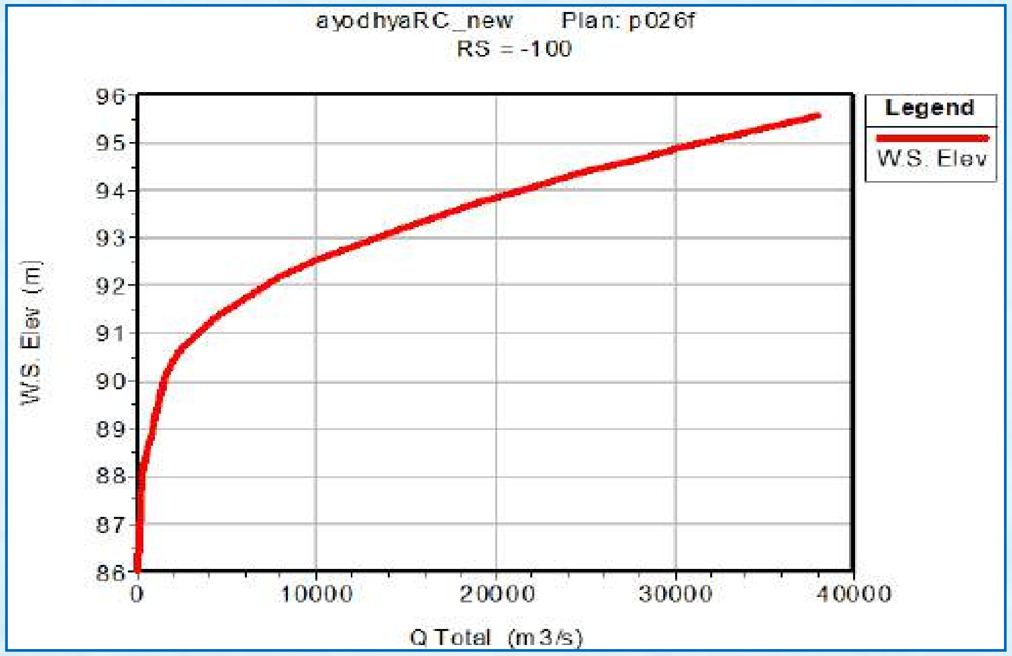


Fig. 19 Rating curve at 200 m u/s of proposed barrage axis

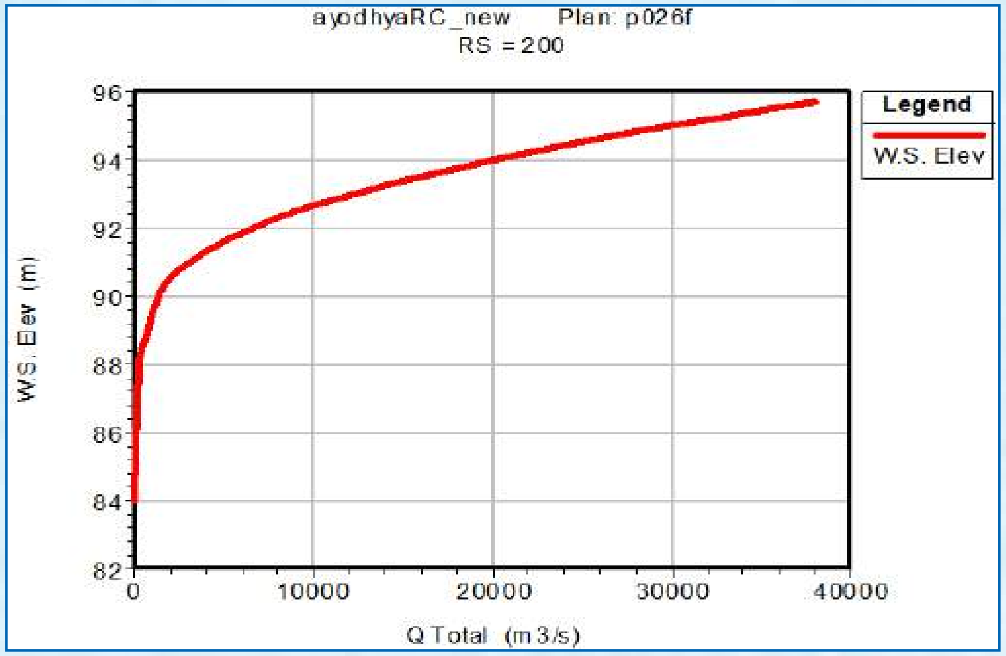


Fig. 20 Rating curve at 100 m d/s of proposed barrage axis

Fig. 21 Sardar Sarover Dam

ENVIRONMENTAL FLOW ASSESSMENT

Environmental flows (EF) are an ecologically acceptable flow regime designed to maintain a river in an agreed or predetermined state. Therefore, EF is a compromise between water resources development on one hand and maintenance of river in a healthy or at least reasonable condition on the other hand. Difficulties in the actual estimation of EF values arise primarily due to the inherent lack of both the understanding of and quantitative data on relationships between river flows and multiple components of river ecology. The major criteria for determining EF should include the maintenance of both spatial and temporal patterns of river flow, i.e., the flow variability, which affect the structural and functional diversity of rivers, and which in turn influence the species diversity of the river. All components of the hydrological regime have certain ecological significance.

High flows of different frequency are important for channel maintenance, bird breeding, wetland flooding and maintenance of riparian vegetation. Moderate flows are critical for cycling of organic matter from river banks and for fish migration, while low flows of different magnitudes are important for algae control, water quality maintenance and the use of the river by local people. Therefore, many elements of flow variability have to be maintained in a modified-EF-regime.

The International Union for Conservation of Nature (IUCN) (2003) defines "E-Flows as the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated.

Central Water Commission has carried out Environmental Flow Assessment for the Himalayan Ganga and reach of river Ganga from Haridwar to Unnao. CWC is also monitoring the environmental flow releases from river valley projects in Himalayan Ganga and reach of river Ganga from Haridwar to Unnao through its field formations.

Methodologies for Assessment of Environmental Flow

Hydrological Methods

- Tenant and Modified Tenant method
- Flow Duration Curve Method and Shifting FDC Techniques based on EMC

Hydraulic Methods

- Hydraulic rating Method
- Habitat Simulation Method

Holistic Methodologies

- Building Block Methodology (BBM)
- Downstream Response to Imposed Flow Transformation (DRIFT)

Case Study: Environmental Flow Assessment for Reach of River Ganga from Haridwar to Unnao

Fig. 21 River reach for environmental flow assessment

Input Data

- 10 daily discharge data of river Ganga at Garhmukteshwar and Kachhlabridge G&D sites
- Inflow, diversion and release data at Bhimgoda, Bijnor and Narora barrages;
- Command area of Upper, Middle and Lower Ganga Canals;
- 4 to 5 cross sections of river Ganga at Garhmukteshwar, Kachhlabridge and Kanpur to represent a river reach of about 1 km, have been used in the present study.

Methodology Adopted

For environmental assessment hydraulic rating cum habitat simulation methodology has been adopted.

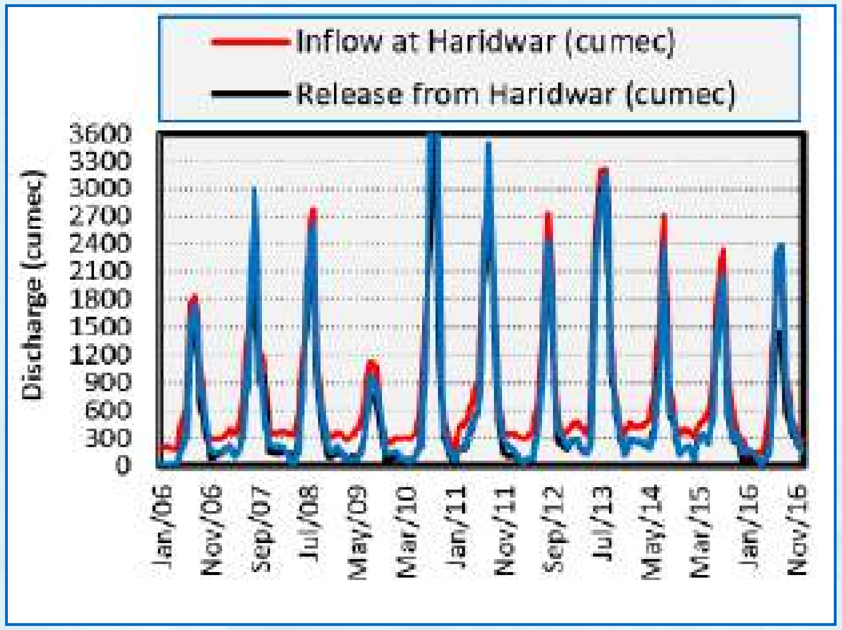


Fig. 22 Analysis of Inflow, release data of Haridwar and observed discharge at Bijnor

Flow Pattern Analysis

The flow pattern shows that in general discharge observed at Bijnor barrage is more than the release from Bhimgoda. Hence, This river reach is effluent one as certain amount of flow is getting added into the river from intermediate catchment, from ground water and irrigation return flow.

Flow pattern analysis shows that this river reach is also effluent one where considerable contribution of base flow from ground water as well as return flow is being added into the river.

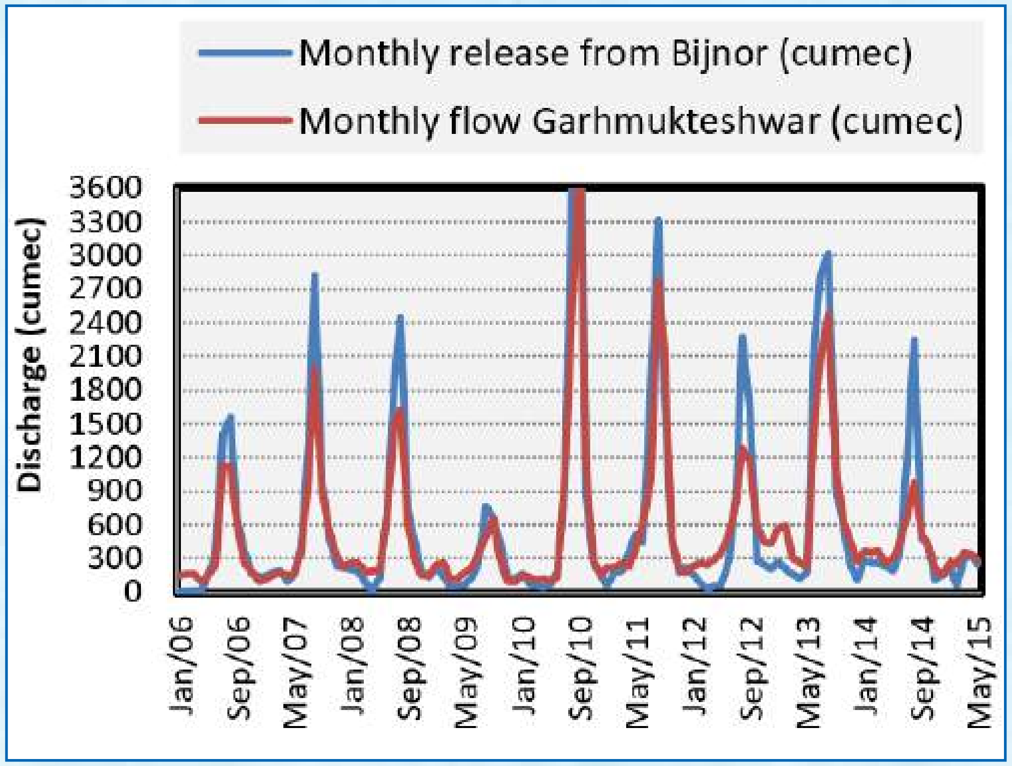


Fig. 23 Analysis of release from Bijnor and flow observed at Garhmukteshwar

Habitat Parameters

Habitat parameter for the study river reach was supplied by CIFRI, major fish species contributing to the fishery below:

Species	Weight range	Depth (Lean period)	Velocity
Labeodyocheilus	30-800g	60-80 cm	0.8-1.5m/s
Labeodero	94-563g		
Cyprinuscarpio	120-563g		
Schizothoraxrichar-dsonii	80-500g		
Crossocheiluslatius			
Botialohachata	10-175g		
Bariliusbendelisis			
Tor putitora	30-800g		

To quantify the environmental flow requirements a depth of 0.90 m has been considered in monsoon months to mimic the natural flow conditions.

Assessment of Hydraulic Parameters for Different Flow Conditions

Hydraulic parameters viz depth of flow, topflow width, flow velocity etc have been estimated using hydrodynamic simulation on HEC-RAS at three different locations where surveyed river cross sections were taken.

From the simulation results plot of discharge vs depth were prepared.

Fig. 24 HEC-RAS Model Set up at Kachhlabridge

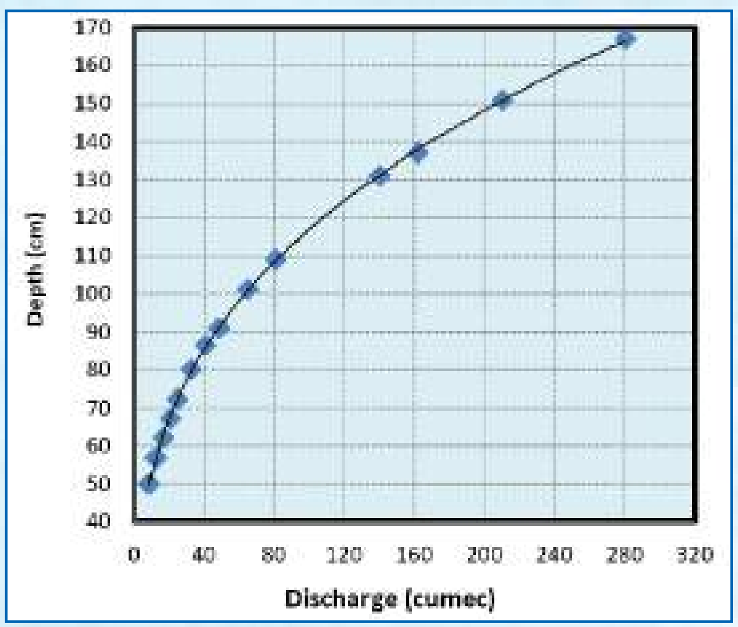


Fig. 25 Plot of Discharge vs depth at Kachhlabridge

Study Outcome

Minimum release of 36 cumec (1270 cusec) from Bhimgoda barrage and 24 cumec (850 cusec approx) from Bijnor barrage should be ensured during non-monsoon months (November to May).

During the monsoon months the minimum release from Bhimgoda and Bijnor barrages should be ensured as 57 cumec (2000 cusec) and 48 cumec (1700 cusec approx) respectively.

A minimum release of 24 cumec (850 cusec) during the non monsoon months (October to May) and 48 cumec (1700 cusec) during the monsoon months (June to September) should be ensured downstream of Kanpur barrage to meet the environmental flow requirements.

High Flows to Connect with Flood Plains

Environmental flows regime is not only low flows, it is also concerned with high flows which establish connectivity between the river and flood plains. It is seen that high flows at various places in the river are 2600 cumec at Haridwar, 2800 cumec at Bijnor, 2800 cumec at Garhmukteshwar, 2800 cumec at Narora, and 2400 cumec at Kachlabridge. These flows stay high for about 15 days or more. Analysis of data by using HEC-RAS shows that during these periods, the top width is about 400 m or more and the flow inundates flood plains. Thus, the connectivity between the river and flood plains is maintained satisfactorily.

Environmental Flows for Special Purposes

Ganga river has a special place in Indian culture and at numerous occasions, lakhs of pilgrims gather on its banks for bathing. Flow requirements are high during these short periods of typically one or two days. Such requirements can be met from natural flows, supplemented by additional water from Tehri dam or by reducing diversions.

PROBABLE MAXIMUM PRECIPITATION (PMP) ATLASES PUBLISHED BY CWC

Central Water Commission in association with India Meteorological Department has prepared the PMP Atlases for various basins in the country. These PMP Atlases would be very useful not only in assessing the inflow design flood for planning of any water resources project but also in assessing the hydrologic safety of old dams many of which have aged and require periodic safety review. The grid wise PMPs given in the Atlas may be used for quick/ direct assessment of applicable PMP/SPS for a catchment. However, such assessment should be limited to small and medium catchments only and should not be used for large catchments. Also, the detailed and precise analysis would be desirable for taking a final decision on applicable design storm.

PMP Atlases Published by CWC

- Ganga River Basin
- Brahmaputra River Basin
- Mahanadi and Adjoining River Basins
- Godavari River Basin
- Narmada, Tapi, Sabarmati, and Luni River Systems and Rivers of Saurashtra and Kutch Regions including Mahi
- Cauvery and Other East Flowing River Basins
- West Flowing Rivers of Western Ghats

Key Points about PMP Atlases

- Prepared on GIS platform
- Storm Isohyetal maps of almost all major storms
- Provides Sub-basin wise SPS and PMP estimates in tabular form

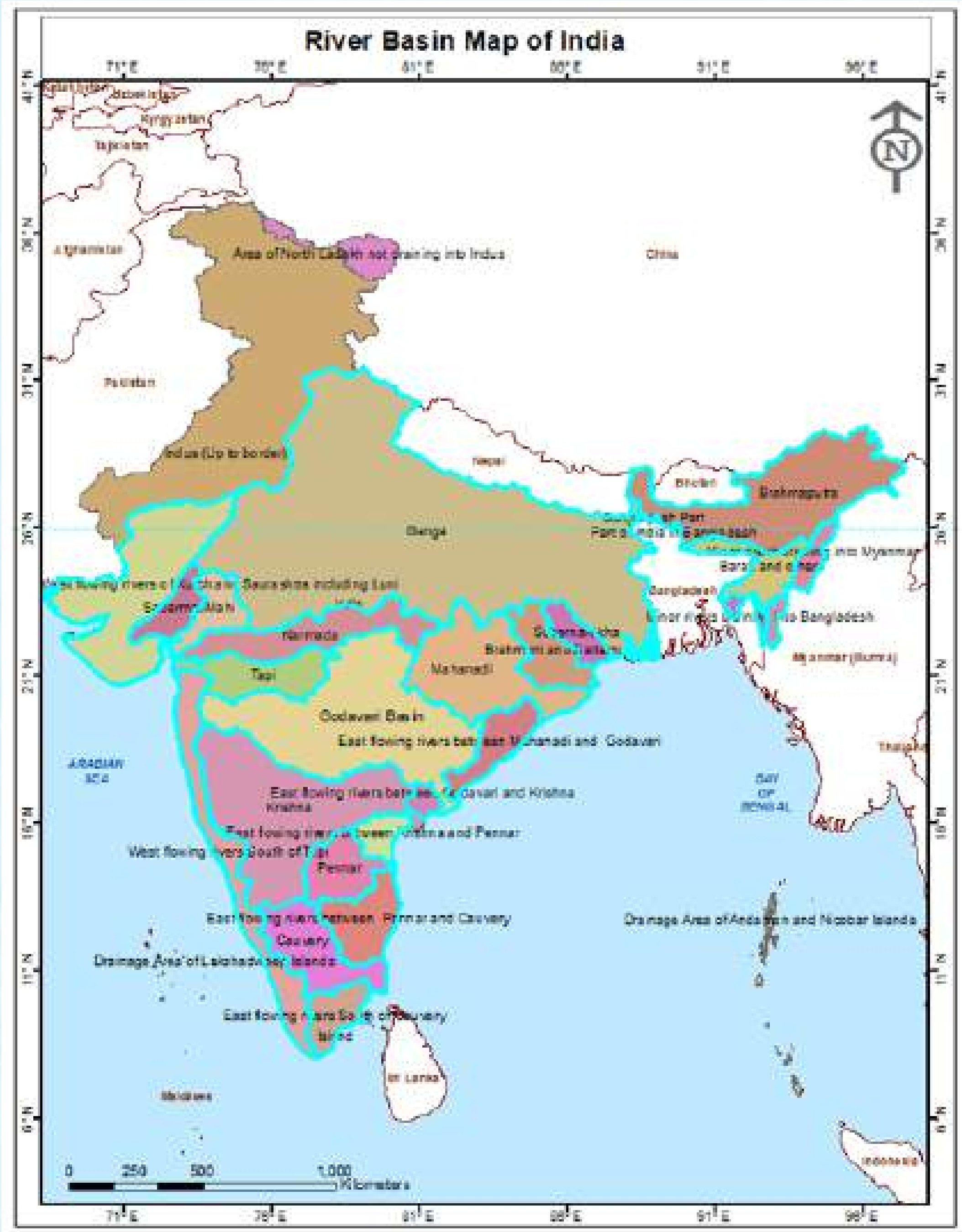


Fig. 26 Basins for which PMP Atlases published by CWC

- Provided Sub-basin wise hourly rainfall distribution coefficients
- Provides grid wise PMP estimate for quick/direct assessment of applicable PMP/SPS for a catchment.
- Provides maximum persisting dew point temperature data of entire country during the different fortnights

Storm Isohyetal Maps

Storm isohyets are the basic inputs for design rainfall depths computations. For design rainfall depth estimate of quasi distributed hydrological analysis the transposable storm isohyets are transposed in the catchment area of the project to get the maximised transposed depths. The transposed depths are further multiplied with Moisture Adjustment Factor (MAF) to get the Probable Maximum Precipitation (PMP) estimates for each sub-catchment.

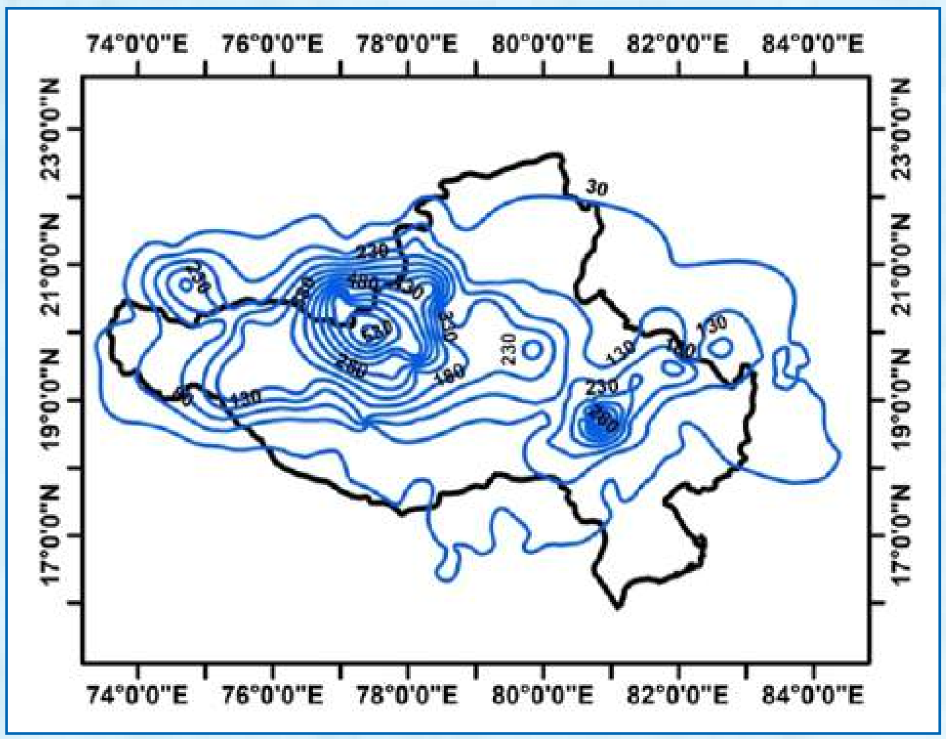


Fig. 27 Storm Isohyets

Maximum Persisting Dew Point Temperature

Maximum persisting dew point temperature data is a key input for computation of computation of Moisture Adjustment Factor (MAF). In each PMP Atlas the Maximum persisting dew point temperature maps for all the 24 fortnights have been provided.

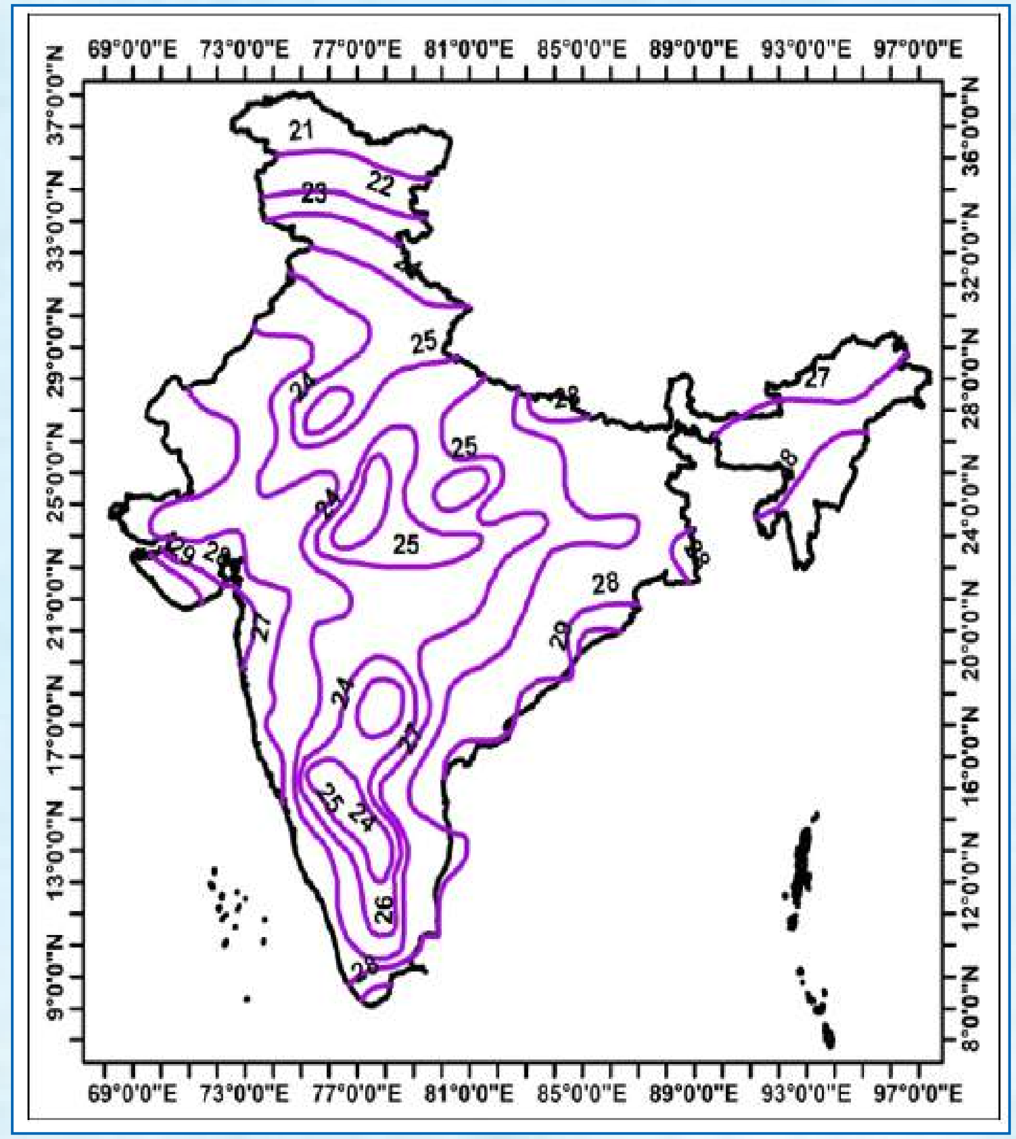


Fig. 28 Maximum persisting dew point temperature plot

Grid Point Locations

SPS and PMP values are read from the tables provided in PMP Atlases on the basis of Grid Point Location. After mapping the project catchment, the location of centroid of the catchment is marked and its latitude, longitude are noted. Based on the latitude and longitude of the catchment centroid, the relevant Grid Point Location is read from Atlas.

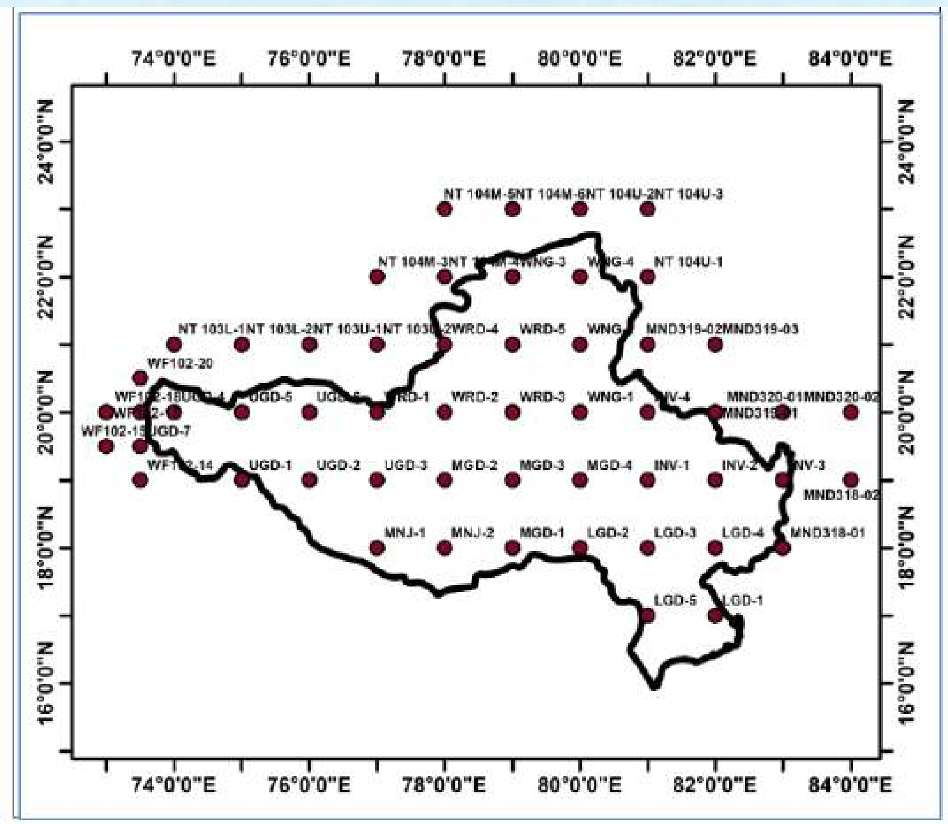


Fig. 29 Grid Point Location

Grid PMP Depth

Depending upon the catchment area the 1day, 2day and 3 day PMP depths can either be read from the relevant table corresponding to Grid Point Location or from Grid PMP Map.

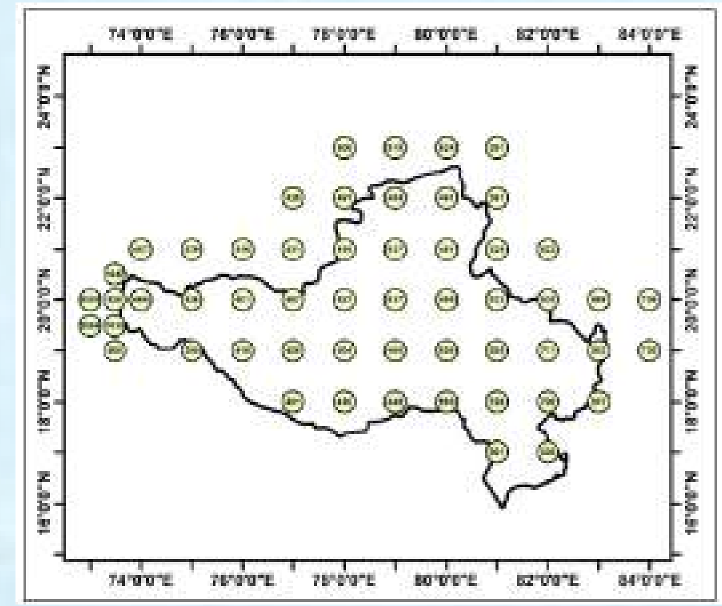


Fig. 30 1day Grid PMP

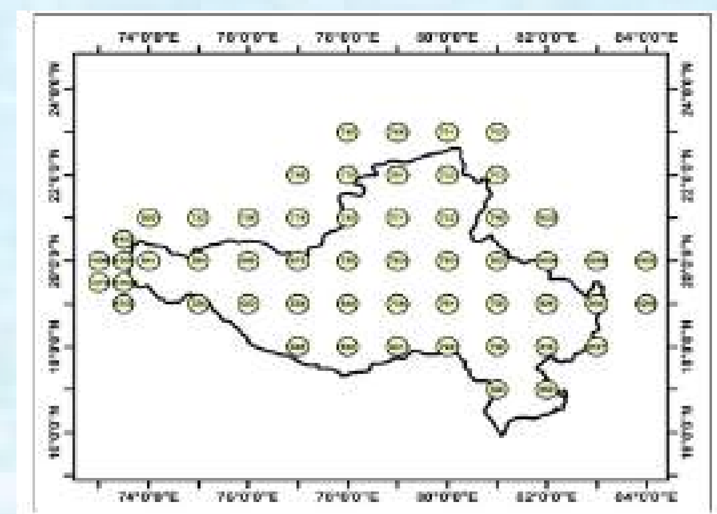


Fig. 31 2day Grid PMP

The grid wise PMP estimates which are given in tabular as well as at Grid point locations are very handy for estimating the design flood for any hydraulic structure.

DAM BREAK FLOOD ANALYSIS FOR LAND SLIDE DAM FORMATIONS

Blockage of rivers due to landslides in Himalayas and consequent formation of lakes behind landslide dams poses a major threat of flash flood to downstream areas due to possible breaching of such dams. As Landslide dams are natural phenomena, they are vulnerable to failure by overtopping and breaching. For an effective disaster management planning, it is essential to have an estimate of lake volume behind landslide dam, possible dam break flood peak, differential rise in river water level and travel time of flood peak at different downstream locations of the river reach.

CWC estimates the above essential parameters through detailed hydro-dynamic analysis and provides the same to National Disaster Management Agency (NDMA) for effective disaster management planning with the help of concerned agencies. In the past a number of flash flood events due to breaching of landslide dams on river Parechu, Kurichhu, Kanka, Sunkosi, Phuktal, Yarlung Zangbo etc were analyzed by CWC to provide the necessary inputs to NDMA.

Methodology for Estimation of Lake Volume and Land Slide Dam Break Flood Simulation

- Mark the land slide dam location on Google Earth and Extract the river cross section using SRTM or other suitable DEM of at 30m resolution at a closer interval from land slide dam location up to few km upstream of the lake fetch thus formed
- Using the river cross sections estimate the lake volume formed behind land slide dam by hydrodynamic simulation to get the fetch of the lake. This will also provide an approximate estimate of dam height
- Extract the river cross sections downstream of land slide dam upto the desired location of the river reach at a suitable interval
- Collect the information about prevailing discharge quantity in the river
- Delineate the catchment area at of river at land site dam location, prepare the hypsometric curve to estimate the runoff volume for different rainfall scenario
- Using the river cross Prepare a hydrodynamic model set up for dam break simulation and carry out the dam break simulation assuming a suitable trapezoidal breaching section and breach development time. The breach development time should be estimated on the basis of top width of the land slide dam
- Estimate the dam break flood, differential rise in river water level and travel time at all the desired locations

Case Study: Sun Kosi Landslide Dam, Nepal

This landslide took place on 02.08.2014 in the upper reaches of Sun Kosi river in Sindhupalchowk district of Nepal at a location having latitude $27^0 45' 40''$ N, longitude $85^0 52' 08''$ E, which blocked the Sun Kosi river about 1.2 km u/s of existing Sun Kosi Hydro Power Dam. The consequent impounding of water behind landslide dam submerged the area upto about 5 km u/s of the landslide dam location.

Catchment Area

The catchment area of the Sun Kosi river at landslide dam location was about 2494 sq.km, out of which about 1004 sq.km was above the elevation band 5000 m

Fig. 32 Photograph of landslide dam on Sun Kosi river

River Cross Sections

River cross sections upstream and downstream of land slide dam location have been extracted using ASTER DEM.

Fig. 33 Extraction of River Cross Sections

Etimation of Lake Volume for Known Lake Fetch Using Hec-Ras

Reach	River Sta	Profile	Min Ch El	W.S. Elev	Flow Area	Top Width	Volume
			(m)	(m)	(m2)	(m)	(1000 m3)
LSDUS	8000	PF1	862.11	862.74	11.83	37.6	31248.43
LSDUS	7000	PF1	840.59	841.52	9.25	19.79	31237.89
LSDUS	6000	PF1	836.36	840	75.49	43.27	31195.52
LSDUS	5000	PF1	825.37	840	1600.46	157.22	30357.55
LSDUS	4000	PF1	813.73	840	3294.37	195.52	27910.13
LSDUS	3000	PF1	785.49	840	16380.13	474.23	18072.88

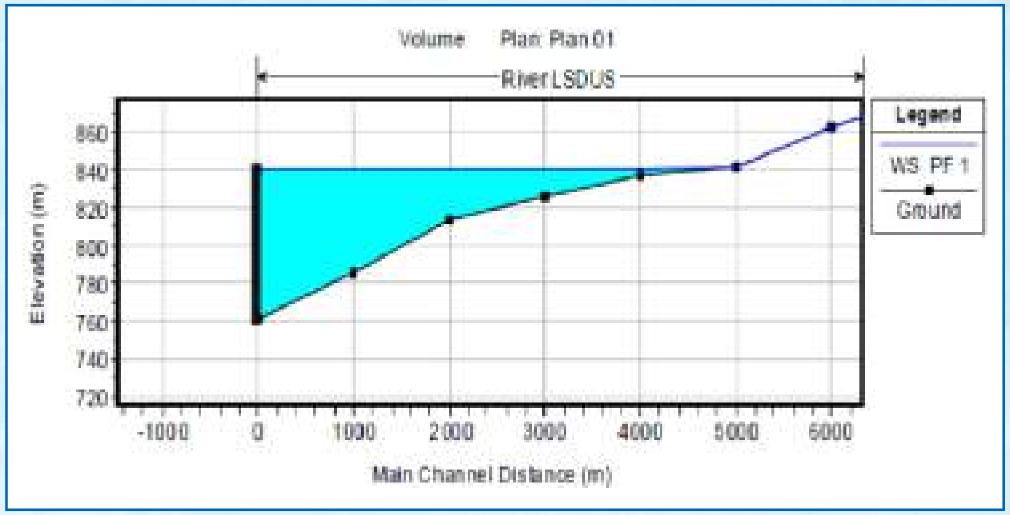


Fig. 34 Estimated lake volume for 5 km fetch was about 31 MCM.

Dam Break Simulation

For the estimated volume of 31 million cubic meter, the possible critical dam break scenario was generated to estimate the flood peak, its travel time and possible rise in river water level. For dam break scenario the initial condition flood in the river at Kosi barrage was adopted as 3540 cumec, which was distributed along the entire 280 km study reach of the river from landslide dam location upto Kosi barrage in catchment area proportion. The catchment area of the Kosi river at Kosi barrage is about 57971 sq.km. Taking the river cross section from ASTER DEM, the dam break study was carried out using 1 dimensional mathematical model MIKE11.

Fig. 35 MIKE11 Model Setup

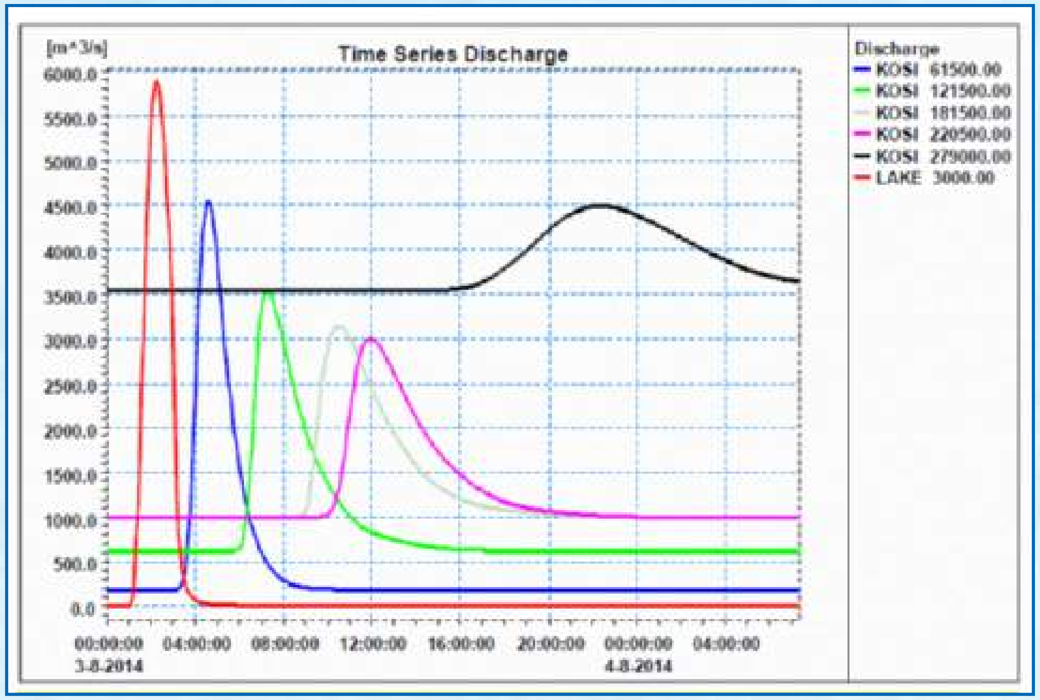
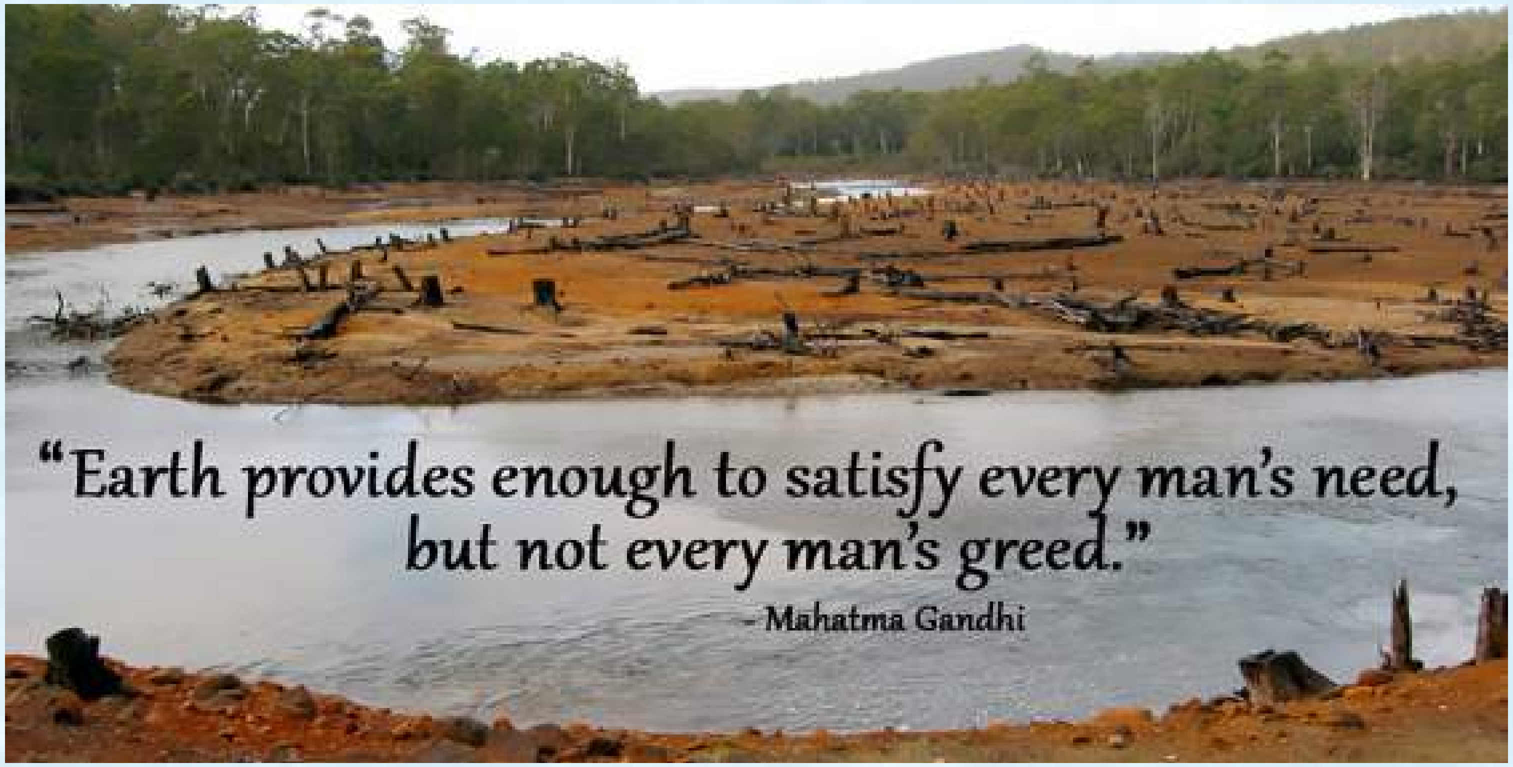


Fig. 36 Estimated Flood Peak, its Travel Time and Additional Rise in River Water Level

Locatiom (m) downstream of land slide dam	Initial flood in river (cumec)	Initial flood + land slide dam breach flood (cumec)	Flood peak due to land slide dam (cumec)	Possible additional rise in water level due to land slide dam breach (m)	Flood peak occurrence time (date- hr:min
Land slide dam	0	5885	5885	8.50	3/8/2014 2:15
KOSI 1500.00	152	6977	5826	8.89	318/2014 2:19
KOSI 4500.00	162	6895	6743	6.72	3/8/2014 2:30
KOSI 7500.00	152	6868	5706	7.36	3/8/2014 2:34
KOSI 22500.00	182	6764	6682	9.96	3/8/2014 2:55
KOSI 31500.00	182	5413	5231	10.03	318/2014 3:19
KOSI 124500.00	620	3470	2850	4.31	318/2014 7:24
KOSI 175500.00	997	3197	2200	2.89	3/8/2014 10:04
KOSI 237714.28	997	2618	1621	1.88	3/8/2014 13:34
KOSI 279000.00 (Near Kosi barrage)	3540	4482	942	0.44	3/8/2014 22:20



GLACIAL LAKE OUTBURST FLOOD (GLOF) STUDY

Glacial Lake Outburst Flood (GLOF) is the flood generated due to outburst of glacial lake. The impact of the outburst flood waves on human lives and infrastructure can be highly destructive and far- reaching. The Himalayan regions including the Bhutan Himalaya have suffered many glacial lake outburst floods (GLOF) events. GLOFs from the Bhutan Himalaya were recorded at least in the early 1940s, 1957, 1960, 1969 and 1994. In India the outburst of Chorabari glacial lake in Kedarnath, Uttarkhand in June 2013 caused severe casuality of human life and devastation of properties in downstream. The GLOF study is an important component of disaster Management Planning. Apart from that GLOF study is also essential for finalising the discharging capacity of spillway for the River Valley Project being planned in Himalayan regions, if potentially dangerous glacial lakes are present in their catchment area.

Central Water Commission had carried out a number of GLOF study in past. Some of the important studies are GLOF Studies for Punatsangchhu Hydroelectric Project, Bhutan, Arun-III Hydroelectric Project, Nepal, Kalai-I, Kalai-II, Hutong-II and Oju Hydroelectric Projects, Arunachal Pradesh, Project Arunachal Pradesh, Lhonak Glacial Lake Outburst Flood Estimate, Sikkim, Chorabari glacial lake outburst, Uttarkahand etc.

Formation Process of Moraine Dam Glacial Lakes

In the retreating process of a glacier, glacier ice tends to melt in the lowest part of the glacier surrounded by Lateral Moraine and End Moraines.

As a result, many supra-glacial ponds are formed on the glacier tongue. These ponds sometimes enlarge to become a large lake by interconnecting with each other and have a tendency to deepen further.

Fig. 37 Raphstreng Glacial Lake, Bhutan

A Moraine Dammed lake is thus born. The lake is filled with melt water and rainwater from the drainage area behind the lake and starts flowing from the outlet of the lake even in the winter season when there is minimum flow.Moraine Dammed glacial lakes, which are still in contact or very near to the glaciers, are usually dangerous.

Methodology for GLOF Estimation

- Identify the potentially dangerous glacial lakes in the project catchment based on the location of lakes, associated mother glaciers, and topographic features around the lakes and glaciers.
- Identify the possible combination of potentially dangerous glacial lakes

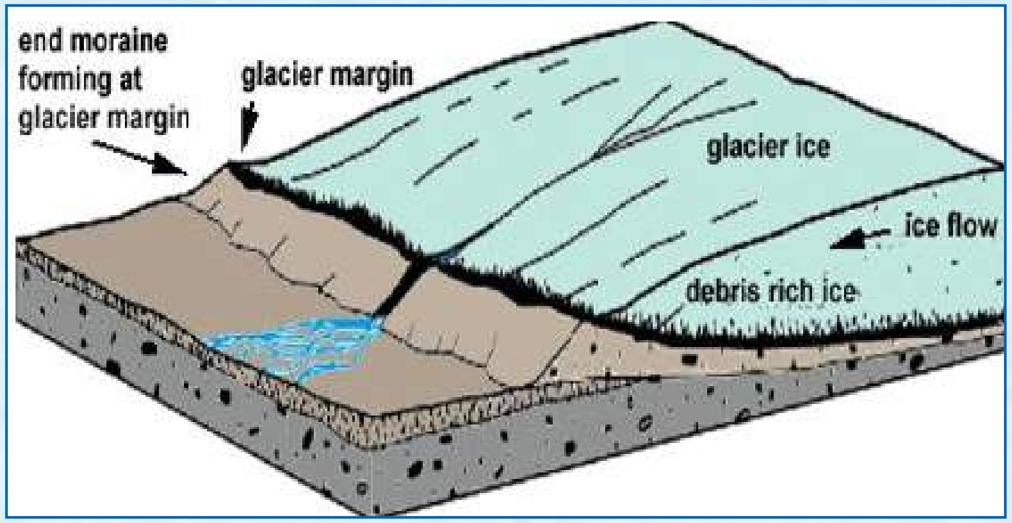


Fig. 38 Schematic of Moraine Dam Glacial Lake Formation

- Estimate the lakes water spread area and their volume and finalize of Glacial lakes for GLOF simulation after a detailed criticality analysis based on lake volume, its distance from the project site and average slope of the river from the glacial lake till the project site.
- Estimate the breach parameter for moraine dam and simulate dam breach flood using any mathematical model like MIKE11/HEC-RAS.
- Channel route the lake outburst flood through the entire reach of river from the GLOF site to project site to get the magnitude of flood peak at project site.
- 667 glacial lakes in the basin – 13 Potentially dangerous
- The criticality analysis carried out based on the possible combination of adjacent glacial lakes in future, lake surface area and their distance from the project site
- After the criticality analysis the 3 glacial lakes finalized for the GLOF simulation
- The GLOF simulation carried out using one dimensional mathematical model MIKE11.

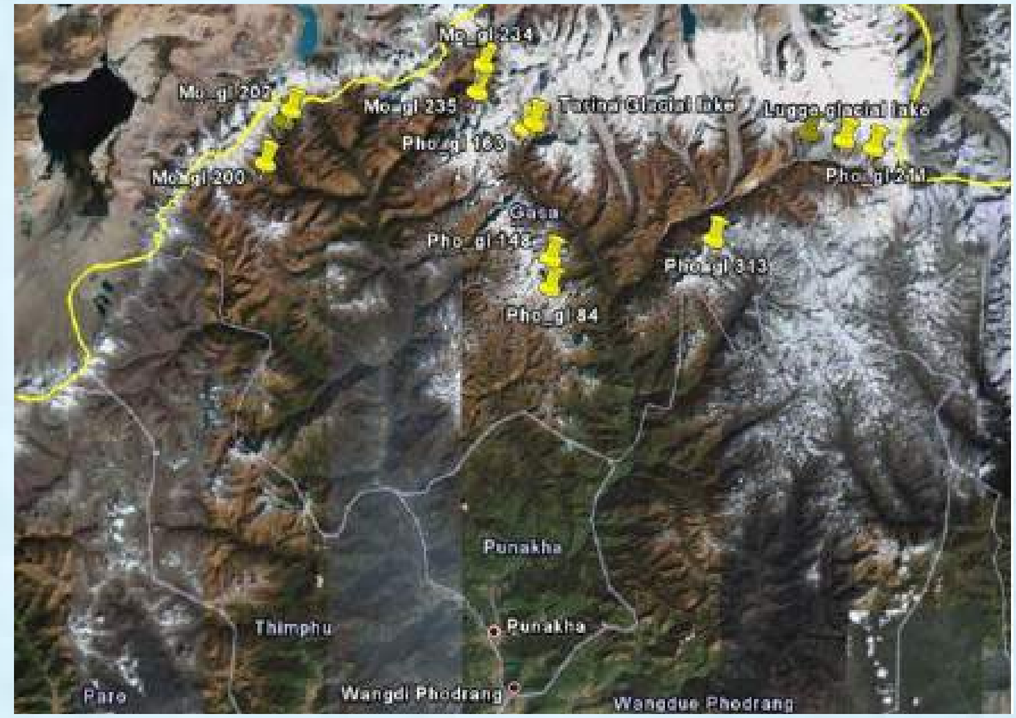


Fig. 39 GLOF Simulation For Punatsangchhu Hydro Power Project

Critical Glacial Lakes Identified for Glof

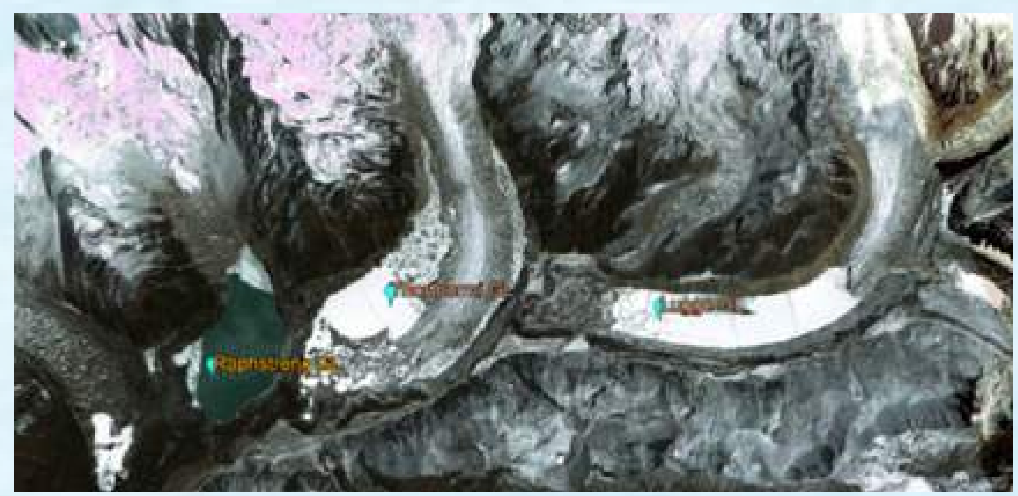


Fig. 40 Critical glacial lakes in Punatsangchhu Sub-Basin

Hydrodynamic Model Set Up for Glof Simulation

For GLOF simulation, the river reaches from glacial lake location and upto the dam site have been represented in the model by a number of cross sections extracted from DEM at an interval of 3 to 5 km.

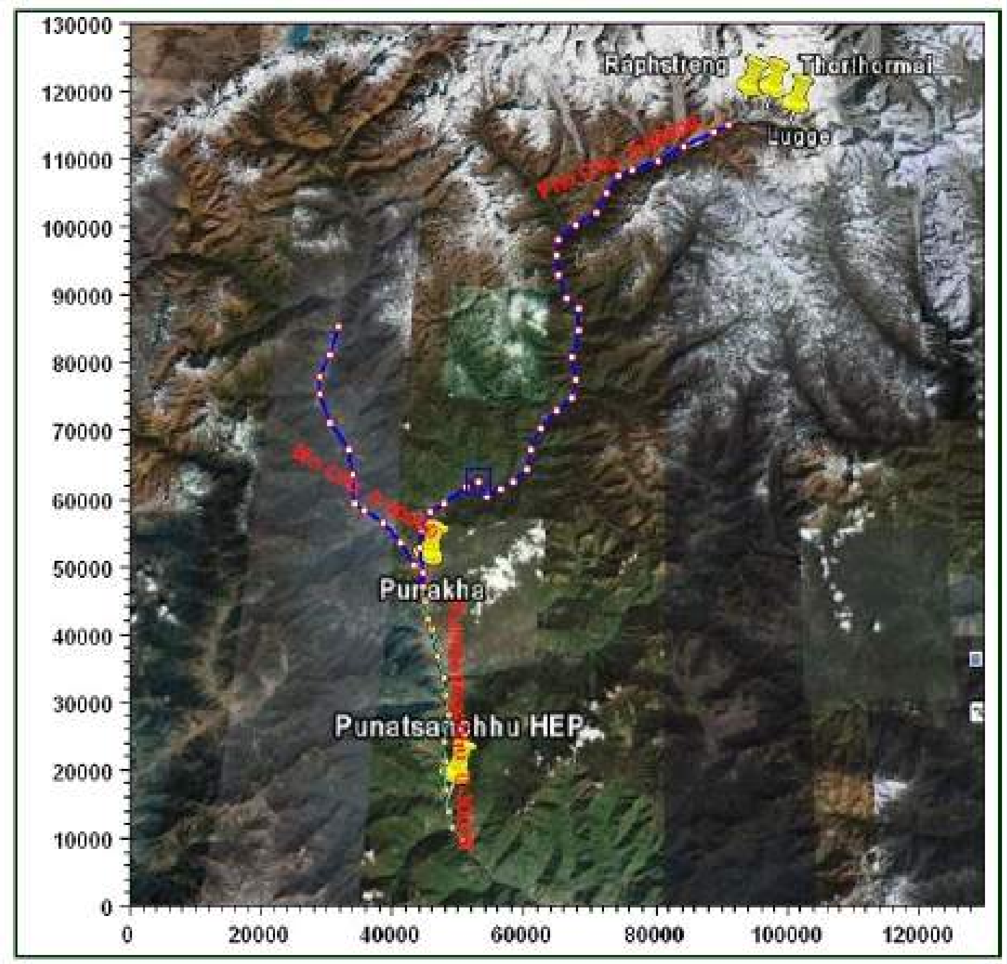


Fig. 41 MIKE11 Model Set up

MIKE11 Model Set up

BREACH PARAMETERS FOR GLOF SIMULATION

Raphstreng GL	Top breach width 60 m, Breach depth 20 m Breach development time 1hour, side slope 0.5H:1V
Raphstreng and Thorthormi Glacial Lakes	Top breach width 90 m, Breach depth 30 m Breach development time 1hour, side slope 0.5H:1V
Lugge Glacial Lakes	Top breach width 77 m, Breach depth 25 m Breach development time 1hour, side slope 0.75H:1V

Initial Conditions

- Created corresponding to 100 yr return period flood for Punatsangchhu HE project
- This 100 yr flood has been distributed based on the catchment area proportioning and impinged as constant lateral inflow at different locations of the study river reach

Study Outcome

The GLOF attenuation and translation as obtained through hydrodynamic simulations for Rapshtreng glacial lake, Lugge glacial lake and combination Raphstrengh and Thorthormi glacial lakes as per adopted breach parameters are given in Case A, B and C.

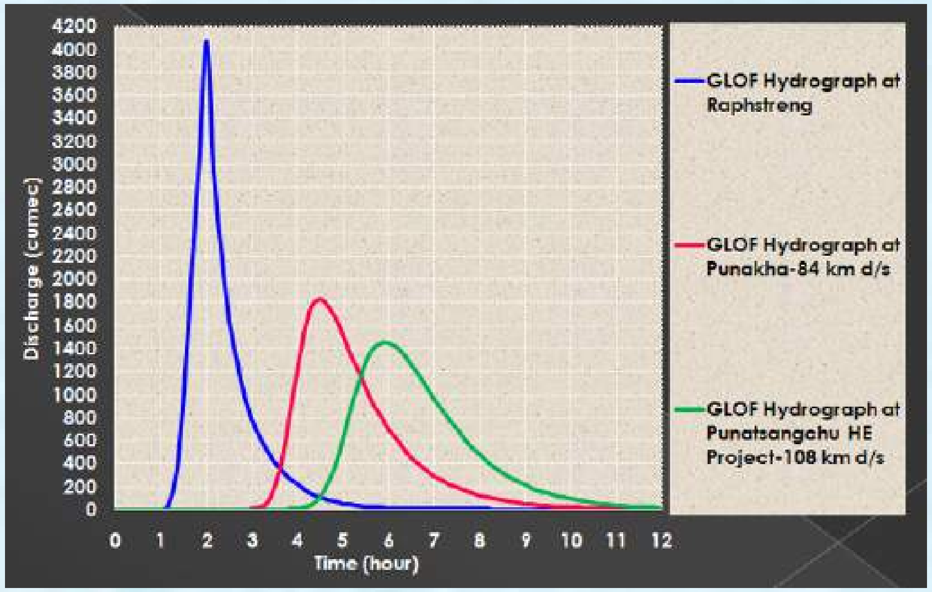


Fig. 42 GLOF simulations for Raphstreng Glacial Lake

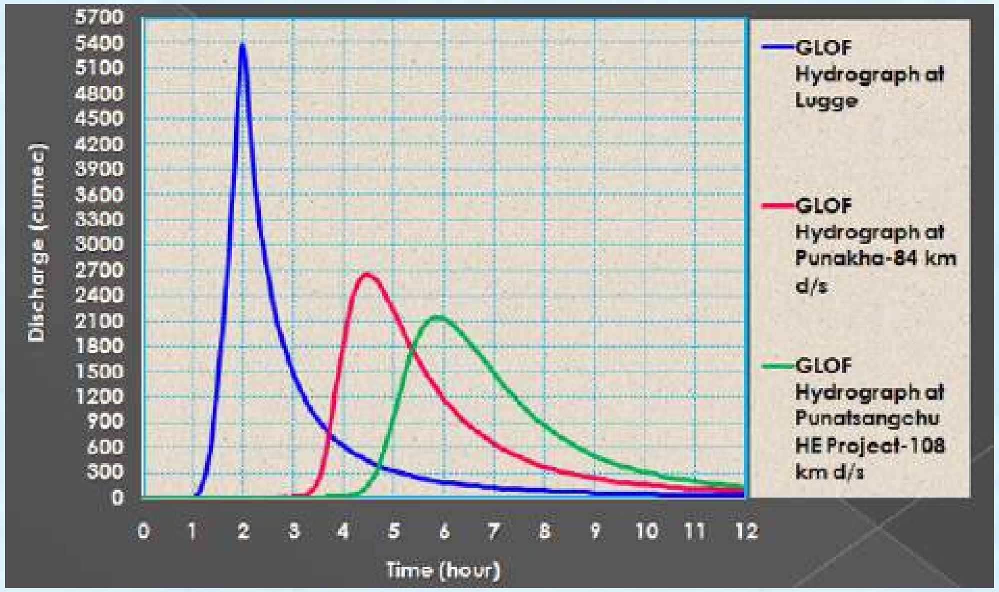


Fig. 43 GLOF simulations for Lugge Glacial Lake

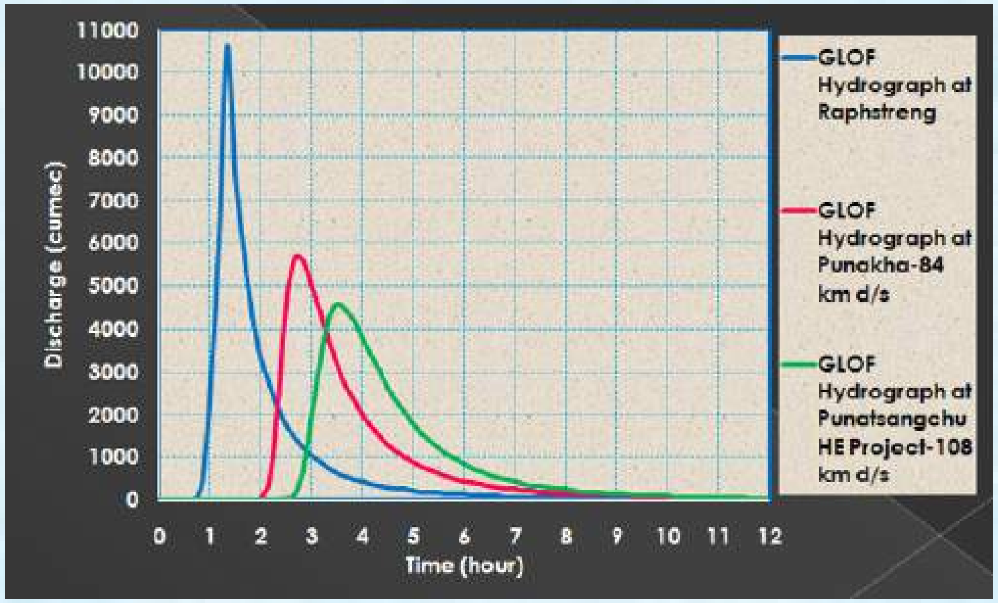


Fig. 44 GLOF simulations for Raphstreng and Thorthormi Glacial

Based on the different GLOF Simulated cases the GLOF Peak for the Punatsangchhu HE Project Bhutan can be taken as 4600 m^3/s.

KEDARNATH FLOOD OF JUNE 2013

Uttarakhand and neighbouring states experienced very heavy rainfall during 16-18th June 2013. Kedarnath temple town was subjected to two consecutive flood disasters at an interval of about 12 hours. The first flood event occurred on 16 June 2013 at 5:15PM when the torrential rains flooded the Saraswati river and Dudh Ganga catchment area, resulting in excessive flow across all the channels. Due to heavy downpour, the town of Rambara was completely washed away on 16 June evening. The second event occurred on 17 June 2013 at 6:45 AM, after overflow and collapse of the moraine dammed Chorabari Lake which released large volume of water that caused another flash flood in the Kedarnath town leading to heavy devastation. CWC estimated the both flood events using hydrological and hydrodynamic modelling.

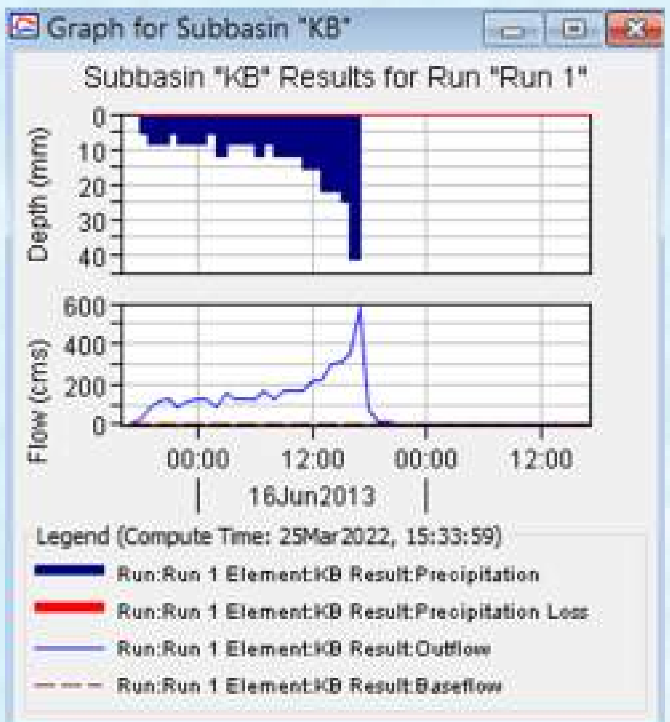


Fig. 45 Simulated flood of 16 June 2013

Flood Event of 16 June 2013

Flooding event of 16th June 2013 was analysed using Kinematic Wave modelling approach of HEC-HMS. The estimated flood peak was about 600 cumec.

Simulated Flood of 16 June 2013

The flood peak passed Rambara with a shooting velocity of about 8.5 m/s resulting rise in water level by about 4.5 m.

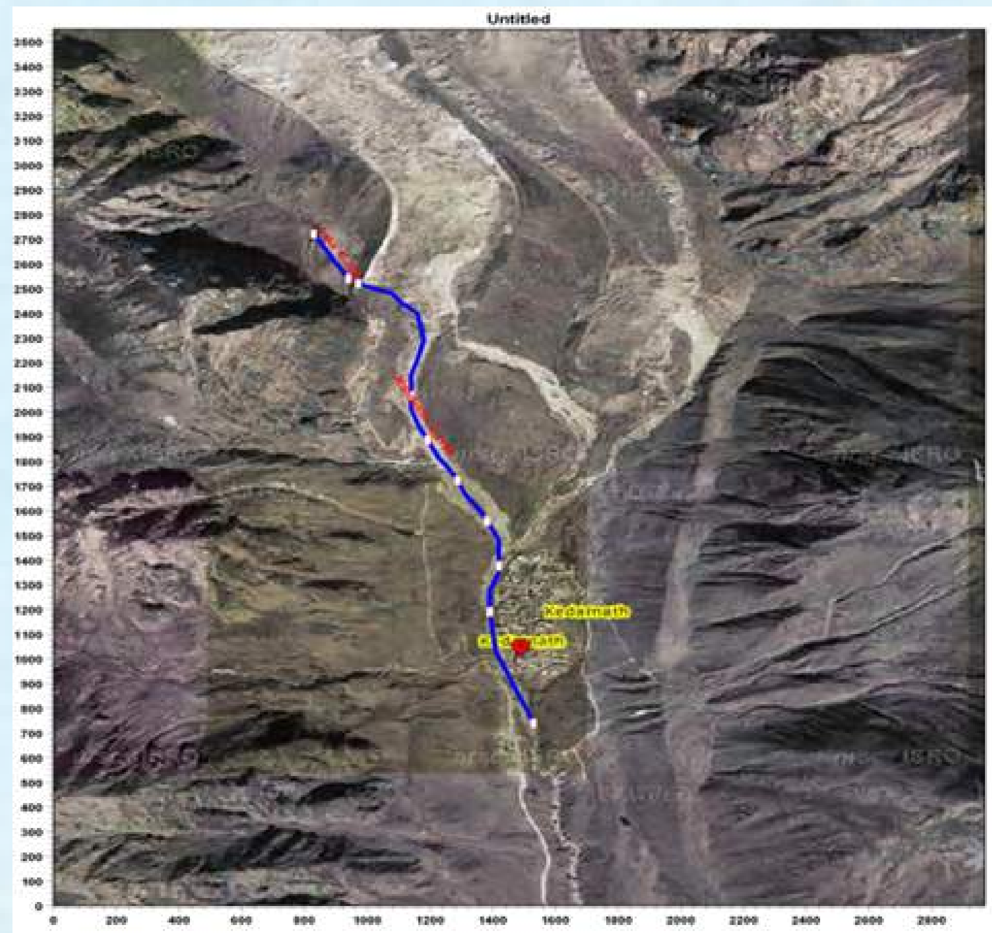


Fig. 46 MIKE11 model setup for Chorabari lake

Flood Event of 17 June 2013

Chorabari lake outburst occurred in early morning of 17th June 2013. The lake was emptied in less than 15 minute resulting devastating flood in Kedarnath temple complex and huge loss of lives. The Chorabari lake was located at an elevation 3960 m, about 2.1 km upstream of Kedarnath temple complex. Chorabari GLOF was simulated on MIKE11 to estimated flood peak and its travel velocity.

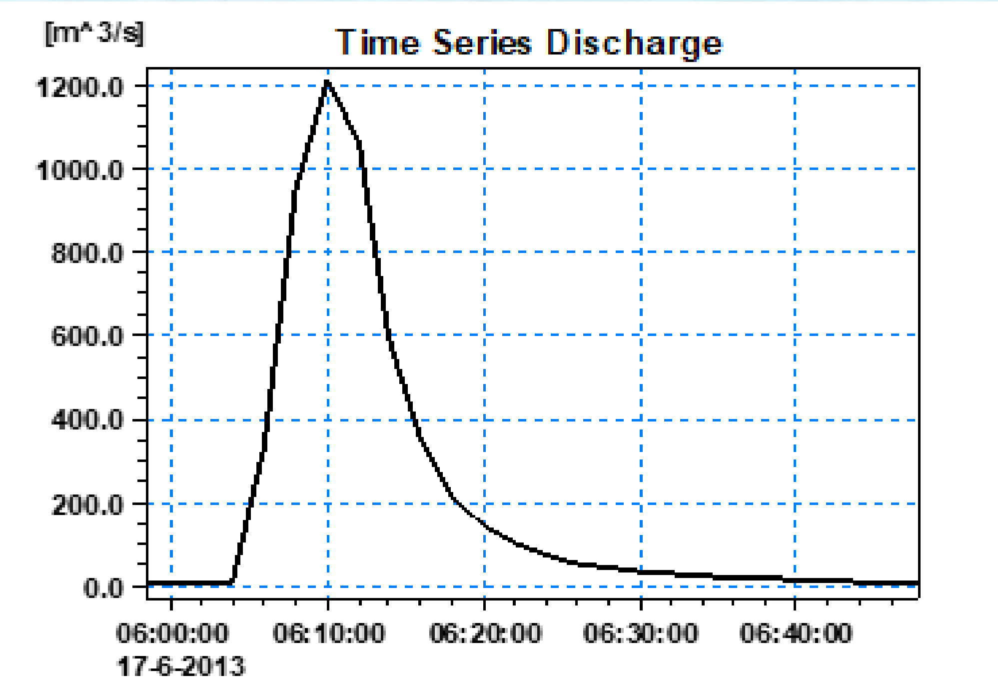


Fig. 47 Simulated GLOF hydrograph

Findings

Rainfall event of 16 June created a shooting flood wave of 4.5 m deep travelling with velocity of about 8.5 m/s, causing devastation of Rambara and some portions of the Kedarnath. The Chorabari lake outburst flood was about 1200 cumec causing sudden rise is water level by about 5 m near Kedarnath and 6 m near Rambara, which passed with a velocity of about 9.5 m/s resulting huge devastation in Kedarnath and downstream.

HYDROLOGICAL ANALYSIS OF MAJOR FLOOD OCCURRENCES

Due to hydro-meteorological conditions, India witness severe flooding conditions during the monsoon months in different regions of the country. The flood severity in the plains where the catchment area of the river is quite substantial depends upon the magnitude of rainfall recorded in the catchment area in one day, two day, 3 day durations etc. In case of hilly terrains the severity of flood is governed by not only on the depth of rainfall occurred in 1 day or 2 day durations, but also upon the depth of rainfall occurred in one hour duration. Hence, an in depth hydrological analysis of sever flood occurrences is essential to find out the causative factors and to plan the flood mitigation strategies in future.

Central Water Commission has analysed the severe flood occurrences of Uttarkhand Flood of year 2013, J&K Flood of year 2014, Bihar Flood of year 2016, Kerala Flood of Year 2018 to find out their causative factors and to suggest flood mitigation strategies in future.

Methodology

- Collect the daily rainfall records of flood occurrence month of all the available rain gauge stations in the catchment area and stations closer to catchment area.
- Collect the observed discharge records of all relevant G&D sites
- Collect the reservoir level data, release records of dams and other structures, spillway discharging capacity and other relevant details of all the hydraulic structures lying in the catchment area
- Estimate the catchment area representative rainfall either making raster of rainfall or making Theissen polygon
- compare the rainfall occurrence with historical rainfall records
- Estimate the inflow volume and flood peak received in the reservoir and volume of water released from the dam. Compare the peak release with inflow flood peak and spillway discharging capacity
- Depending upon the site specific requirements, carry out further analysis to establish the causative factors
- In some cases apart from hydrological analysis, hydrodynamic simulations may also be required

Case Study: Kerala Flood 2018

The floods, that occurred in the month of August 2018, in Kerala caused a large scale devastation in terms of lives and property along with causing misery to a large section of population of Kerala. The incessant rain and consequent flooding was most severe during 15-17 August 2018. The worst affected sub-basins in Kerala were Periyar, Pamba, and Chalakudy. CWC report on Kerala floods has presented the complete analysis of rainfall, runoff in Periyar, Pamba, Chalakudy, and Sholayar river systems.

Month wise actual rainfall, normal rainfall and percentage departure from normal

Period	Normal Rainfall (mm)	Actual Rainfall (mm)	Departure from normal (%)
June, 2018	649.8	749.6	15
July, 2018	726.1	857.4	18
1-19, August, 2018	287.6	758.6	164
Total	1649.5	2346.6	42

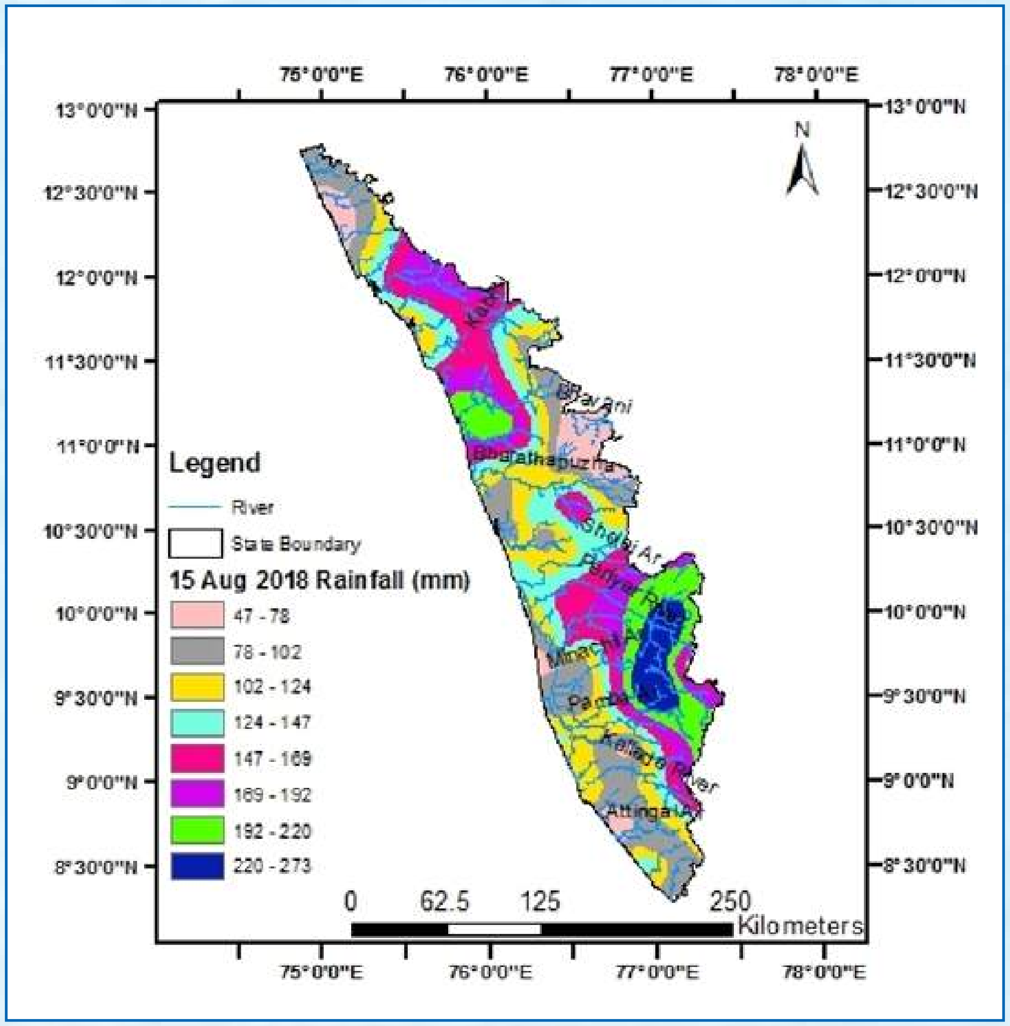


Fig. 48: 1 day rainfall of 15 August 2018

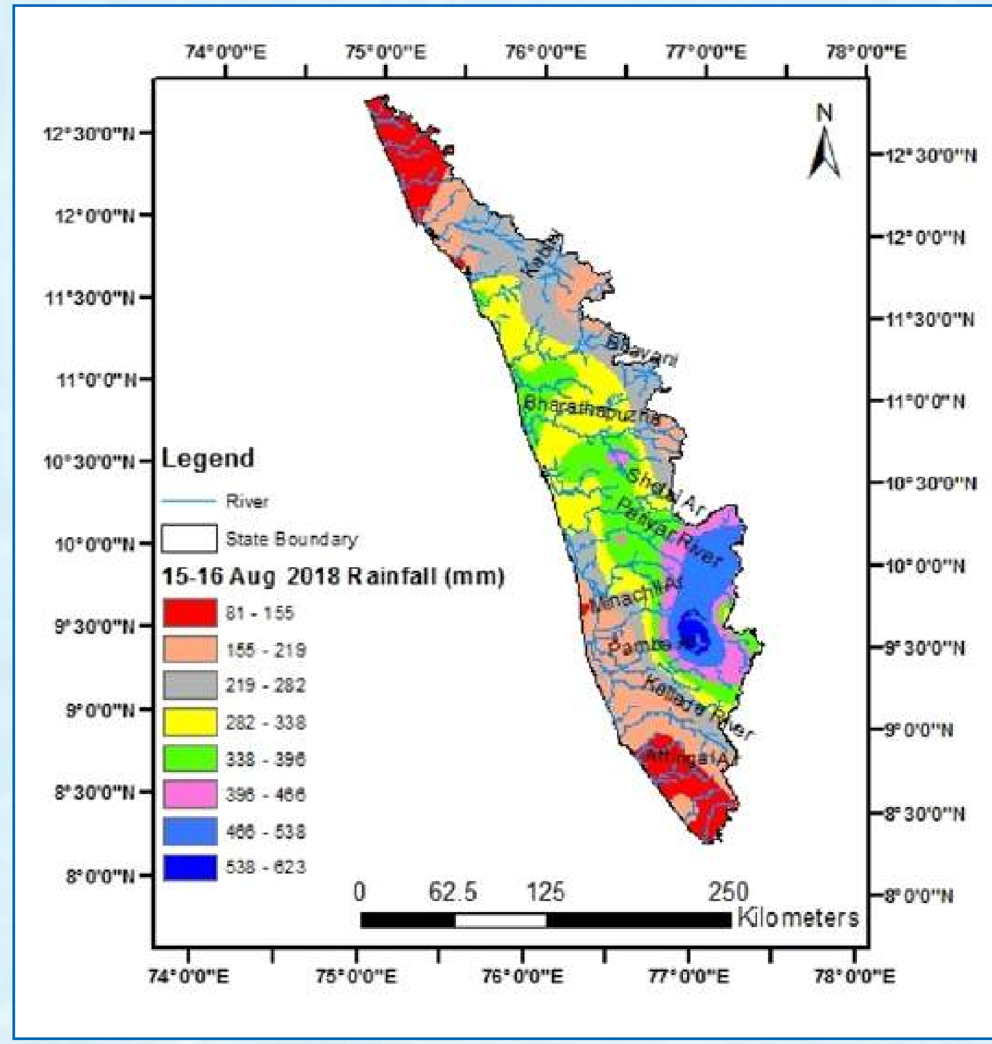


Fig. 49: 2 day cumulative rainfall of 15-16, August 2018

1 Day, 2 Day and 2 Day Rainfall Rasters

From the rainfall records of IMD, 1day, 2day and 3 day rainfall raster were prepared for the rainfall of 15-17, August 2018.

On scrutiny of data, it has been found that cumulative rainfall realised during 15-17, August 2018 was quite significant, with more than 800 mm rainfall at Peermade rain gauge station followed by more than 700 mm at Idukki. The estimated rainfall in different sub-basins were

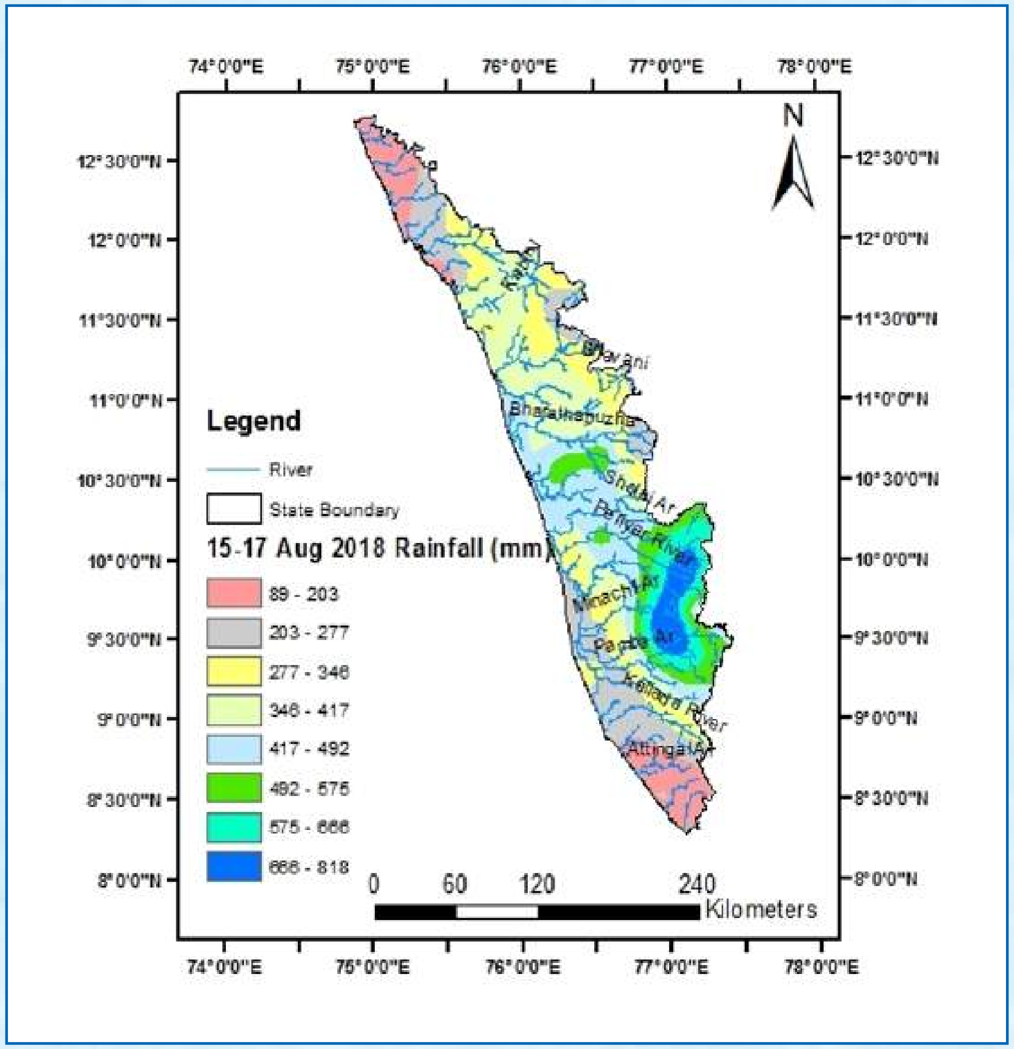


Fig. 50: 3 day cumulative rainfall of 15-17, August 2018

compared with severe most historical rainfall of 16-18, July 1924 with eye of storm at Devikulam. From the analysis, it has been found that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924

Runoff Generated During 15-17, August 2018 Rainfall

In order to estimate the runoff volume generated in the rainfall event of 15-17, August 2018, the sub-basins where severe flooding occurred have been analysed and estimated runoff volume compared with the discharge records of CWC observation sites.

A case of Periyar basin is discussed here. In the similar way runoff volume of all other basins were analysed.

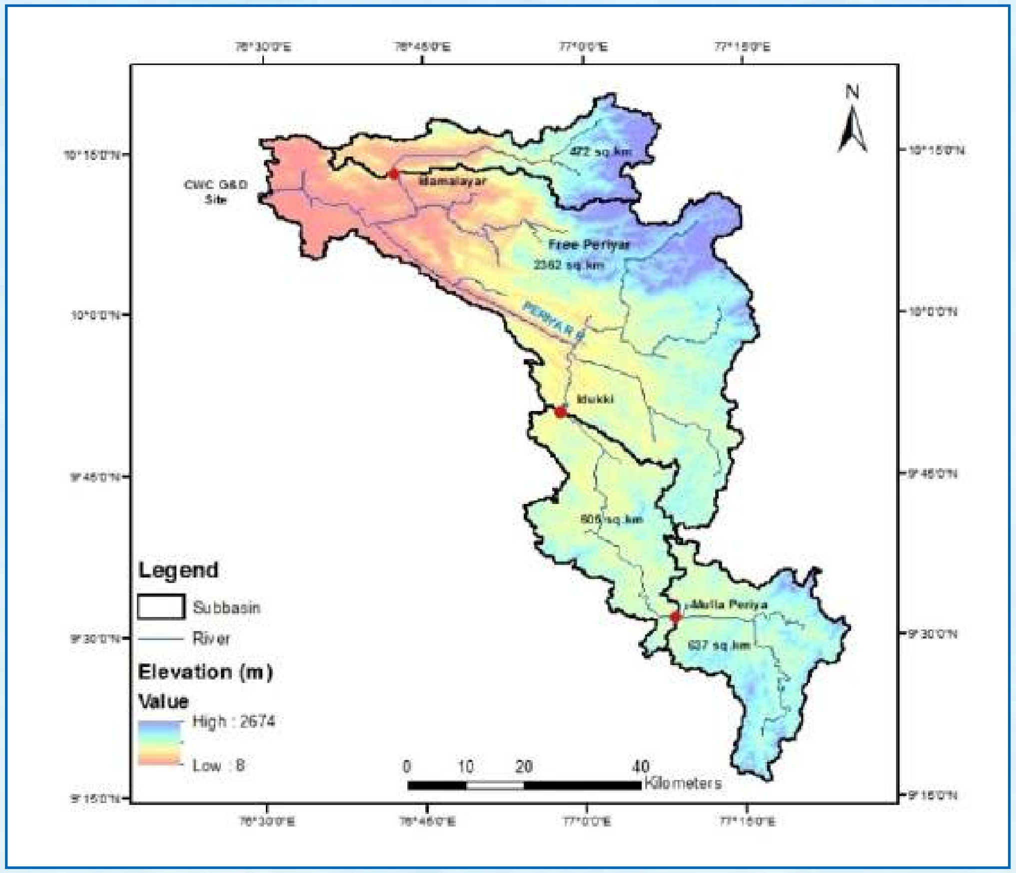


Fig. 51 Drainage area map of Periyar river up to Neeleshwaram G&D Site

Catchment	Area	Estimated runoff from rainfall		
		Runoff 15Aug 2018 (1-day)	Runoff 15-16, Aug 2018 (2-day)	Runoff 15-17, Aug 2018 (3-day)
	(sq.km)	(MCM)	(MCM)	(MCM)
Free Periyar	2362	374	845	1084
Between Idukki and MullaPeriyar	605	123	269	351
MullaPeriyar	637	106	225	290
Idamalayar	472	72	158	199
Total	4076	675	1498	1925

The cumulative runoff for 15-17, August 2018, computed from the Neeleshwaram G&D records is about 1.93 BCM, while the estimated runoff from IMD rainfall is about 1.925 BCM for a runoff coefficient of 0.78 for free catchment and 0.85 for catchments tapped by dams.

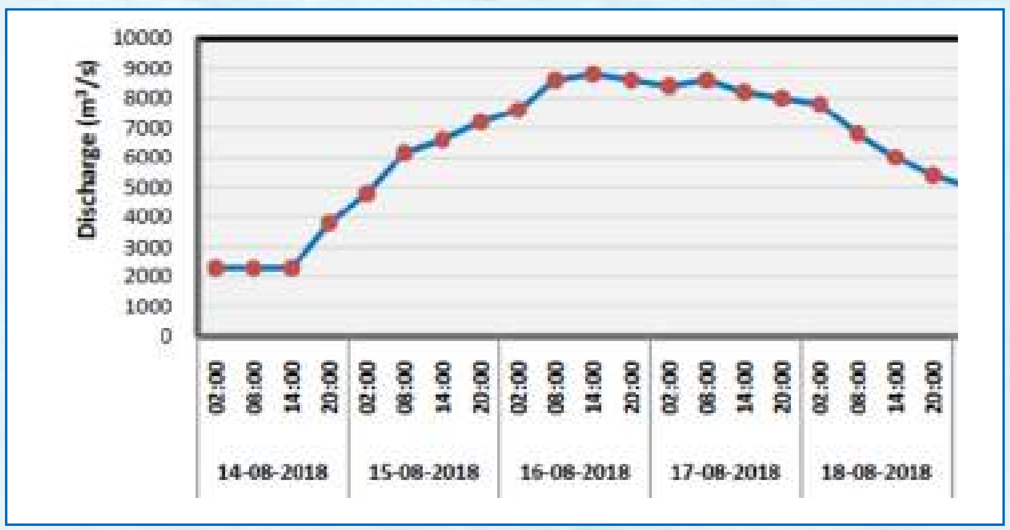


Fig. 52 Discharge data of Periyar river at Neeleshwaram G&D site

Combined Runoff of Pamba, Manimala, Meenachil and Achenkovil Rivers

Four major west flowing rivers namely Achenkovil, Pamba, Manimala and Meenachil drain directly into the southern part of Vembanad Lake while a southern branch of Periyar (further north of Muvattupuzha) drains into Cochin Kayal and finally into the Arabian sea through Kochi outlet. The runoff generated from Pamba, Manimala, Achenkovil and Meenachil rivers during 15-17 August rainfall was about 1.63 BCM (1630 MCM) against the 0.6 BCM (600 MCM) carrying capacity of Vembanad lake.

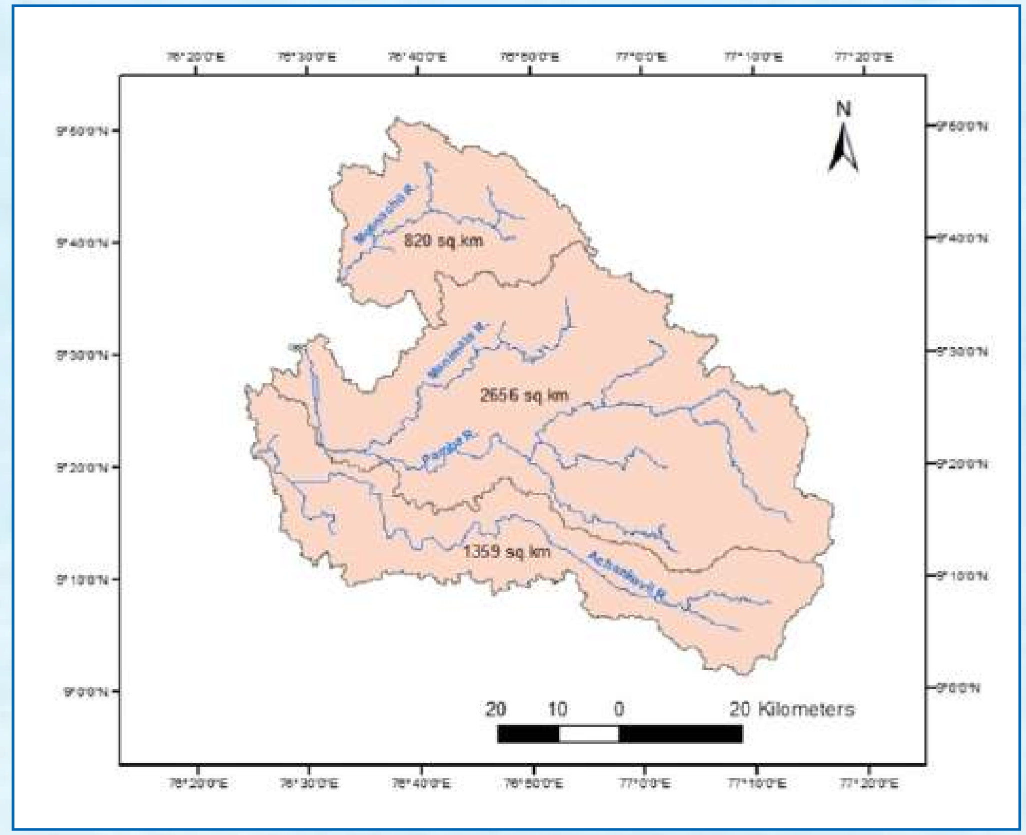


Fig. 53 Catchment area map of Pamba, Manimala, Achenkoil and Meenachil river systems

Further, the discharging capacity of 630 cumec of Thottappally spillway was other major constraint for the disposal of runoff. Considering the lake carrying capacity of about 600 MCM and discharging capacity of 630 cumec of Thottappally spillway and about 1706 cumec present discharging capacity of Thaneermukkom barrage, it can be concluded that out of 1.63 BCM the runoff generated during the 15 to 17 August 2018 rainfall, only about 0.605 BCM runoff was possible to drain out of the Vembanad lake. The remaining runoff volume of about 1 BCM created the rise of the water level in the lake and nearby areas. This continuous rising of lake water may be one of the reason of overall change in the river hydrodynamics of Pamba, Manimala, Meenachil and Achenkovil river systems resulting higher water level for a particular discharge in these rivers.

Operation of Idukki Resevoir in Periyar Sub-Basin

The peak inflow of about 2532 cumec into dam occurred at 22:00 hrs on 15 August 2018 when the corresponding release from the dam was of the order of 1614 cumec (1500 cumec spill + 114 cumec power house release). Thus, the peak was attenuated from 2532 cumec to 1500 cumec (an attenuation of about 41% downstream of Idukki).

In similar way inflow, outflow and reservoir levels of other major reservoirs viz, Idamalyar and Kakki etc were analysed.

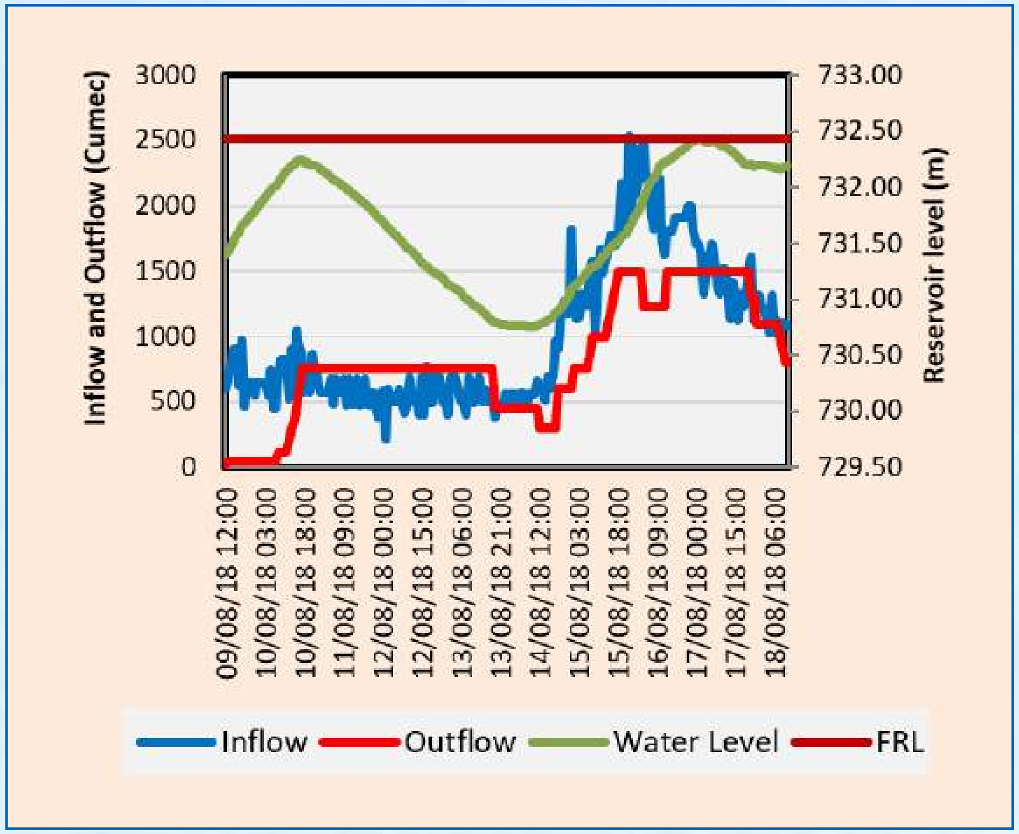


Fig. 54 Inflow, outflow and water level at Idukki reservoir

Study Outcome

- Kerala flood of 2018 was due to extreme rainfall. The average cumulative rainfall of 15-17, August 2018 was about 414 mm for entire Kerala. The consequent cumulative runoff of three days for the entire Kerala (area about 38,800 sq.km) is about 12 BCM (12,000 MCM) for a runoff coefficient of 0.75.
- Catchment area tapped by dams in Kerala excluding barrages is about 6610 sq.km. Runoff generated from the catchment tapped by the dams during the 3 days rainfall of 15-17, August 2018 has been estimated about 2.19 BCM, out of total runoff of 12 BCM for entire Kerala.
- The release from reservoirs had only minor role in flood augmentation as released volume from the reservoirs were almost similar to inflow volumes. In fact Idukki reservoir absorbed a flood volume of about 60 MCM during 15-17, August 2018.
- Rule curves of major reservoirs in the country need to be reviewed to have some dynamic flood cushion.

Idamalayar, Kerala (1985)

5

Dam Safety Aspects

- Dam Safety Organisation
- National Committee on Dam Safety
- Dam Safety Assurance and Rehabilitation Project
- Dam Rehabilitation and Improvement Project
- National Register of Large Dams
- Dam Health and Rehabilitation Monitoring Application
- Dam Safety Act, 2021
- Mulla Periyar Dam- Case Study
- Dam Instrumentation
- National Committee on Seismic Design Parameters
- Other Special Studies

Dam Safety Aspects

DAM SAFETY ORGANISATION

State Ministers of Irrigation in their First Conference held in July 1975 under the aegis Govt. of India at New Delhi discussed the question of dam safety and recommended that, in view of the increasing number of large dams in India, the Government of India may constitute an advisory Dam Safety Service to be operated by the Central Water Commission. Pursuant to the directives of the State Ministers' Conference and realizing the importance of dam safety, a Dam Safety Organization (DSO) was established in CWC, in May 1979. Realizing the importance of ensuring safety of dams, in 1982, the Govt. of India (through the erstwhile Ministry of Irrigation) constituted a standing Committee under the Chairmanship of Chairman, CWC to review the existing practices and to evolve unified procedures for safety of dams. The Standing Committee submitted its report titled "Report on Dam Safety Procedures" in July, 1986. The report elaborated the then existing procedures, their evaluations and suggestion for institutional arrangement for dam safety at the level of States and the Centre. In view of contemporary International practices, the Committee also recommended for enactment of Dam Safety Legislation. Since then the Dam Safety Organization in CWC has made great efforts in creating awareness in the country and has succeeded to a large extent in convincing the States towards the concept of dam safety which has now been accepted by them. The DSO, CWC has compiled/ formulated various standards and guidelines for the safety inspection of dams and a number of other dam safety literatures. This organization has also been assisting the State Governments in locating the causes of distress in dams, and to suggest remedial measures for the same on their specific requests.

NATIONAL COMMITTEE ON DAM SAFETY

In order to evolve a uniform simplified procedure based on the latest 'State-of-the Art' techniques, the Government of India constituted a Standing Committee in August 1982 to review the existing practices of inspection/ maintenance of dams and allied structures in various States and to evolve standard guidelines for the same. The Standing Committee was reconstituted with wider representation and focused and pin pointed mandate in October 1987 in the name of National Committee on Dam Safety (NCDS) under the Chairmanship of Chairman, CWC. The committee consists of 31 members, which has representation from central govt. & major dam owning states. It also includes specialists in the field of dam safety. So far 39 meetings of NCDS have been convened. Last meeting was held on 12th February, 2019 at Bhubaneswar. This committee acts as a forum for exchange of views on various issues pertaining to dam safety. NCDS works for devising Dam Safety Policies and regulations for maintaining best practices and standards of dam safety so as to prevent any dam safety related disasters. It acts a forum for analyzing and discussing distress condition in specified dams and appurtenant structures. Such exchange of views evolves best techniques to be adopted for tackling the problem. The committee is mandated to evolve and suggest changes in the Planning, Specifications, Construction and Operation & Maintenance practices by analysing the causes of major historical dam incidents and dam failures. Its mandate includes as an advisory body to the Central Government on specific matters related to the dam safety as referred to it and also to make recommendations to the Government in respect of dams located outside the territory of India. It also evolves methods and makes recommendations for rehabilitation of old dams.

NCDS takes note of the rehabilitation programmes funded by centre or external aid. NCDS is to act as a fillip for the research activities by identifying the areas and arranging the funds for the same. NCDS may coordinate between agencies for operations of the reservoirs of cascading dams in coordinated manner.

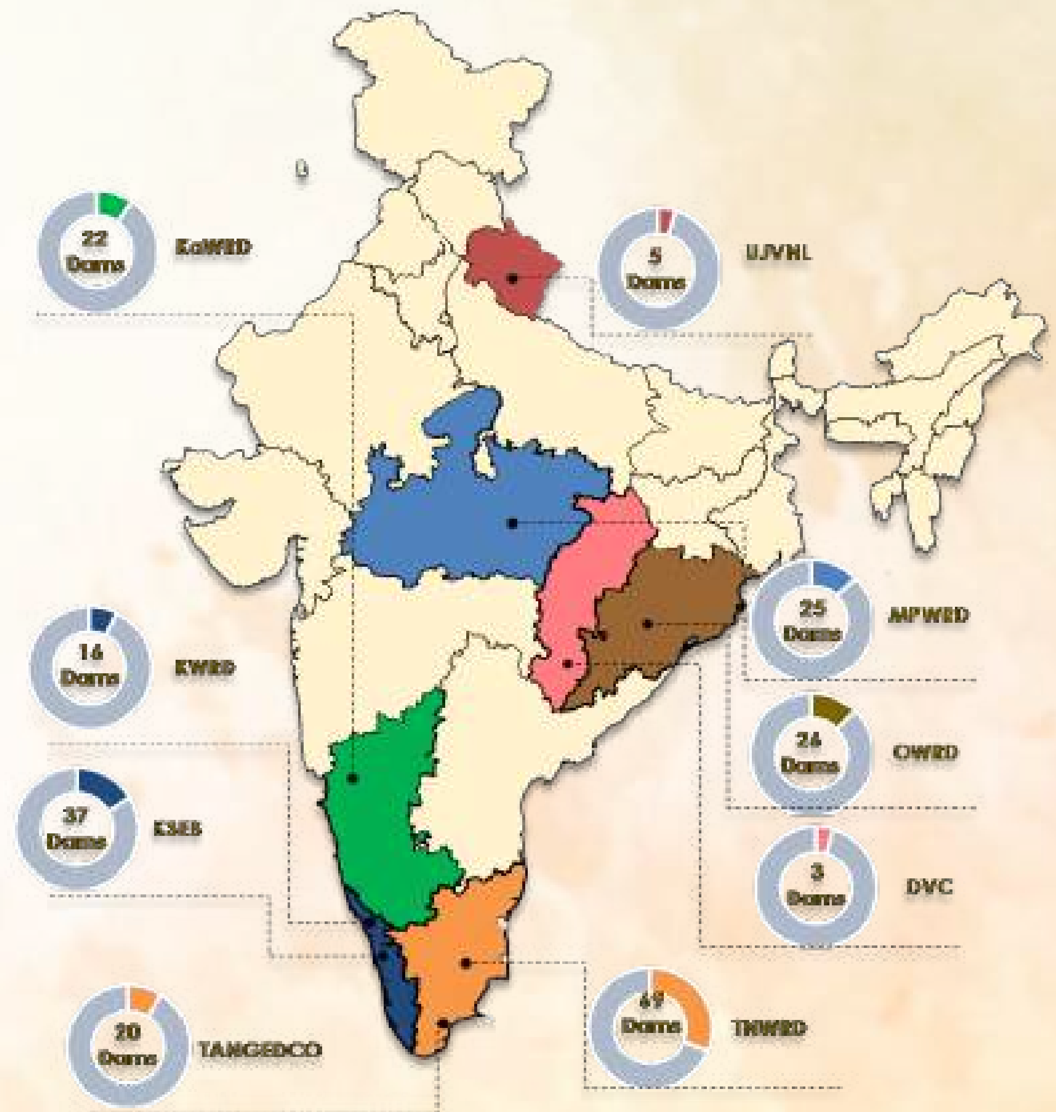
DAM SAFETY ASSURANCE AND REHABILITATION PROJECT (DSARP)

The Dam Safety Assurance & Rehabilitation Project (DSARP) assisted by the World Bank was implemented in four States of the Indian Union, namely Madhya Pradesh, Orissa, Rajasthan and Tamil Nadu, under overall guidance of CWC during the period 1991 to 1999 at a cost of Rupees 422.95 Crore. The objectives of the project were to improve the safety of selected dams in the project states through physical rehabilitation works, install basic dam safety-related facilities and strengthen the institutional strength and capacity building of the SDSO in project implanting states and CWC to have optimum level of dam safety assurance.

Institutional set-up at the Centre in CWC as well as in the four participating States was strengthened through training of officers, purchase & installation of modern equipments etc. Formulation and use of a number of guidelines on dam safety, and preparation of Probable Maximum Precipitation (PMP) Atlases by CWC with assistance from the implementing agencies and dam owners, have been the most significant and unique achievements of the project. In 33 dams remedial measures were completed under this project and they have come up to the desired safety level, reducing the risk and adverse environmental impact on the property and people living downstream.

DAM REHABILITATION AND IMPROVEMENT PROJECT (DRIP)

1. Dam Rehabilitation and Improvement Project (DRIP) was implemented during April 2012 to March 2021. Government of



India with financial assistance from the World Bank implemented phase I of DRIP with rehabilitation of 223 dams located in 7 States (namely Jharkhand, Karnataka, Kerala, Madhya Pradesh, Odisha, Tamil Nadu, and Uttarakhand) with 10 Implementing Agencies on board. The overall coordination and supervision was entrusted to CWC. The financial outlay of the Scheme was originally Rs. 2100 crore. The final completion cost of the scheme was Rs. 2567 crore. The main objective of the scheme was to improve the safety and operational performance of selected dams in the territory of the Participating states with emphasis on institutional strengthening by system wide management approach.

2. The major activities include Design Flood Review, Inspection by Dam Safety Review Panel, preparation of rehabilitation plans for 223 dams, physical rehabilitation to address hydrological, structural and operational safety of selected dams, development of technical regulations and protocols to ensure standardization and uniformity in dam safety practices across the country, development and implementation of web based tool called Dam Health and Rehabilitation Monitoring Application (DHARMA), development of dam specific technical documents viz. Emergency Action Plan (EAP) as well as Operation and Maintenance(O&M) Manuals, Stakeholder Consultation program for disaster resilient dams and communities, capacity building of all DRIP agencies and eight Academic Institutions and two central agencies, annual Dam Safety Conferences etc.

3. **Publication of Guidelines/Manual:** To ensure uniformity and standardisation of various procedures across the country, timely and quality guidance to dam owners 13 important guidelines/ manuals were published.

Racking & pointing of upstream face with UV resistant, high strength crystalline technology including underwater (Malaprabha dam, KaWRD)

Repair of spillway glacis and energy dissipator with M90 concrete (Maneri Dam, UJVNL)

4. **Emergency Preparedness:** "Guidelines for Developing Emergency Action Plans for Dams" which was published in year 2016. Based on this document, 223 dam break analyses were carried out and flood inundation maps prepared. Also, dam specific Emergency Action Plan have been published for 217 dams by various partner Implementing Agencies/States.

5. **Operation & Maintenance of dams:** Appropriate operation and proper maintenance are critical in controlling ageing process of a dam, increasing its service life, as well as mitigate associated risks. A total of 221 O&M manuals were published during the scheme.

6. **National/International Trainings:** Under the project, about 5400 personnel (DRIP-4268, Non DRIP-1174) participated in 186 National training programs. Five (5) international training programs were also organized during 2016 to 2019 wherein 101 officers participated.

7. **National Dam Safety Conferences:** Three numbers of National Dam Safety conferences and one number of International Dam Safety conference was organised during 2016 to 2019.

8. **Instrumentation and Monitoring:** The Scheme proposed Dam Instrumentation and Monitoring by providing Geodetic, Seismic, Hydro-meteorological, and Geotechnical instruments on need basis for scientific monitoring of comprehensive safety evaluation as well as integrated reservoir operations at 118 dams.

Upstream face Geo-membrane (Servalar dam, TANGEDCO)

Dam body grouting with mix of cement, micro-silica (Almatti Dam, KaWRD)

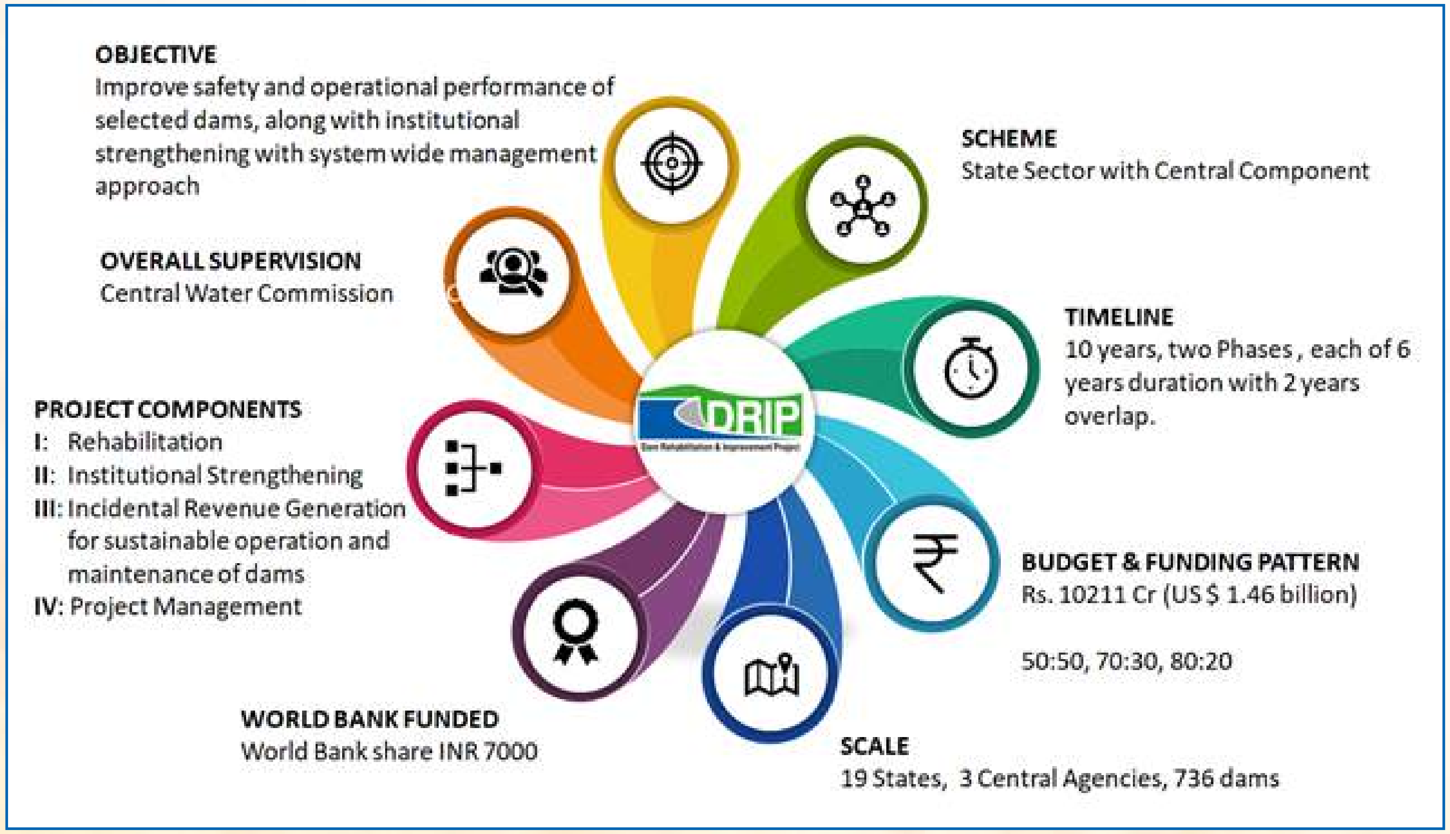
DAM REHABILITATION AND IMPROVEMENT PROJECT PHASE II AND PHASE III

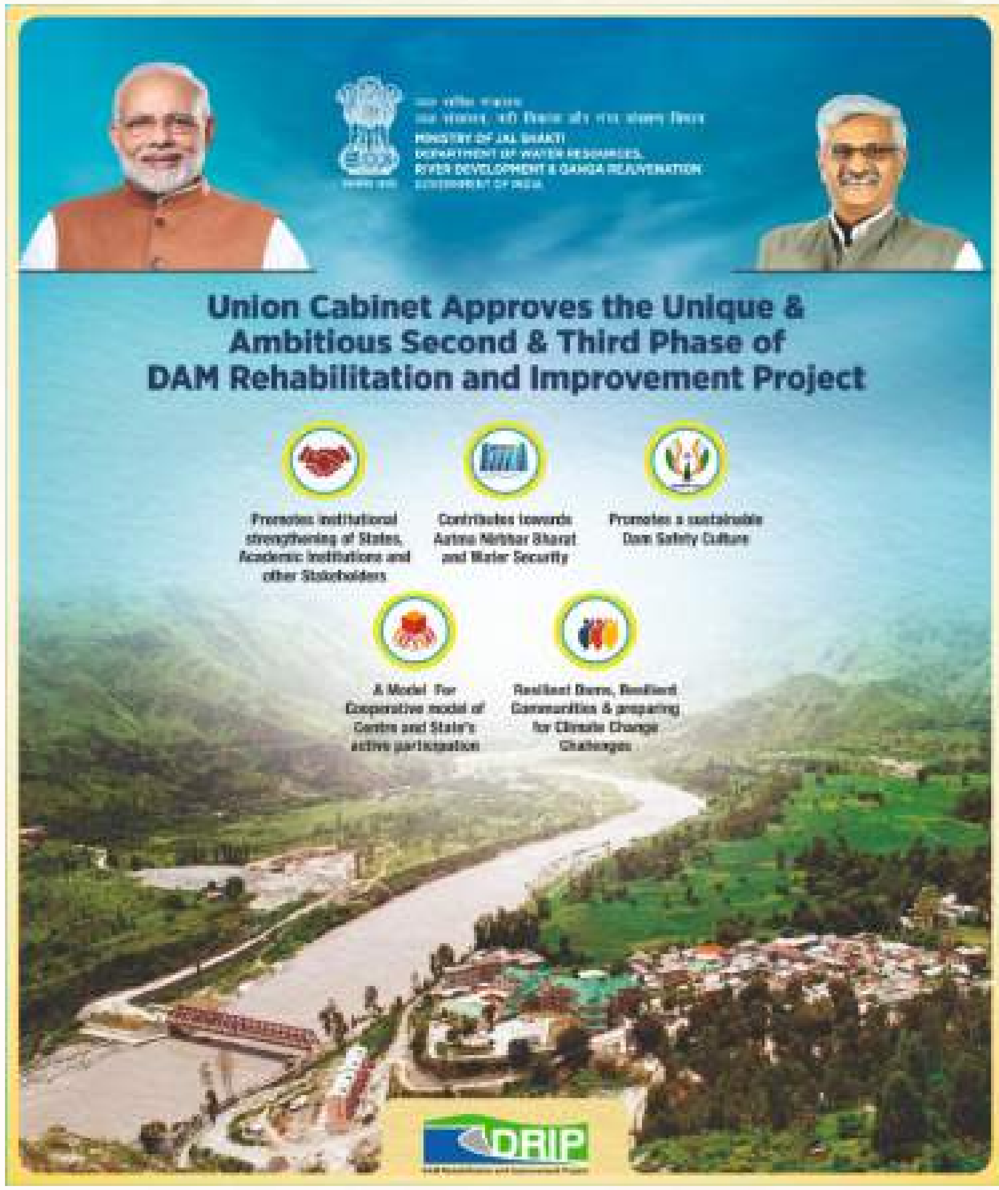
a) **Brief Background:** Based on the success of DRIP, the Union Cabinet approved the phase-II and III of the DRIP scheme on October 29, 2020. DEA granted the approval to both the phases subject to ceiling of INR 5000 Crore/USD 500 million (1 USD= INR 70) for each phase.

b) Loan Negotiation with World Bank for US$ 250 M was held on November 10, 2020, wherein 10 States and CWC participated. The Scheme has flexibility for inclusion of States as and when they meet the Bank's and DEA's Project Readiness Conditions. Five Additional States (Andhra Pradesh, Karnataka, Uttar Pradesh, Uttarakhand, West Bengal) were recommended by Ministry for inclusion in December 2020. The World Bank appraised the readiness conditions of these States in September 2021 and has considered inclusion of four States only except Andhra Pradesh.

c) **Scale:** 19 States and 3 Central Agencies- Andhra Pradesh, Chhattisgarh, Goa, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand, West Bengal; Central Water Commission, Bhakra Beas Management Board, and Damodar Valley Corporation. The Scheme has provision for rehabilitation of 736 dams.

d) **Timelines:** The Scheme is 10 years duration, proposed to be implemented in two Phases, each of six year duration with two years overlapping.





e) **Cost and Funding:** The budget outlay is Rs. 10,211 Cr (Phase II: Rs. 5107 Cr; Phase III: Rs. 5104 Cr). The external loan assistance is Rs. 7000 Cr (US$ 1 Billion) and balanced Rs. 3211 Cr is counterpart funding to be borne by concerned Implementing Agencies. The loan for Phase II and Phase III is US$ 500 M each.

f) **Funding Pattern:** It is 80:20(Special Category States), 70:30(General Category States) and 50:50(Central Agencies). State Sector Scheme with back to back loan arrangement. It also has provision of Central Grant of 90% of loan amount for special category States (Manipur, Meghalaya and Uttarakhand).

g) **Project Components:** (i) Rehabilitation of dams and associated appurtenances to improve the safety and operational performance of selected existing dams and associated appurtenances in a sustainable manner, and (ii) Dam safety Institutional Strengthening to strengthen the dam safety institutional setup in participating States as well as on a Central level, (iii) Incidental Revenue Generation for sustainable operation and maintenance of dams, and (iv) Project Management.

h) **DRIP Phase II Status:** Co-financed by two multi-lateral funding Agencies - World Bank and Asian Infrastructure Investment Bank (AIIB), with funding of US$ 250 million each. The Loan Signing with World Bank(US$ 250 M) was held in August, 2021 in which 10 States (Gujarat, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Rajasthan, Odisha, Tamil Nadu, Chhattisgarh) participated. The Phase II has been declared effective by the World Bank in October 2021. Loan Negotiations for another US$ 250 million with AIIB held on February 17, 2022.

i) **Scheme Progress:** The preparatory activities including Design Flood Review, Inspection by Dam Safety Review Panel, preparation of Project Screening Template and its approval by World Bank, publication of tenders and its award, preparation and finalisation of dam specific Environment Social Due Diligence (ESDD) and Environment and Social Management Plan (ESMP) etc are already in full swing. So far, DFR of221dams, DSRP Inspection of 212dams, PST of 164 dams costing Rs 5136 Cr; ESDD (88 Nos) and ESMPs (79 Nos) have been prepared. The tenders amounting to Rs. 2085 Cr has been published. The contract(s) for Rs. 850 Cr has been awarded.

NATIONAL REGISTER OF LARGE DAMS

Dam Safety Organisation, CWC compiles and maintains nation-wide register of large dams based on input provided by dam owners, which contains salient features including information on age, height, storage capacity of the reservoir, spillway capacities which are essential data for a meaningful inspection of large dams. The first publication titled "National Register of Large Dams" was brought out in April, 1990. Now data for 5745 dams spread over the country has been compiled up to June 2019 and brought out in this publication with major additions, alterations/corrections and updating of information. NRLD 2019 was released by Chairman, CWC on 27th June 2019, which can be viewed at http://cwc.gov.in/publication/nrld

STATE-WISE DISTRIBUTION OF CONSTRUCTED LARGE DAMS IN INDIA Total No. of Constructed dams = 5334

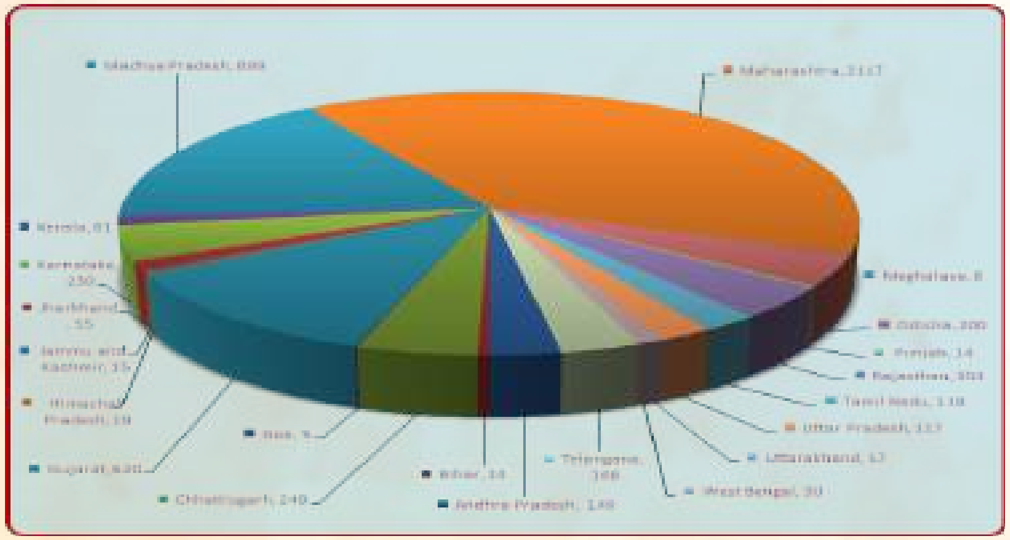


Fig. 1: *Other States includes: Andaman and Nicobar Island (2), Arunanchal Pradesh (1), Haryana (1), Manipur (3), Mizoram (1) Nagaland (1), Sikkim (2), Tripura (1), Assam (3)

STATE-WISE DISTRIBUTION OF UNDER-CONSTRUCTION LARGE DAMS IN INDIA Total No. of Under-Construction dams = 411

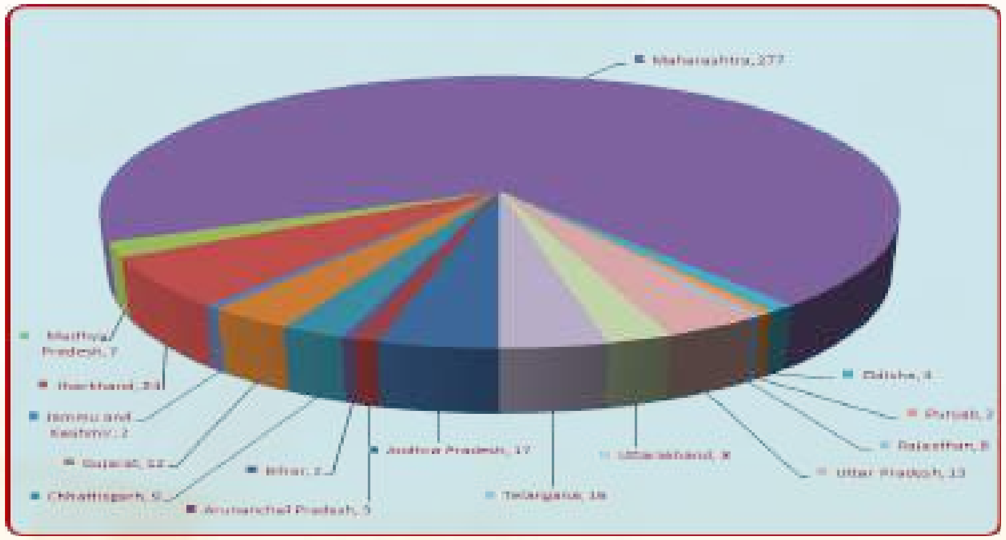


Fig. 2: *Other States includes: Assam (1), Himachal Pradesh (1), Karnataka (2), Manipur (1) and Meghalaya (2)

Large Dams older than 125 years (as on 1.1.2022)

Sr No	Name of Dam	Year of Completion	Sr No	Name of Dam	Year of Completion	Sr No	Name of Dam	Year of Completion
1	Thonnur Tank	1000	27	Mhaswa	1880	53	Periyar	1895
2	Cumbhum	1500	28	Panelia	1882	54	Tekanpur	1895
3	Swaroop Sagar	1560	29	Revania	1882	55	Hesaraghatta Reservoir	1896
4	Udai Sagar	1585	30	Rankala	1883	56	Sarra	1896
5	Dhamapur	1600	31	Ashti	1883	57	Soroda	1896
6	Rajsamand	1676	32	Kalakh Sagar	1883	58	Large Tank, Kachapur	1896
7	Barwa Sagar	1694	33	Parsul	1884	59	Baretha Bund	1897
8	Magar Pur	1694	34	Shanimandal	1885	60	Large Tank, Kamareddy	1897
9	Pachwara Lake	1694	35	Parichha	1886			
10	Jai Samand	1730	36	Mhaswad	1887			
11	Jagannathasagar	1781	37	Tordi Sagar	1887			
12	Rushi	1800	38	Madho Sagar	1887			
13	Mudana	1800	39	Kottur Tank	1888			
14	Kalapvihir	1800	40	Nher	1889			
15	Vihar	1860	41	Fateh Sagar	1889			
16	Hingonia	1862	42	Buchara	1889			
17	Bhadhaka	1868	43	Jaswant Sagar	1889			
18	Ambazari	1870	44	Shanigram	1891			
19	Ekrukh	1871	45	Ajwa	1892			
20	Mayani	1872	46	Boranakanive Tank	1892			
21	Mukti	1873	47	Bhatodi	1892			
22	Kharagpur Lake	1876	48	Tansa	1892			
23	Kharad	1877	49	Peddamallareddy (Tank)	1892			
24	Shirsufal	1879	50	Bhanjanagar	1894			
25	Tulshi	1879	51	Chaparwara	1894			
26	Khadakwasla	1880	52	Maidal Amanikere Tank	1895			

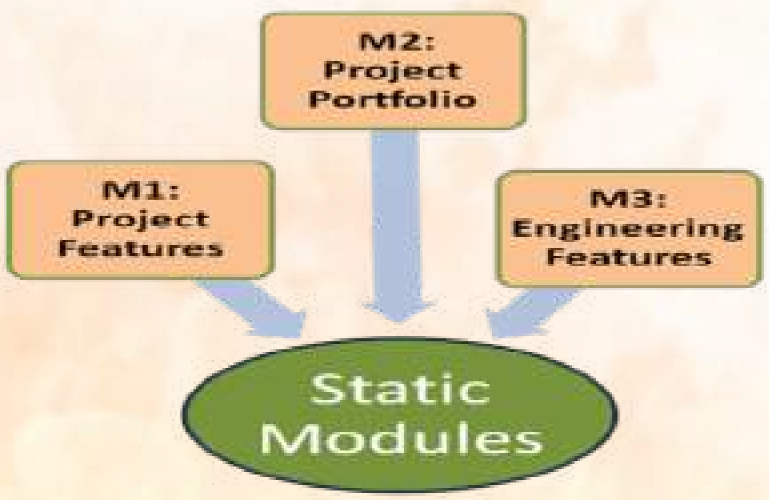
DAM HEALTH AND REHABILITATION MONITORING APPLICATION

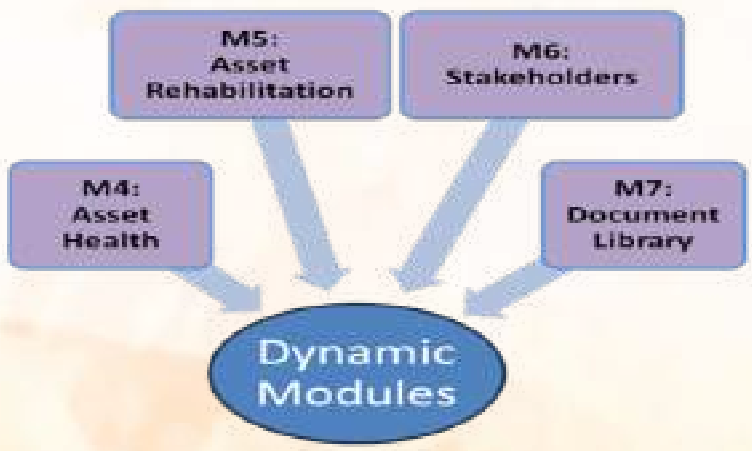
Dam Health and Rehabilitation Monitoring Application (DHARMA), is a web-based asset management tool to support the effective collection and management of authentic asset and health data for all large dams in India conceived & developed by the Central Water Commission, which is functional now. This is a step towards application of Artificial Intelligence (AI) in dam safety to smartly manage our existing water assets. This tool has various levels of access at Central and State Levels. Also, some common information is available in public domain.

DHARMA is a step towards rational assessment of health status of existing dams, firm up appropriate maintenance and rehabilitation measures for ensuring the safety of these large dams at state as well as National level. Among the key objectives of DHARMA include ensure completeness of information, bring stakeholders together, assess soundness of dam health, and effectively manage asset inventory.

It comprises of 7 modules namely: Project Features(Salient features of the dam project); Project Portfolio(Components parts of the project); Engineering Features(Technical information for each component); Asset Health(Inspection, Investigation, Instrumentation data); Asset Rehabilitation(Details of rehabilitation works); Stakeholders(Details of owner, operator, suppliers, contractors); and Document Library (Uploading, archiving of documents and drawings).

DHARMA was launched in January 2018. There has been good progress in the implementation of DHARMA, with more than 1000 Dam Data Managers and Dam Health Engineers who together have entered the data pertaining to approximately 1500 dams in DHARMA. Preliminary information available in National Register of Large Dams data for about 5,745 dams has been transferred into DHARMA. A total of 31 training programs have been conducted in various states in India to provide hands-on training for entering data into DHARMA and over 1100 dam officials have been trained. Licenses have been given to 27 implementing agencies in 18 states to use DHARMA.

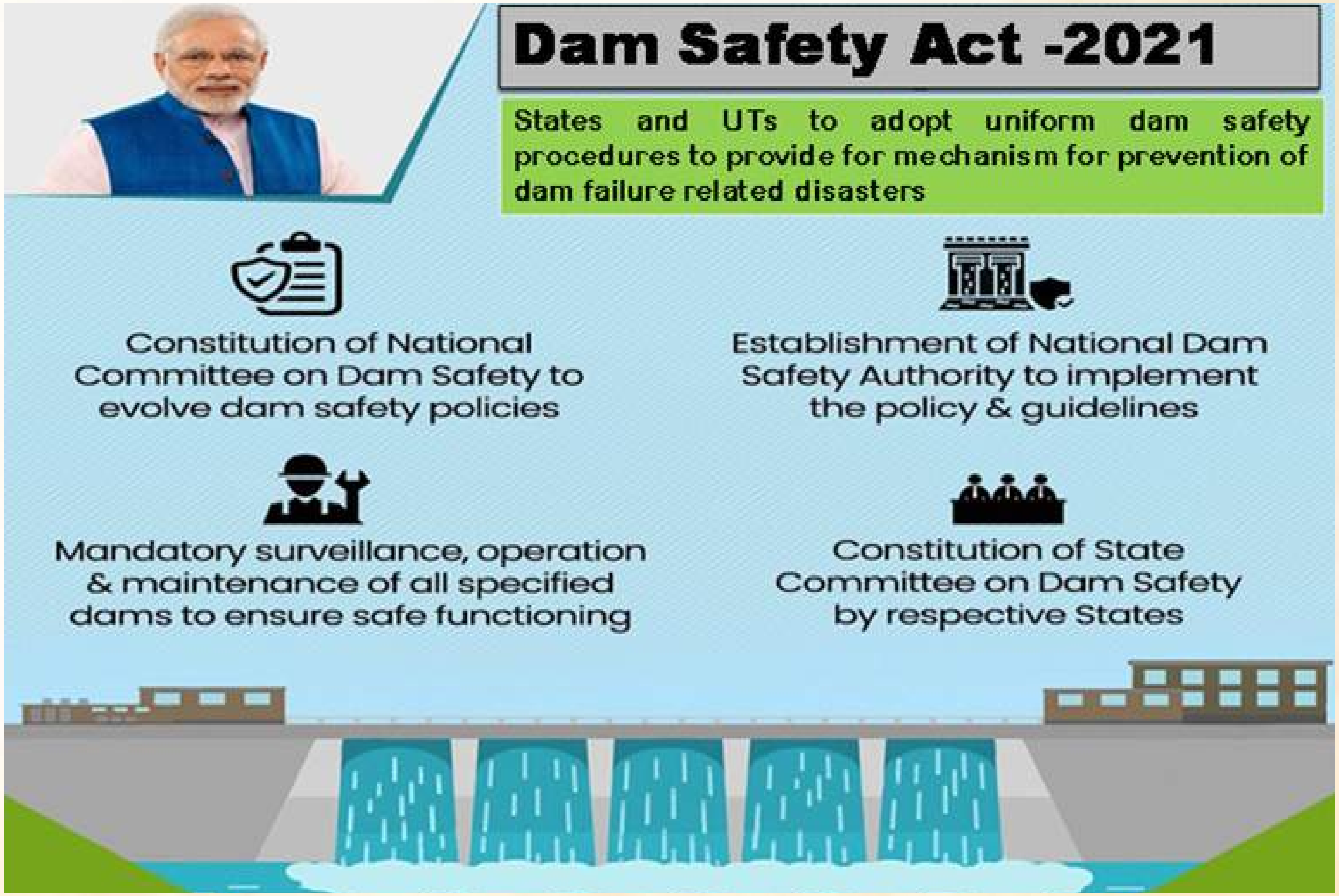




DAM SAFETY ACT, 2021

The Dam Safety Act, 2021 has been enacted by the Parliament and notified in the Gazette of India by Ministry of Law and Justice (Legislative Department) as The Dam Safety Act, 2021 No.41 OF 2021 on 14th Dec 2021; and vide MoJS, DoWR, RD & GR Gazette Notification-S.O. 5422(E) dated 28th Dec 2021 the Central Government appointed 30th Dec 2021 as the date on which the provisions of the said Act shall come into force.

The Government of India, keeping the importance of safety of dams, constituted a Standing Committee in the year 1982 to review the existing practices and to evolve unified procedure for safety of dams in India. The Standing Committee in its report dated the 10th July, 1986 recommended for unified dam safety procedure for all dams in India and the necessary legislation on dam safety. In accordance with the recommendations of the Standing Committee a comprehensive Draft Dam Safety Bill was prepared in 2002 and circulated to the State Governments for comments. The States responded well to the draft Bill. The Government of Bihar enacted the Dam Safety Act, 2006 in line with the draft Bill circulated by the Ministry. The Andhra Pradesh Legislative Assembly adopted a Resolution on 24th March 2007 that Dam Safety legislation should be regulated in the State of Andhra Pradesh by an Act of Parliament. The West Bengal Legislative Assembly also passed a Resolution on 24th July,



2007 empowering the Parliament to pass the necessary Dam Safety Act. The initial efforts were directed towards enactment of State level dam safety legislation by the respective state Governments. The efforts for Central Dam Safety legislation could commence only after the receipt of requests from these two state governments.

The Dam safety Bill was accordingly finalised by the then Ministry of Water Resources after inter –ministerial consultations. After the requisite inter-ministerial consultation on the draft Cabinet Note circulated by Ministry of Water Resources in October 2009, the proposal for enactment of dam safety legislation was approved by the Cabinet on 13th May, 2010. The Bill was tabled before the parliament on the 30th August, 2010, and was subsequently referred to the Parliamentary Standing Committee on Water Resources for examination. The Parliamentary

Fig. 3: Hon'ble Minister for Jal Shakti presenting Dam Safety Bill in the Parliament

Standing Committee submitted its recommendations in its Seventh Report on Dam Safety Bill, 2010 in the Parliament, and the same were referred to Government of India by the Lok Sabha Secretariat. Owing to significant modifications entailed in the Bill while complying with the recommendations of the Parliamentary Standing Committee, the Ministry of Water resources decided to withdraw the Bill and introduced a new Bill in the Parliament.

The Dam Safety Bill, 2018 was prepared for coverage across whole of India incorporating the recommendations of the Parliamentary Standing Committee. However, with dissolution of the Sixteenth Lok Sabha, the Dam Safety Bill, 2018 lapsed. Hence, the present Bill, namely the Dam Safety Bill, 2019 was passed by Lok Sabha on August 2, 2019 and by Rajya Sabha on 2nd Dec 2021 which has been published in the Gazette dated 14th Dec 2021 as the Dam Safety Act, 2021.

In brief the important provisions provided in the aforesaid Act are as follows—

a) constitution of the National Committee on Dam Safety (NCDS) to discharge functions to prevent dam failure related disasters and to maintain standards of dam safety and it shall evolve dam safety policies and recommend necessary regulations as may be required for that purpose;

b) establishment of the National Dam Safety Authority (NDSA) as a regulatory body to implement the policy, guidelines and standards for proper surveillance, inspection and maintenance of specified dams and address unresolved points of issues between the State Dam Safety Organisation of two States, or between the State Dam Safety Organisation of a State and the owner of a dam in that State, and in certain cases, such as dams extending in two or more States or dams of one State falling under the territories of another State. It shall also perform the role of State Dam Safety Organisation thereby eliminating potential causes for inter-State conflicts;

Fig. 4: 2nd December, 2021-Hon'ble Minister alongwith officers of Ministry of Jal Shakti

c) constitution of the State Committee on Dam Safety by the State Governments to ensure proper surveillance, inspection, operation and maintenance of all specified dams in that State and ensure their safe functioning;

d) establishment of the State Dam Safety Organisation in States having specified dams which will be manned by officers with sufficient experience in the field of safety of dams;

e) an obligation upon every owner of a specified dam to establish operational and maintenance set up to ensure continued safety of such dams, to earmark sufficient and specific funds for maintenance and repairs of the dams, for undertaking pre-monsoon and post-monsoon inspections and special inspections during and after floods, earthquakes, etc., to carry out risk assessment studies at such intervals as specified by the National Committee on Dam Safety;

f) an obligation upon the concerned State Dam Safety Organisation to keep perpetual surveillance, carry out inspections and monitor the operation and maintenance of specified dams under its jurisdiction to ensure their safety; and to classify each dam under their jurisdiction as per the vulnerability and hazard classification in accordance with the regulations;

g) an obligation upon the National Dam Safety Authority to forward its Annual Report to the Parliament and the National Disaster Management Authority and the State Dam Safety Organisation to forward their Annual Reports on safety status of dams to the concerned State Legislative and State Disaster Management Authority.

h) Functions of the National bodies and the State Committees on Dam Safety have been provided in Schedules to the Bill. These Schedules can be amended by a government notification.

i) An offence under the Bill can lead to imprisonment of up to two years, or a fine, or both, on a complaint by NCDS/NDSA/SCDS/SDSO.

The Ministry of Jal Shakti vide Gazette Notification-S.O. 757(E) dated 17th February, 2022 has notified the constitution of National Committee of Dam Safety (NCDS) and vide Notification S.O. 758(E) established the National Dam Safety Authority (NDSA). Further, vide Ministry of Jal Shakti Notification in Gazette of India dated 17th February, 2022-G.S.R. 134(E): National Committee on Dam Safety (Procedures, Allowance and other Expenditure) Rules, 2022; and G.S.R. 135(E) National Dam Safety Authority (Functions and Powers) Rules, 2022 have also been notified. Both the Committee and Authority shall come into force wef 18th February 2022. On the similar lines, as per the provisions in the Dam Safety Act, 2021, the State Governments also have to constitute a State Committee on Dam Safety (SCDS) & State Dam Safety Organisation (SDSO) within a period of 180 days from the date of commencement of this Act.

Accordingly, States have Constituted State Committee on Dam Safety and have also established state Dam. Safety organisation as per the provision of Dam Safety Act, 2021.

Vide OM No.N-52011/2/2021-BM/PR dated 04/04/2022, DoWR, RD & GR, GoI, has established the NDSA on additional Charge basis headed by the Member, D&R, CWC with four Chief Engineers of CWC and JS&FA, MoJS as Members to carry out their mandated functions as per the provisions of Dam Safety Act 2021 till such time the RRs and regular staff for regular NDSA being finalized. At present the NDSA is functional on additional charge basis. To sensitize all the stake-holders about the provisions of Dam Safety Act, 2021, National Level workshop was organized on 16.6.2022. NCDS had its first meeting on 02.08.2022 and NDSA so far has held 2 meetings. Further in this regard NDSA has held two Regional Workshops at Coimbatore and Chandigarh and next two are scheduled to be held in Pune and Guwahati respectively.

Fig. 5: National Workshop on “Dam Safety Act, 2021 for Dam Safety Governance in India” held on 16th June, 2022

MULLA PERIYAR DAM –CASE STUDY

The Mullaperiyar Dam (MPD) is a masonry gravity dam constructed across the Periyar river in 1895, is situated in Thekkady District in Kerala. As per the lease agreement 1886 between Maharaja of Travancore and the Secretary of State for India in Council, the Dam is operated and maintained by Govt of Tamil Nadu under 999 years lease agreement signed on 29.11.1886 between the Maharaja of Travancore and the Secretary of State for India in Council.

Fig. 6: Mullaperiyar Dam

In 1979, in pursuance of the request from Kerala Government, the then Chairman, CWC inspected the dam and held a meeting on 25th November, 1979 with the officers of Kerala and Tamil Nadu. In that meeting three level measures, (i) emergency, (ii) medium term and (iii) long-term were suggested for strengthening the dam. It was recommended that, in the mean time, the water level in the reservoir be kept at 136 ft. A second meeting under the Chairmanship of Chairman, CWC was held on 29th April 1980 at New Delhi with officers of Kerala and Tamil Nadu and it was opined that after the completion of emergency and medium term measures, the water level in the reservoir can be restored upto 145 ft. However, no consensus could be reached between the two State Governments to raise the water level beyond136 ft. This led to the filing of number of writ petitions in the Kerala High Court as well as in the Madras High Court sometime in 1998 on the issue for and against raising of water level in the Mullaperiyar reservoir and the safety of the dam.

Hon'ble Minister (WR) convened an Inter-State meeting on 19.5.2000 but no consensus could be reached in the meeting as well, hence decided in the meeting, to constitute an Expert Committee under Member (D&R), CWC with representatives from both the States to study the safety of the dam. The Expert Committee gave its final report of 16th March, 2001. In its report, the Expert Committee had opined that water level in the Mullaperiyar reservoir could be raised to 142 ft. as that will not endanger the safety of the main dam, including spillway, baby dam and earthen bund. Further raising the water level to 152 ft. will be considered after balance strengthening measures are completed. Hon'ble Supreme Court delivered its orders on 27.2.2006, permitting the water level in the Mullaperiyar dam to be raised up to 142 ft.

Further, Hon'ble Supreme Court vide its order dated 18th February, 2010 constituted an Empowered Committee (EC) on Mulla Periyar Dam under the Chairmanship of Justice Dr. A.S. Anand, former Chief Justice of India to look into all the issues in relation to Mulla Periyar Dam. The EC in its report dt April 2012 concluded that as the existing Dam is found Hydrologically, Structurally and Seismically safe, the FRL may be raised from EL 136 ft to 142 ft. A new independent Expert Committee may look into the need of raising the FRL beyond 142 ft.

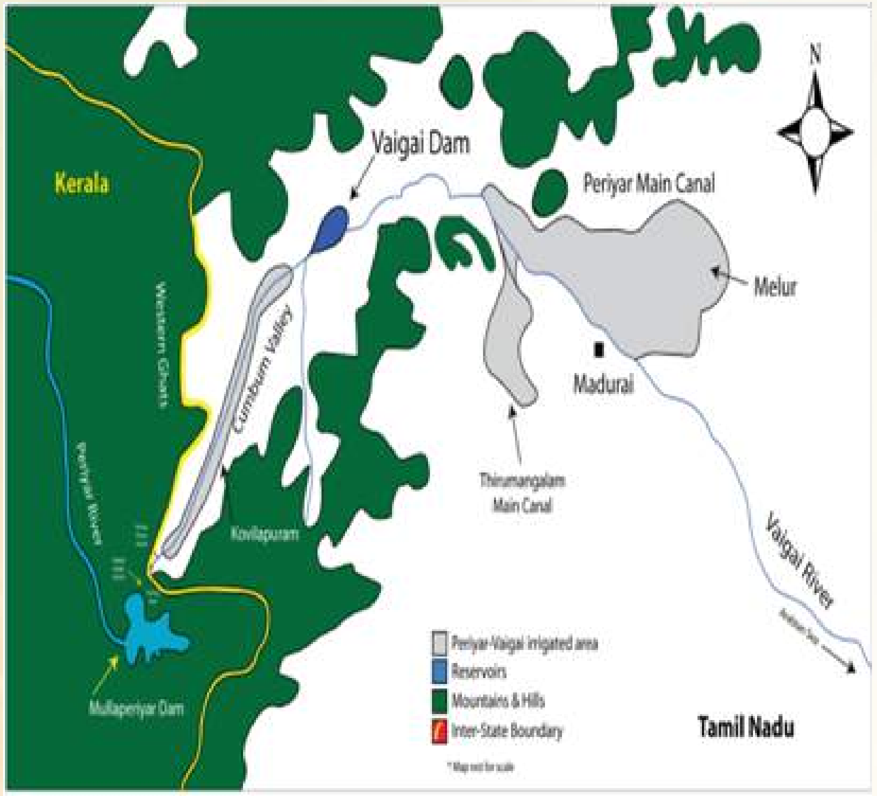


Fig. 7: Location of Mullaperiyar Dam

The Hon'ble Supreme Court in its Judgment of 07.05.2014, in the matter of Original Suit No. 3 of 2006 of India, held that the dam is safe and hence permitted to raise the reservoir water level upto 142 ft. Further on completion of balance strengthening works as per Hon'ble Court's judgment dated 27.2.2006 and on examination of the same by the independent experts, the water level is permitted to be raised upto 152 ft.

The Hon'ble Supreme Court in its judgment of 07.05.2014 also directed to constitute a Supervisory Committee to allay the apprehensions of Kerala- though none exists - about the safety of the Mullaperiyar dam. Accordingly the committee was constituted with Chief Engineer, Dam Safety Organisation, CWC as Chairman and Principal Secretary, PWD, Tamil Nadu and Additional Chief Secretary, WRD, Kerala as members. The Supervisory Committee has met and inspected the dam 14 times since the Supreme Court judgment of 2014. The last meeting was held in February, 2021. So far any sign of distress has not come or brought to the notice of the Committee.

Further under the directions of Hon'ble Supreme Court dated 11.01.2018, a Sub Committee headed by Secretary, MoWR, RD &GR under National Executive Committee (NEC) of National Disaster Management Authority (NDMA) to monitor the measures for ensuring high level of preparedness to face any disaster has been constituted. So, far four meetings of the sub-committee have been convened.

In the case of WP (C) 880 of 2020 and other connected matters, Hon'ble Supreme Court vide Order dated 08.04.2022 has directed to reconstitute the existing Supervisory Committee for the purpose of its strengthening.

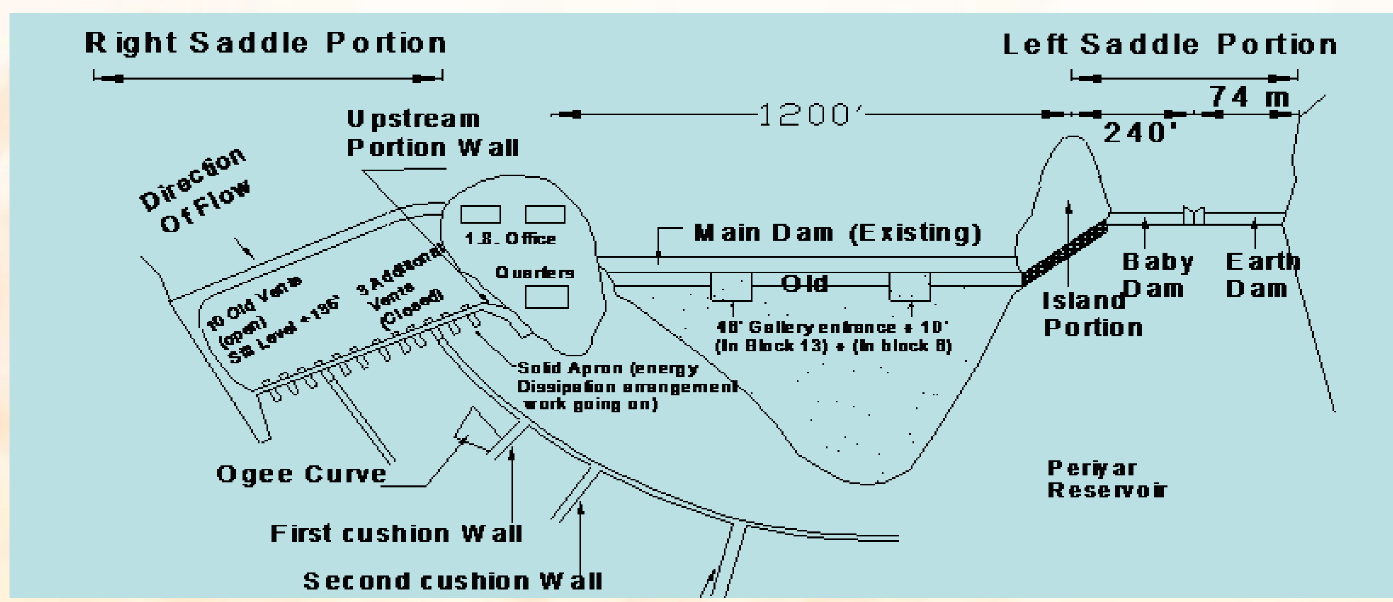


Fig. 8: General Layout of the Mullaperiyar Dam

The two technical experts have to be included as Members in the Supervisory Committee, one each from the State of Kerala and State of Tamil Nadu, who are well-versed in dam management, reservoir operation, instrumentation, etc. Further, Hon'ble Court has also directed that until the regular National Dam Safety Authority (NDSA) becomes functional in terms of Section 8 of the Dam Safety Act2021, till such time, the reconstituted Supervisory Committee would be in a position to discharge all the functions and also exercise all the powers which otherwise are required to be exercised by the NDSA for ensuring safety of the Mullaperiyar Dam, as also, prevention of dam failure related disasters. Accordingly, DoWR, RD &GR, MoJS vide OM dated 09.05.2022 has reconstituted the Supervisory Committee with the revised ToR as directed by the Hon'ble Supreme Court order dated 08.04.2022. The Supervisory Committee on MPD inspected the Mullaperiyar dam on 9th May 2022 along with new members nominated by the respective State Governments to the Supervisory Committee on MPD. The 15th meeting of the Supervisory Committee on Mullaperiyar Dam (MPD) was held on 6thJune, 2022, 16:00 hrs at CWC, New Delhi.


HOME / KERALA / GENERAL

Supervisory committee visits Mullaperiyar dam; report will be submitted to Supreme Court the next day

Tuesday 10 May, 2022 | 1:03 AM

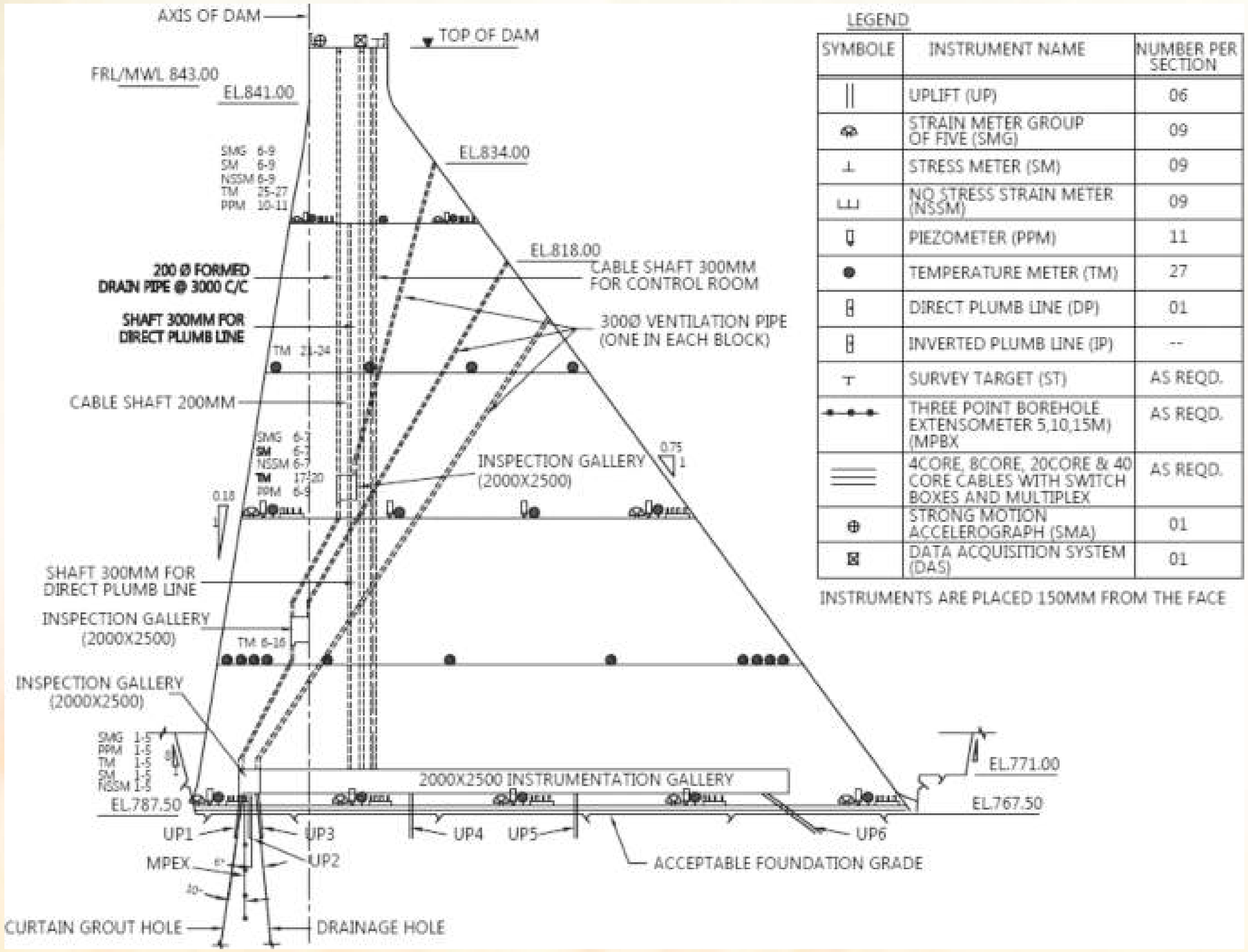

THE HINDU

Supreme Court-appointed supervisory committee visits Mullaperiyar dam

DAM INSTRUMENTATION

India has more than 5300 large dams, 80% of which are more than 25 years old. Their health and safety are of paramount importance for the sustainable use of these valuable national assets. The Central Water Commission (CWC) encourages and facilitates dam safety practices to reduce any risk to life and property from the consequences of potential dam failures.

Dam instrumentation plays a pivotal role providing an understanding of the foundation and structural behavior both during construction and operation of the dam. A monitoring program provides the information that is needed to develop a better understanding of the performance of the dam. Knowing that the dam is performing as expected is



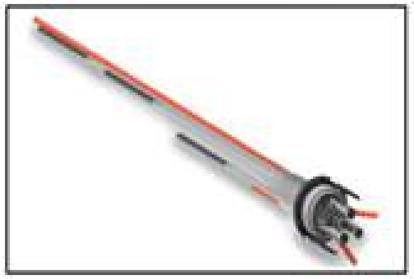
reassuring to dam owner and other stakeholders including the general public. The ability to detect a change in this performance is critical for the dam owner who is directly responsible for any consequences. With operational performance knowledge, dam owners will have the ability to operate and maintain their dams in a safe manner.

The Central water Commission had played an important role in planning and design of Instrumentation in the important large dams which have already been constructed or under construction in India and abroad.

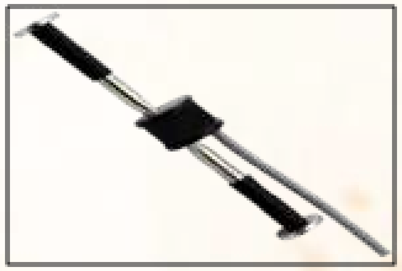
CWC officials under Dam Safety Organization (DSO) are entrusted in handling dam instrumentation activities such as - Technical examination of DPR with respect to instrumentation aspects; planning and preparation of instrumentation chapter/ drawings; Vetting of instrumentation drawings for projects under construction stage etc.

Recently, DPRs of Dugar H.E. Project (Himachal Pradesh), Dagmara H.E. Project (Bihar); Pinnapuram Standalone Pumped Storage Project in Andhra Pradesh; Lower Arun HEP Project (Nepal); Revised DPR of Transfer of Rajasthan share of Yamuna Water at Tajewala Headworks to Churu and Jhunjhunu districts of Rajasthan by Underground Conveyance System have been examined and cleared. Further, Instrumentation drawings of Polavaram Project, Isarda Dam, Rajasthan, Punatsanchhu –I HEP, Bhutan have also been vetted; and Instrumentation Chapter along with instrumentation drawings for two projects namely Rukni Irrigation Project and Sonai Irrigation Project of Assam have been prepared and submitted to project authorities.

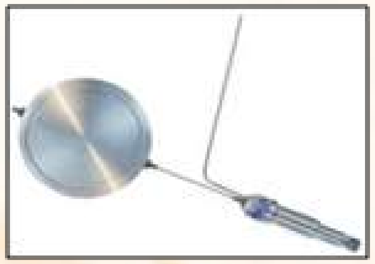
Normal Plumb line



Multipoint Borehole Extensometer



Strain Gauge (Vibrating Wire)

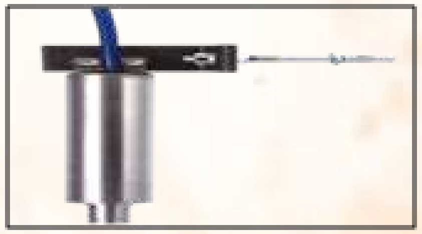


Pore Pressure Cell (Vibrating Wire)

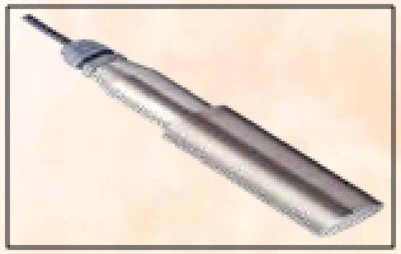
Strong Motion Accelerometer

Piezometer

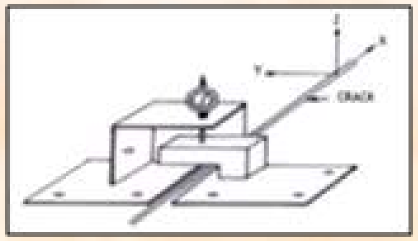
Joint meter



Tiltmeter



Temperature Gauge (Vibrating Wire)



3D Mechanical Crack meter

NATIONAL COMMITTEE ON SEISMIC DESIGN PARAMETERS (NCSDP)

Ministry of Water Resources had constituted a high level inter-disciplinary official body, the "National Committee on Seismic Design Parameters (NCSDP) for River Valley Projects" in 1991 (formerly known as Standing Committee) to recommend the site specific design seismic parameters for design of dams and other appurtenant structures of the river valley projects. Member D&R, CWC is the chairman and Director FE&SA is the Member Secretary of this committee. The first guidelines for **"Preparation and Submission of Site Specific Study Report of River Valley Project to NCSDP"** were published by FE & SA, CWC in October, 2011.

NCSDP deals with the following:

a) Recommending design co-efficient/dynamic analysis for proposals received from dam owners.

b) Seismic risk mapping.

c) Identify seismogenic sources and associated seismic potential.

d) To recommend attenuation relationships and derive Maximum Credible Earthquake (MCE).

e) Finalize recommendation on Controlling Maximum Credible Earthquake (CMCE).

f) Finalize recommendation on Design Base Earthquake (DBE).

g) Identify potential for fault rupture in the dam foundation or in the reservoir area.

h) To consider probability of Reservoir Induced Seismicity (RIS) and make appropriate recommendation for design parameters.

i) To decide seismic network and specification for seismic instruments.

j) To consider analysis of seismic data from such networks.

The site specific reports for determination of seismic parameters involve estimation of seismic parameters using the deterministic seismic hazard analysis (DSHA) method and the probabilistic seismic hazard analysis (PSHA) method.

The site specific seismic studies need to be carried out and submitted for the approval of NCSDP in respect of all such river valley project/dams that are classified under 'high' or 'extreme' hazard potential categories.

There are **36 meetings** held till now and **180 projects** had been cleared in these meetings.

The committee also approves the Micro Earthquake studies for Dams having height greater than 100 m.

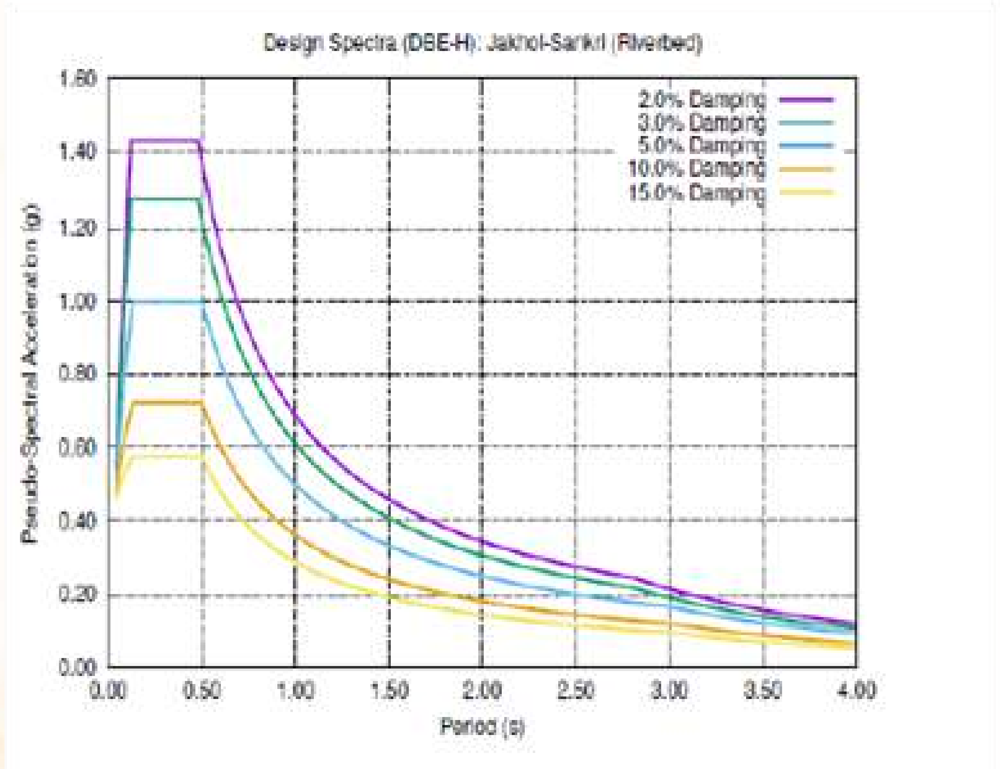


Fig. 9: Design Spectra for different damping ratios

Seismic Hazard Assessment Information System (SHAISYS) is web based interactive application tool being developed in CWC under Dam Safety Organization (DSO) to estimate the seismic hazard at any point in Indian region. The SHAISYS shall be capable of estimating seismic hazard using the deterministic as well as probabilistic approach. The software is under development by IIT Roorkee for South Indian Region and by CWPRS for North and North Eastern region, under institutional strengthening and capacity building for DRIP.

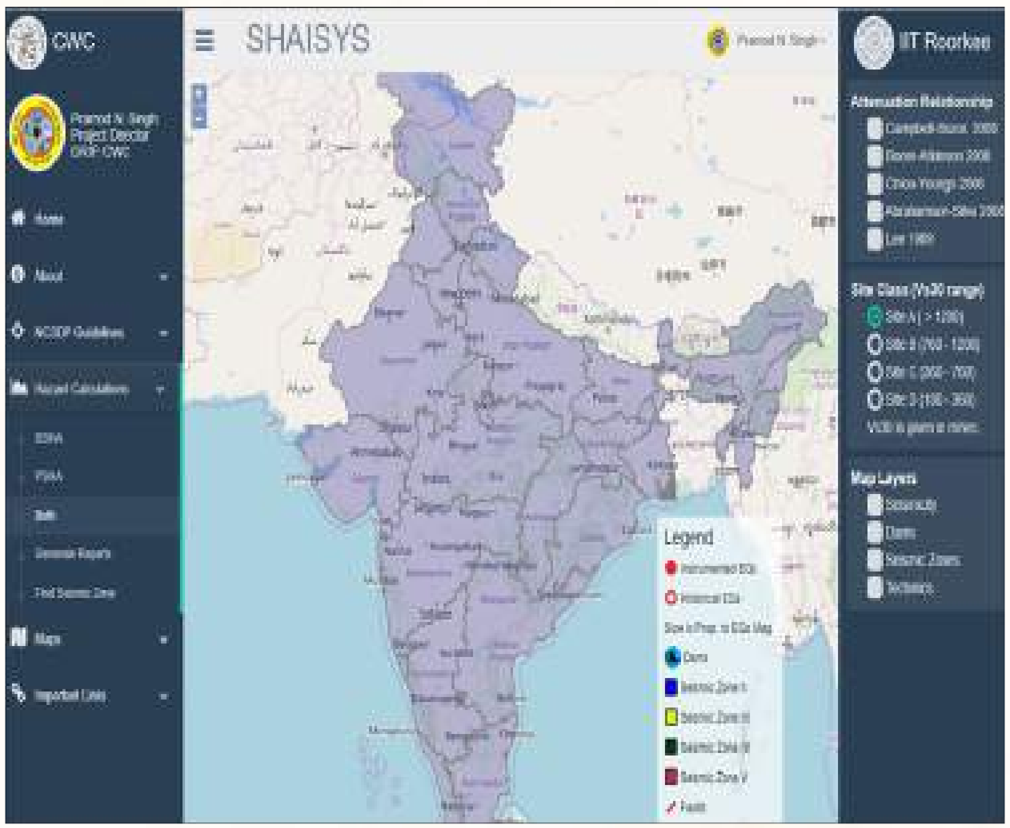


Fig. 10: Interface for Seismic Hazard Assessment Information System (SHAISYS)

OTHER SPECIAL STUDIES

CWC is also involved in following other special studies:

a) The Impact of floods, including floods due to breach of dam in the TAR region (if any such dam is proposed) with flood storage in Upper Siang Project and the effects of the same on reduction of flood discharge/ levels at CWC's G&D sites of Pasighat, Tezpur, Pandu and near India-Bangladesh Border.

b) The study on breach of artificial lakes created due to landslide events in year 2018, 70 km downstream of Nuksia in Tibet Autonomous Region (TAR) and their impact on downstream i.e Tuting, proposed Upper Siang project, Passighat and up to India Bangladesh Border.

c) CWC studied the landslide lake formed on a tributary of Rishiganga River. This new lake formation was the result of the debris back flow due to the disaster that took place in Rishiganga valley on 7 February, 2021 and the length of lake was about 350 m with a dam height of 60m.

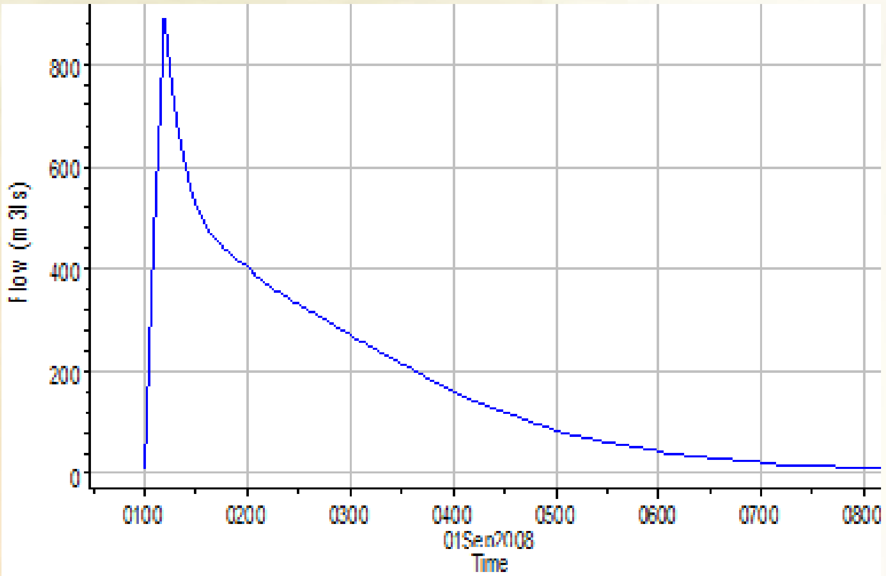
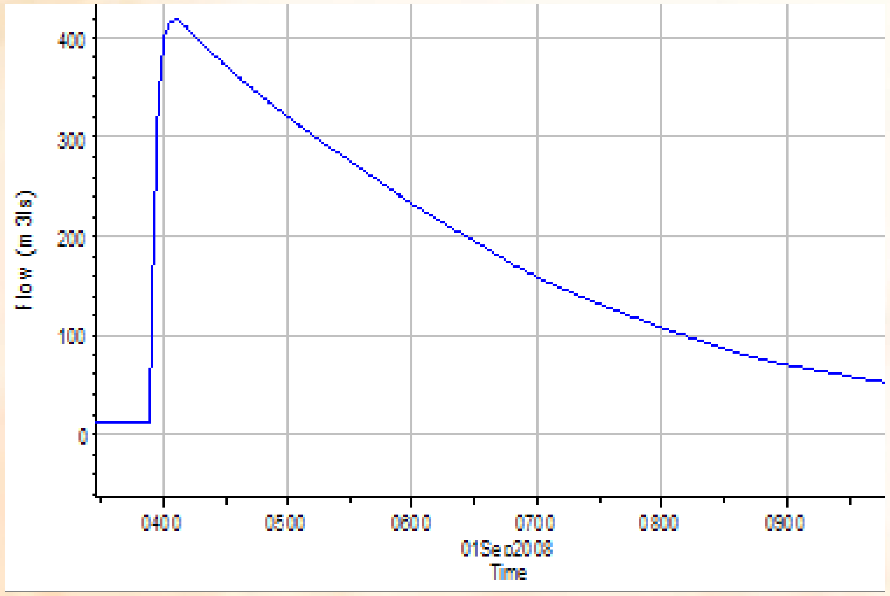


Fig. 11: Flood hydrograph just downstream of Landslide Lake



CWC observed maximum discharge of 891 cumec just downstream of lake in case of lake breach. This flash flood routed to 418 cumec at about 50 km downstream of lake and take around 2 hour 50 minutes. (Given time is only for reference purposes).

Dam Break Modelling

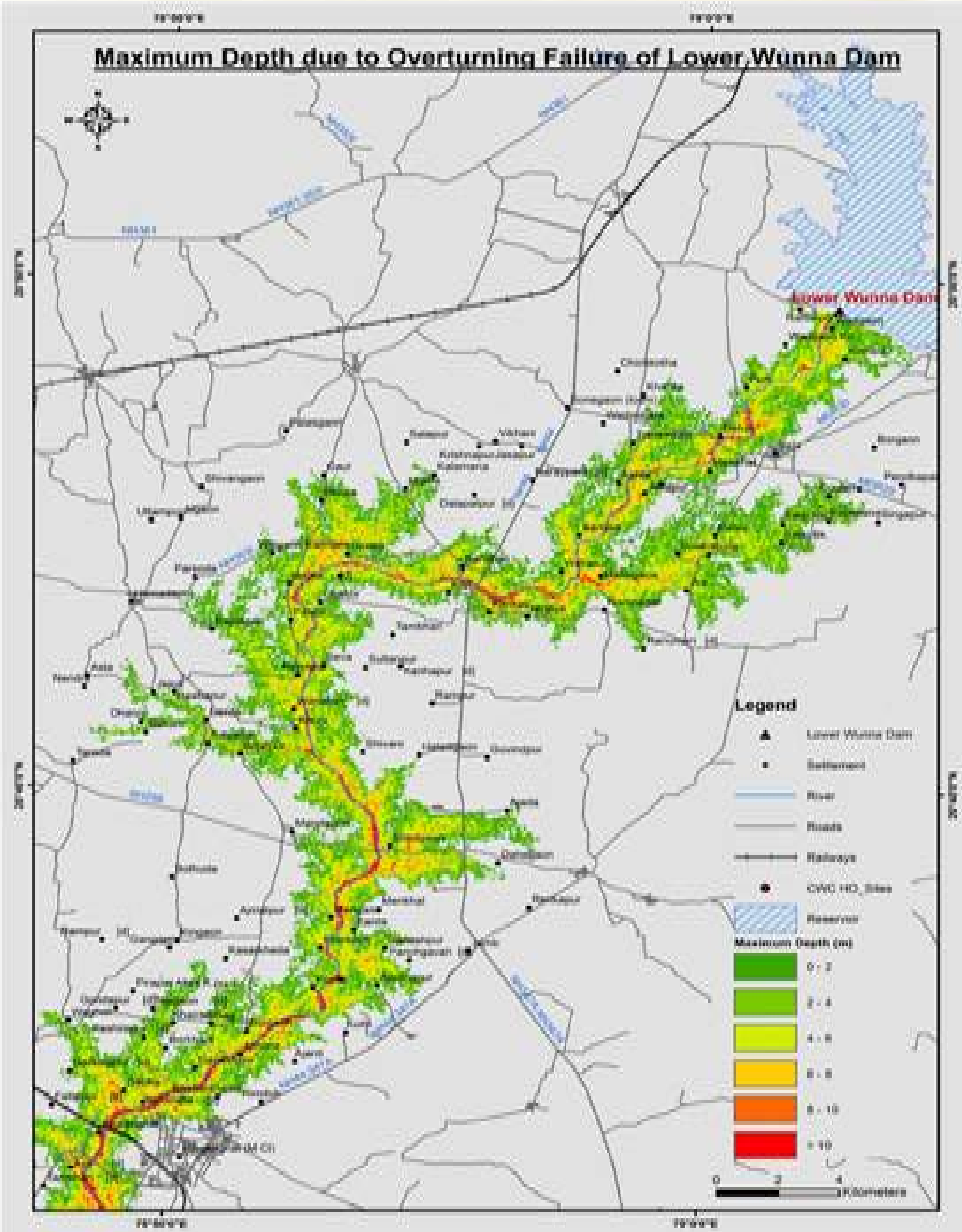
Dam Break Modeling is carried out to foresee the likely effects of high flood generated in case of a dam breach event in downstream catchment such as inundated area, flood depth, flood velocity and arrival time of flood waves. It further helps in preparing Emergency Action Plan (EAP) for evacuation of human population and to minimize the property loss in case of an unlikely event.

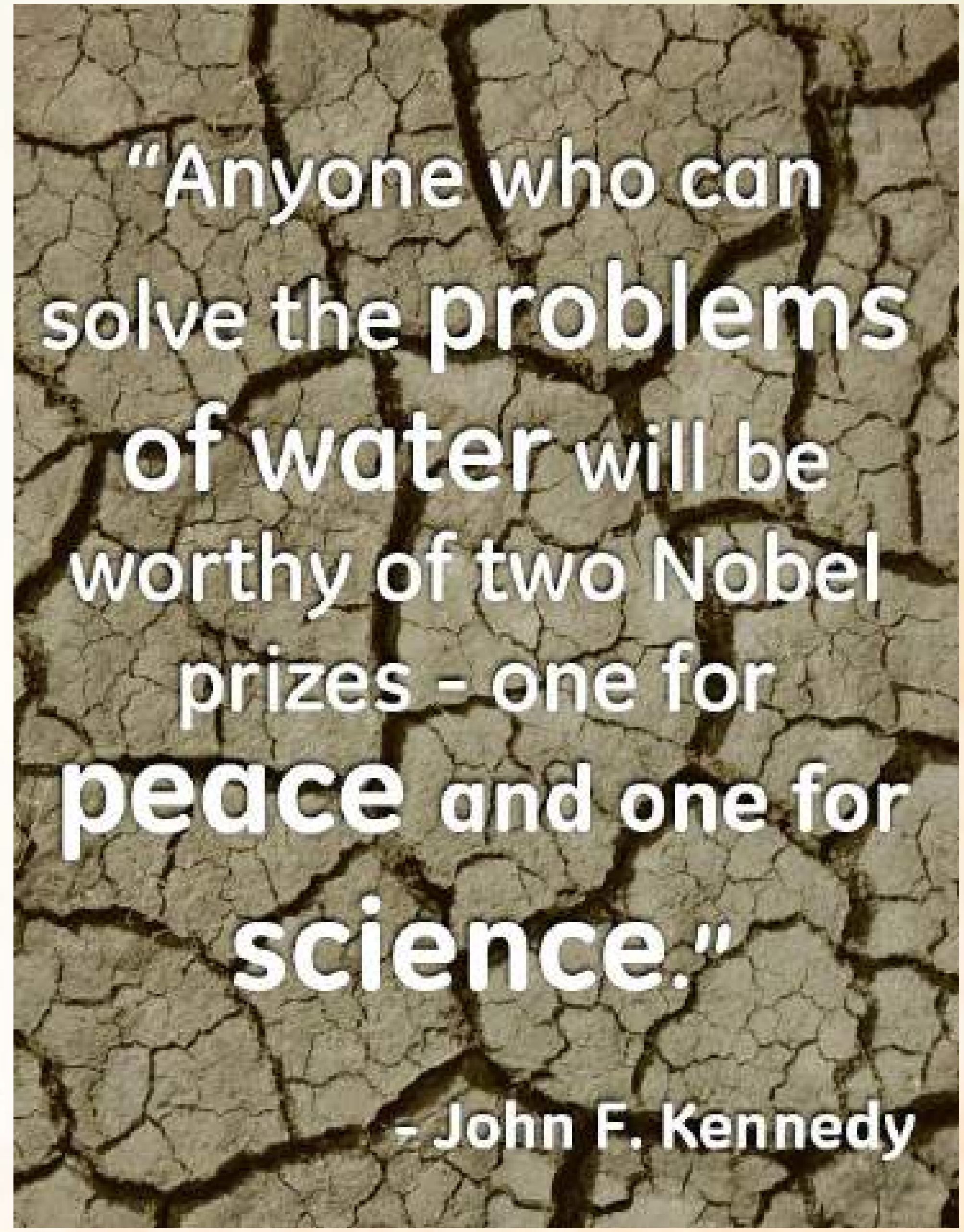
Methodology: Digital Elevation Model (DEM) and Land Use Land Cover (LULC) maps of the concerned area are used to generate simulation models. The simulation models can best be generated either in HEC-RAS or MIKE-11 software. Design flood hydrograph can be used as upstream boundary condition, while normal depth can be used as downstream boundary condition. Breach parameters can be calculated as per the formulae given in CWC guidelines.

After generating model, the model simulation is run as per the required conditions and various inundation maps for flood depth, velocity, water surface elevation and arrival time are generated.

CWC have successfully developed dam break models for 8 dams in recent times. The reports have been shared with concerned project authorities.

Figure shows inundation maps of maximum flood depth due to overtopping failure of Lower Wunna Dam (Maharashtra) for different settlements at downstream. Similar maps can also be generated for velocity, water surface elevation and arrival time.


Maximum Depth due to Overturning Failure of Lower Wunna Dam
Lower Wunna Dam
Legend
Kilometers


"Anyone who can solve the problems of water will be worthy of two Nobel prizes - one for peace and one for science."
- John F. Kennedy

6

Hydrological Observation Network of CWC– Transition Over the Years

- Hydrological Observation
- Evolution of H.O Network in CWC Over the Years (1950-2020)
- Basin wise distribution of 1543 H.O sites maintained by CWC

HYDROLOGY PROJECT

- Project Objective
- Project Highlight
- Project Overview
- Concept
- Project Components
- Implementation Arrangement
- Beneficiaries

SNOW HYDROLOGY STUDIES

- Early activities of Snow Hydrological Division includes establishment of :
- National extension of Snow Hydrology in Five Himalayan River basin
- Objectives

WATER QUALITY ACTIVITIES IN CENTRAL WATER COMMISSION

- Objectives of Water Quality Monitoring
- Water Quality Monitoring Network in CWC at Present
- Classification of Water Quality Monitoring Stations
- NABL accreditation of Water Quality Laboratories in CWC
- Important Publications
- Way forward in the field of Water Quality

Hydrological Observation Network of CWC–Transition Over the Years

Hydrological Observation

The National water resources are limited & unevenly distributed resulting in seasonal abundance, and even devastating floods in some areas, while large tracts in other regions are persistently drought affected. The above situations have been compounded with the apprehended Climate change, which calls for data collection on large scale to carryout climate change studies to help, find possible sustainable solutions. This erratic occurrence necessitates precise hydrological observations in rivers for the optimum planning of water resources projects and their subsequent operations.

Availability and accessibility of hydrological information is the basic requirement for development and management of water resources. Water scarcity is fast becoming a critical issue and climate change impacts will further intensify the water related problems spatially and temporally in India. The need of the hour is to develop, manage, update, and maintain a centralized national level water resources information system and provide standardized data and value added services to all stake holders for its management and sustainable development.

Hydrological data observation is a specilaized work, which is being carried out by CWC on PAN-India basis covering all majors rivers in the country. The hydro-meteorological data thus collected is compiled and published annually as Water Year Books for all major river basins in the country. CWC has been operating a network of stream flow observations based on requirements such as:

- Basin wise assessment of availability and management of water resource
- Planning & design of water resources projects
- Flood forecasting& flood management
- Reservoir in flow forecasting
- River water pollution control and environmental management
- River behaviour and morphological studies
- Formulating National Water Policy
- Resolving interstate & international water disputes
- Sediment assessment, inland navigational planning
- Climate change study and other purposes

The various stages of HO Observation in CWC is given below.

Evolution of H.O Network in CWC Over the Years (1950-2020)

The evolution of HO Network in CWC can be broadly classified into the following periods:

1. **Period of 1950-1994**

   The first hydrological observation station under CWC was open in 1948 at Hathidah-Patna on river Ganga. CWC was then using manual gauges for observation of rainfall and water level and High Frequency (HF) Wireless Sets for data communication from the remote site to divisional flood control rooms. Wireless sets were having crystal-based frequency selector which transmits only in frequency generated by crystal used. From thereon, during a span of 44 years, CWC has opened and functionalised a number of HO stations on various rivers in the country. Most of these sites being operated as Gauge sites (G) whose prime function was the collection of water level. By 1986, CWC was collecting and compiling HO data at about **500 key stations** in India.

2. **Period of 1995-2003 (Phase-I of Hydrology Project)**

- Modernization – use of Very High Frequency (VHF) communication towers to communicate the data
- Satellite-based system of communication with automated data acquisition - started under Dam Safety Assurance and Rehabilitation Project (DSARP) during 1999. 55 numbers of telemetry station were installed and 2 numbers of Earth Receiving station (ERS) at Burla in Odisha & Jaipur in Rajasthan were installed.
- Total 945 hydrological observation stations operational as on 01.01.2003. Out of the 945 HO stations, there were 245 gauge stations, 282 nos of gauge & discharge, 41 nos of gauge, discharge & sediment, 115 nos of gauge, discharge & water quality and 261 nos of gauge, discharge, sediment & water quality monitoring stations.

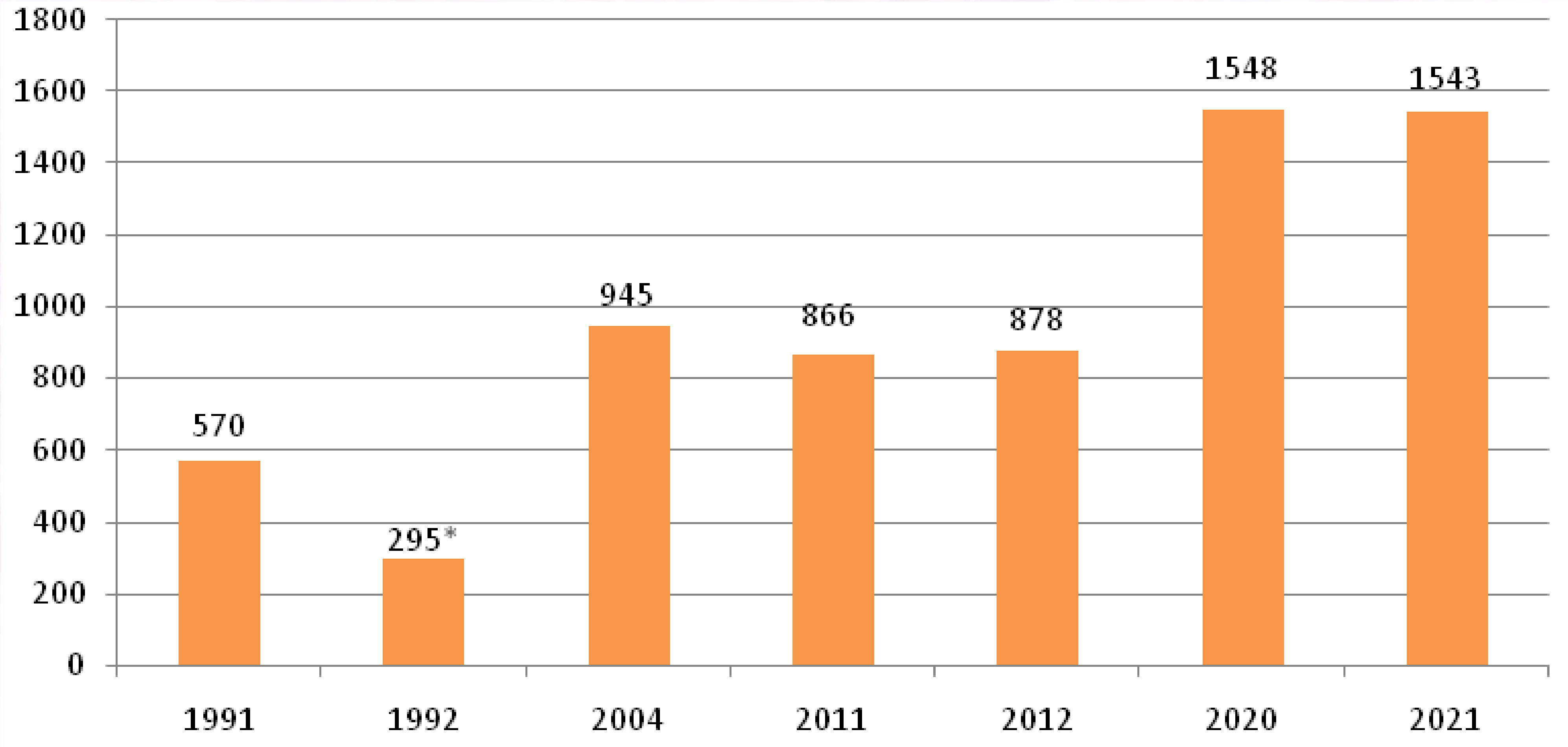
3. **Period of 2004-2014 (Phase-II of Hydrology Project)**

   During this period, CWC reviewed its HO Network and was operating about **878** hydrological observation stations as on December 2012.Out of which, there was 295 nos of gauge sites, 154 nos of GD sites, 131 nos of GDQ sites, 33 nos of GDS sites, 239 nos of GDSQ sites and 26 nos of GQ sites. 168 and 222 nos of telemetry station were installed in 2005 and 2011 respectively. One nos ERS was installed at New Delhi.

4. **Period After 2014**

   As a continuation of the XII plan efforts of strengthening of hydrological observation including snow hydrology, water quality and monitoring of glacial lakes, 800 new sites were proposed to be opened and 100 existing sites were to be upgraded by adding additional parameters. Out of the targetted 800, CWC has already opened 730 new sites under the XII five-year plan. As a result, as on January 2021, CWC has an HO network comprising of 1543 hydrological observation sites. Out of which, there are 451 Gauge sites, 403 Gauge & Discharge sites, 183 Gauge, Discharge & Water quality sites, 37 Gauge, Discharge & Sediment, 370 Gauge, Discharge, Sediment & Water quality, 99 Guage & Water Quality. In addition, there are also 193 exclusive meteorological observation stations. These HO sites undergo constant changes due to shifting/closing depending upon the necessity. For instance, a number of HO sites are opened on important rivers from time to time for investigation purposes and are closed soon after the completion of the project.

- The developments in the field of data acquisition has also come a long way since its inception in 1999 and today CWC is getting data on near real-time basis from nearly 968 stations in various river basins. There is a proposal to increase the coverage by



*only peninsular river

Fig. 1: Summary of HO sites maintained by CWC over the years

another 125 stations under the 14th Finance Commission period for which work is in progress. Another 100 stations are also likely to be added by 2025 taking the total automatic sensor based data acquisition and satellite based data transmission to around 1193 stations.

Basin wise distribution of 1543 H.O sites maintained by CWC

Sl.No	Name of Organisation	G	GD	GDQ	GDS	GDSQ	GQ	Grand Total
1	Brahmani-Baitarni	12				11	1	24
2	Cauvery		13	17		24		54
3	East Flowing rivers between Mahanadi and Pennar	13	2			5		20
4	East Flowing rivers between Pennar and Kanyakumari		19	10		8		37
5a)	Ganga	222	158	46	12	114	7	559
5b)	Brahmaputra	13	7	44		34	76	174
5c)	Meghna-Barak	6	21	7	10	18	7	69
6	Godavari Basin	48	43	13		32	4	140
7	Indus Basin	23	16	3	11	8		61
8	Krishna	14	14	12		29	3	72
9	Mahanadi	30	2	1		22		55
10	Mahi	10	4	2		3		19
11	Minor rivers draining into Myanmar and Bangladesh	2	9		3	3		17
12	Narmada	18	35	6		11	1	71
13	Pennar		4	4		4		12
14	Sabarmati	7	4	1		1		13
15	Subarnarekha	6	2	1		6		15
16	Tapi	17	18	1	1	3		40
17	West Flowing rivers from Tadri to Kanyakumari		16	9		26		51
18	West flowing rivers from Tapi to Tadri	7	6	4		5		22
19	West flowing rivers of Kutchh and Saurashtra including Luni	3	10	2		3		18
	Grand Total	**451**	**403**	**183**	**37**	**370**	**99**	**1543**

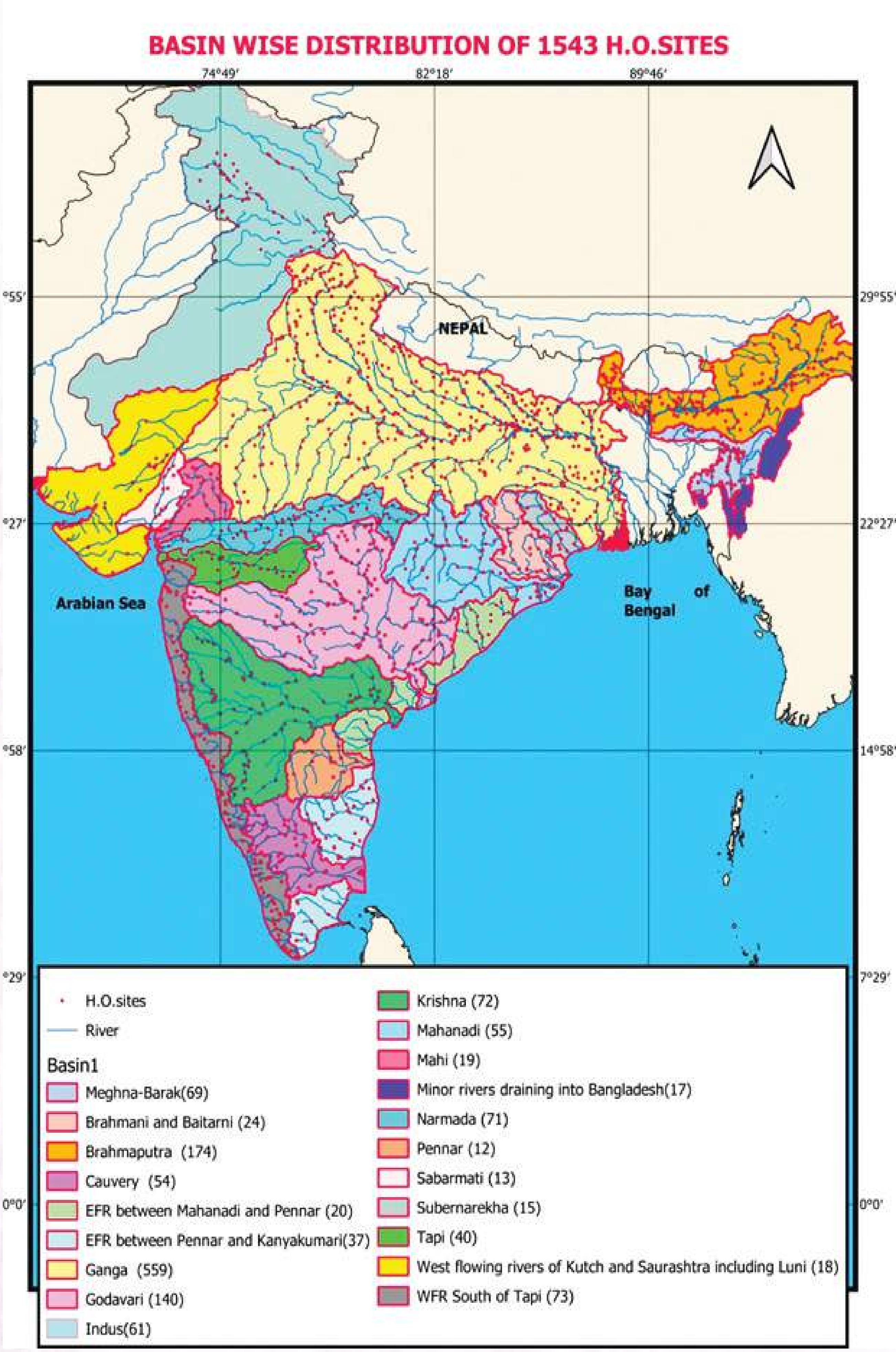


Fig. 2: Flood Forecasting Stations Network – Basin Wise

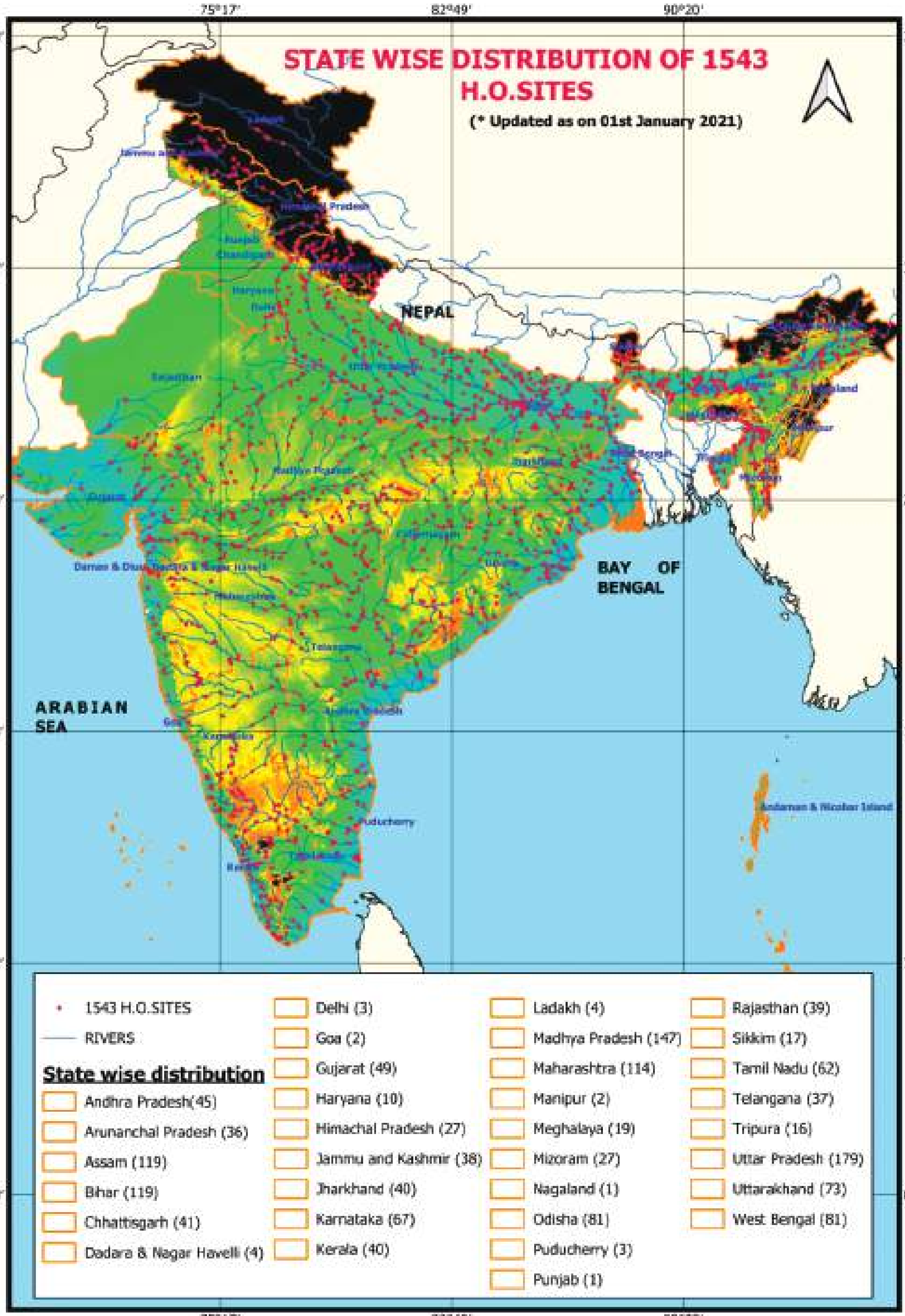
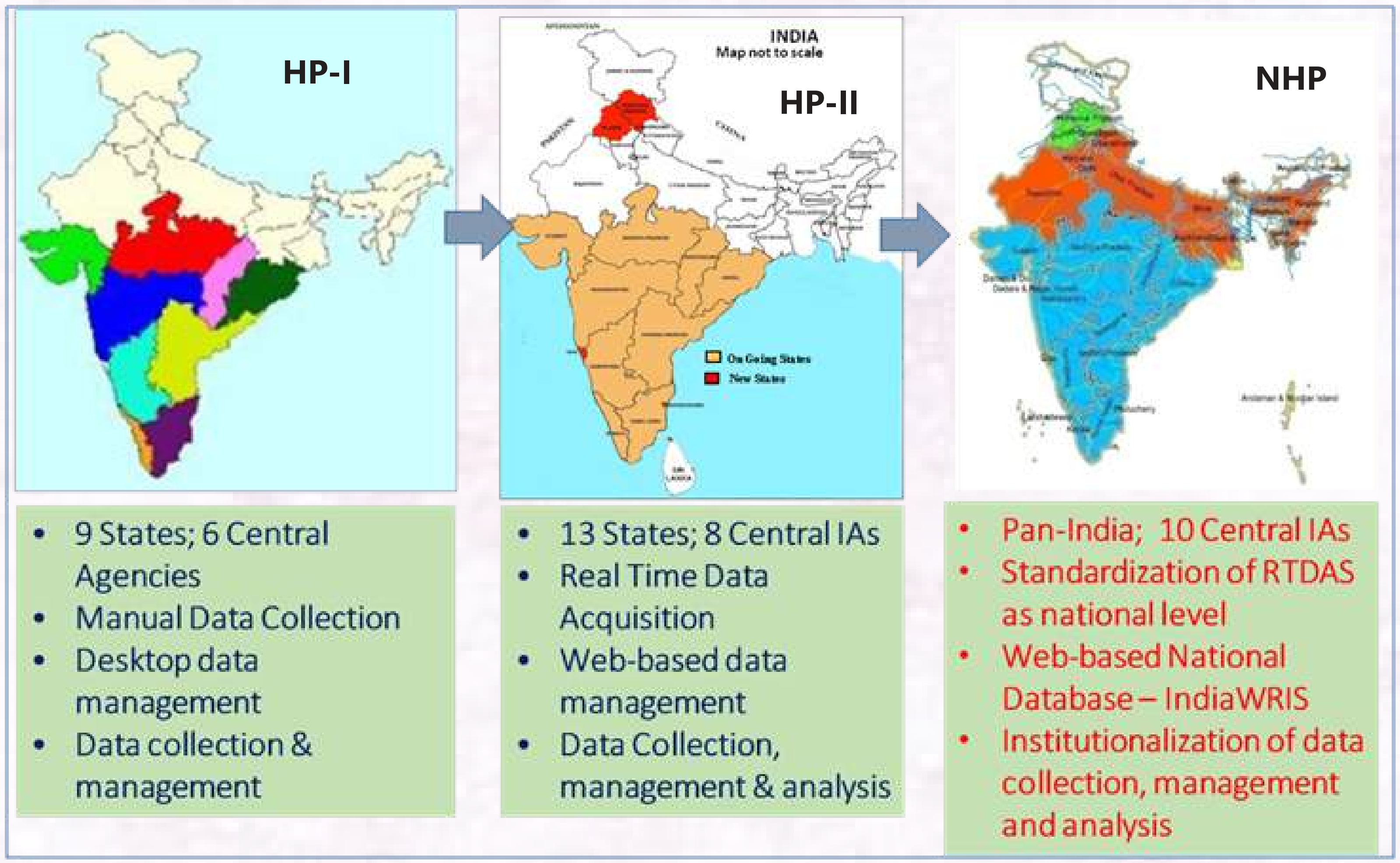


Fig. 3: Flood Forecasting Stations Network – State Wise

Project Overview

Hydrology Project, an initiative of Government of India with financial assistance from World Bank has been central to efforts in India to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. The project having completed two phases (Phase–I between 1995 - 2003 and Phase–II between 2006 - 2014) has successfully established the backbone of a comprehensive Hydrological Information System (HIS) in India providing scientifically verified, uniformly accepted and widely accessed hydrological records covering all aspects of the hydrological cycle. This project was instrumental in setting a paradigm shift from relatively isolated water resources development towards comprehensive planning development and management of water resources in a river basin context. It has created a platform for water agencies in India to learn from each other, which encouraged them to move from manual to Real-Time Data Acquisition Systems (RTDAS), and develop tools for Integrated Water Resources Planning and Management with the objective to enhance the productivity and cost effectiveness of water related investments. Based on the successful outcome of project, the Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India with financial assistance from World Bank is now expanding the project as National Hydrology Project, to cover the entire country including the Ganga and Brahmaputra Basin states as well as the north eastern



states. The project will thus strengthen information and its access, and will enable a cultural change of open access to information. It will also build up institutional capacity for informed decision making in water resources planning and operational management at the basin scale across India using the latest technology and tools.

Project Objective

To improve the extent, quality, and accessibility of water resources information and to strengthen the capacity of targeted water resources management institutions in India.

Project Highlight

- Central Sector Scheme, with 100% grant to the States
- Budget Outlay: about Rs 3,640 Crore, with World Bank Assistance to the tune of 50% of the project cost
- Timeline: 8 years from 2016-17 to 2023-24
- Scale: Pan India
- Lead Agency: MoWR, RD&GR
- Implementing Agencies: 49 (including 10 from Central Government, 35 from States, 2 UT's and 2 River Basins)

Concept

1. **Modernizing Monitoring network:** The project will establish & strengthen monitoring networks in project states, with a focus on deploying new sensors, data storage, and telemetry technologies across the whole country, to establish comprehensive, modern, automated, real-time monitoring systems for surface water and ground water.
2. **Transforming Knowledge Access:** The project will build on the dramatic advances in cloud computing, internet, mobile devices, social media and other communication tools to modernize access to and visualization of customized water information by different stakeholders.
3. **Enhancing Analytical Tools:** The project will develop and demonstrate tools for water resources assessment, hydrologic and flood inundation forecasting, water infrastructure operations, ground water modelling, and river basin and investment planning.
4. **Modernizing Institutions:** The project will complement technology investments with investments in people and institutional capacity. Support will be provided for developing center of expertise, innovative learning approaches, collaboration with academia and research institutes, and outreach programs. Office and equipment will be modernized to streamline workflows to effectively leverage the technology investments.

Project Components

A. Water Resources Monitoring Systems: This component will finance the establishment/modernization of new and existing hydromet monitoring systems including meteorology, streamflow, ground water, water quality and water storage measurements, and construction of hydro-informatics centers that capture both water resources and uses. This component will be implemented by states/UTs with the support of core central agencies. The major activities will include

(i) establishment of hydro-met observation networks (real time data acquisition system);

(ii) establishment of water quality laboratory;

(iii) establishment of Supervisory Control and Data Acquisition (SCADA) systems for water infrastructure; and

(iv) establishment of hydro-informatics centers.

B. Water Resources Information Systems: Component B will support the strengthening of national and sub-national water information centres with web-enabled WRISs through standardization of databases and products from various data sources/departments and make comprehensive, timely, and integrated water resources information available to decision makers for effective planning, decision making, and operations.

The sources of data/information will include the real-time data acquisition networks and centres under Component A, remote sensing data, and topographical maps and knowledge products developed under Component C. Emphasis will be on improving quality of and access to water information and on expanding public access beyond data to analytical results (trends, water balance, and so on) as well as to contribute to evidence based operational and investment plans. The project will support development or strengthening of centres for web-based WRIS at the central, regional, river basin, and state/UT levels. Some of the key activities under this component are:

(i) Strengthening of India Water Resources Information System (WRIS);

(ii) Upgradation of online Surface Water Information System (eSWIS)

(iii) Regional /State Water Resources Information System.

C. Water Resources Operations and Planning Systems: This component will support the development of interactive analytical tools and decision support platform that would integrate database, models and scenario manager for hydrological flood forecasting, integrated reservoir operations, and water resources accounting for improved operation, planning, and management of both surface water and ground water, based on basin approach. The component will provide interactive systems to analyze the impacts of alternative management scenarios and generate knowledge products using real-time data under Component B. Component C has three subcomponents:

(i) Studies ofbasinwise Extended Hydrological Prediction, Sedimentation transport in the river basin, streamflow forecasting, integrated reservoir operationsystems, reservoir sedimentation studies and irrigation design and operations);

(ii) Purposedrivensupport; and

(iii) Piloting innovative knowledge products.

D. Institutional Capacity Enhancement: Component D aims to build capacity for knowledge-based water resources management. It will support subcomponents in the establishment of (i) water resources knowledge centres, (ii) professional development, (iii) project management, and (iv) operational support.

The project will develop partnerships with national and international institutes, establish communities of practice, internships and visiting expert programs, customized training and workshops for knowledge exchange and professional networking. Centers of Excellence (national as well as regional) will also be established to address specific needs. Outreach and awareness programmes will be an integral part of the project and will showcase the NHP to a broad audience, both for specific target audiences such as local communities in irrigated or flood prone areas and for the public at large.

Implementation Arrangement

Overall, there are 49 Implementing Agencies (IAs):

- Lead Implementing Agency - MoWR, RD&GR
- Twelve (12)Central Implementing Agencies; viz. Bhakra Beas Management Board and Damodar Valley Corporation from the Ministry of Power; Central Water Commission, Central Ground Water Board, National Institute of Hydrology, Narmada Control Authority, National Water Informatic Centre and Central Water and Power Research Station from the Ministry of Water Resources, River Development & Ganga Rejuvenation; Central Pollution Control Board from the Ministry of Environment & Forests and Climate Change, Survey of India from the Department of Science &Technology and National Remote Sensing Centre from the Department of Space.
- 37State/UT implementing agencies (dealing with surface water and ground water development activities.

Beneficiaries

The project has two groups of direct beneficiaries:

(a) Central and State Implementing Agencies (IAs) responsible for surface water and/or ground water planning and management, including river basin organizations (RBOs) and

(b) users of the WRIS across various sectors and around the world. The ultimate beneficiaries will be the selected farm communities which benefited from pilot projects for water management; rural and urban water and power users;populations affected by floods and droughts, especially poor rural people, and farm families who may benefit from improved irrigation water supply and management; stakeholders across the energy, inland waterways, environment, and agriculture ministries; research and educational institutions; students and researchers; and non-governmental organizations, civil society organizations, and the private sector.

SNOW HYDROLOGY STUDIES

The Snow Hydrology Studies is a new initiative taken up by Central water Commission in the year 1984 with the help of UNDP on a small water watershed in Yamuna Basin. An exclusive Snow Hydrology Divisio was established for the study with its office at Shimla.

The main aim of the study is to modernize the existing collection of meteorological and hydrological data and to develop Snowmelt Run-off Model for short and long range prediction of snowmelt using state of art methods/ technologies.

The Project envisaged mainly:

- Identification of suitable watershed
- Setting of Snow Observatories with manual and automatic data collection system.
- Analysis of data and driving snowmelt run-off relationship.
- Extending scope of study in the entire catchment

Four Phases of the study are:

(i) Development Phase

(ii) Trial Phase

iii) Operational Phase

(iv) National Extension Phase in other river basins

Early activities of Snow Hydrological Division includes establishment of :

1. Snow Hydrological Observatory-I, at Jubbal
2. Snow Hydrological Observatory-II at Jubbal
3. V Notch weir site Sundlinala to measure the discharge of water shed
4. Snow Hydrological Observatory , Chopal
5. G&D site, at Nathi/Hamal/Shanta Khuds near Neoti - Chaupal

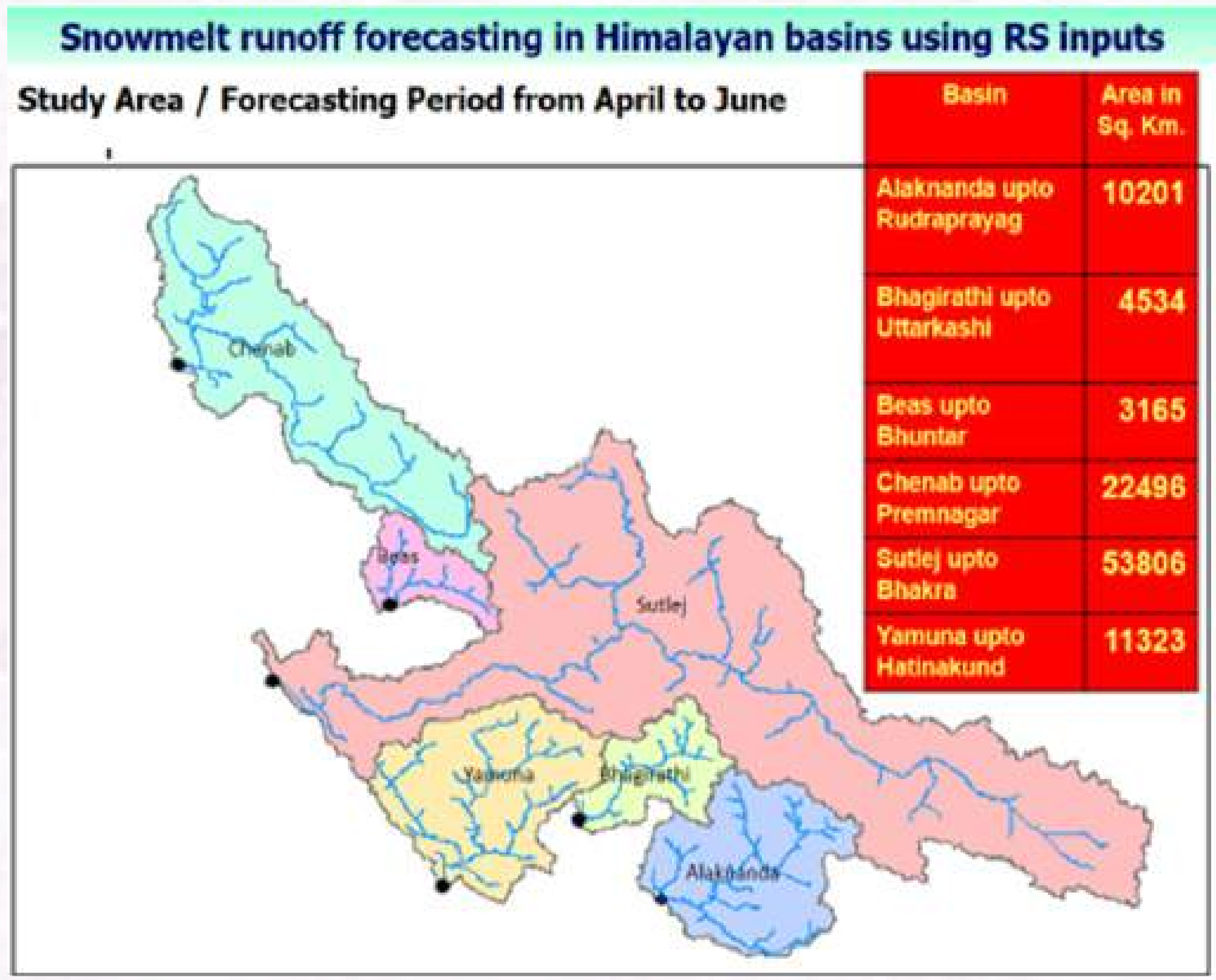
The various hydro-meteorological parameters like Air Temperature, Relative Humidity, Evaporation, Wind Speed, Atmospheric Pressure, Rainfall, Snow Depth, Snow Water Equivalent and Snow Cover Depletion are being observed using various manual and auto recording equipment like Ordinary Thermometers, Dry and Wet Bulb. Thermometers, Anemometer, Microbarograph, Hydro-Thermograph, ORG and SRRG, Snow Stake, Snow Pillow and Easy Logger. Snow surveys are also being deployed since the establishment of these sites. Using the observed data, simulation studies have been carried out using Martinec-Rango Snow runoff Model in the pilot catchment of Sundli-Nala, which is compared with the actual observed discharge.

National extension of Snow Hydrology in Five Himalayan River basin

Based on the studies on small watershed from year 1984 to till 10th Five Year Plan (2002-2007), there was a need to extend this study to entire Himalayan River Basins. Accordingly, during 11th Five Year Plan (2007-2012) a Snowmelt Runoff Model (SRM) was developed by CWC in collaboration with NRSA Hyderabad, presently installed & being run at M&A Directorate, Shimla.

Every year during the month of April to June, 6 short term forecast (ranging from 13 to 16 days interval) and one seasonal forecast is being done, based on the data collected from 19 Telemetry based Snow Gauge & Meteorological Station (SG&MS) and 6 Manual SHO being operated under this Division. The following types of sensors have been installed at above 19 Telemetry SG&MS:

Station	Sensors At Telemetry Sites
AWS	Atmospheric temperature, Evaporation , RH, Solar radiation , Wind velocity &Wind direction
A- Type	Rainfall
B- Type	Rainfall, Water level by BTP
D- Type	Atmospheric temperature & Relative humidity, Evaporation, Rainfall, Water level by Radar, Solar radiation, Wind velocity & Wind direction.
E Type	Atmospheric temperature & Relative Humidity, Evaporation, Snow depth, Snow precipitations , Solar radiation , Wind speed & Wind direction
SG & Met	Atmospheric temperature & Relative Humidity, Evaporation, Snow depth, Snow Water Equivalent, Snow precipitations , Rain gauge, Solar radiation , Wind speed & Wind direction
	Manual Snow Sites
SHO	Rainfall, Atmospheric temperature , Humidity, Snow Gauge & [Snow Line at Jubbal Site only]



CWC New Snow Observatories

At Kee Monastery in Spiti Basin

Established in Spiti Basin (tributary of Satluj River)

14.06.2017 at 3930 mtr. (MSL)

At Hango In Spiti Basin.

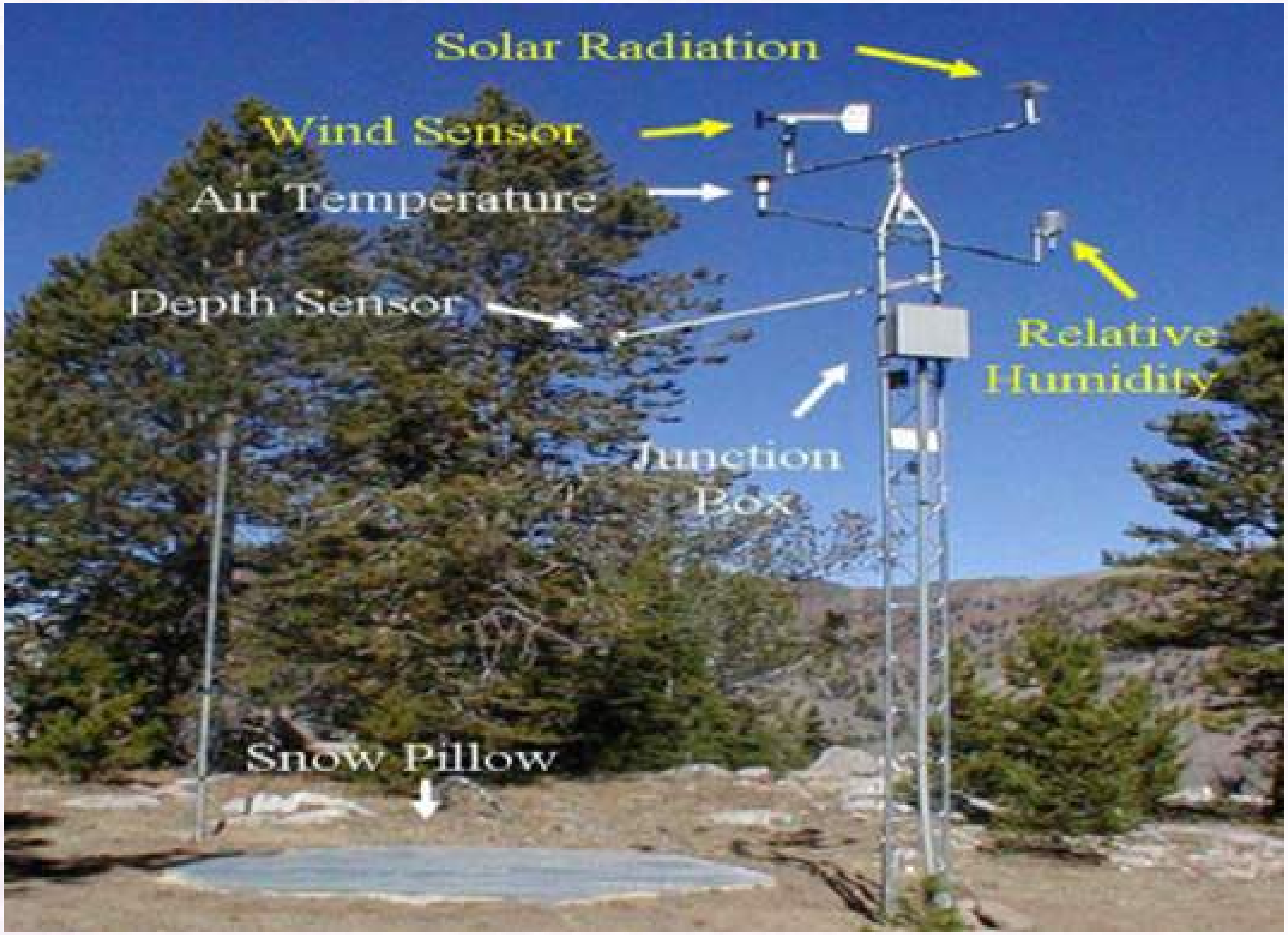
Established in Spiti Basin (tributary of Satluj River)

05.06.2017 at 3420 mtr. (MSL)

Objectives

Seasonal (April-May-June) forecast for these River basins

Short-term forecast Apr-May-June for these River basins



WATER QUALITY ACTIVITIES IN CENTRAL WATER COMMISSION

Central Water Commission (CWC), over the years, has developed expertise and capabilities in areas of water resources management in the country through its extensive hydro-meteorological observation sites across the country and observing river gauge / discharge / sediment / water quality parameters. Presently, CWC is observing water quality at 764 key locations (652 on Hydrological Observation network and 112 Water Quality Sampling Sites as on January, 2021) all over India.

In addition to this, a proposal for expanding the water quality network with the addition of 459 new sites was submitted to the Ministry. The expansion of WQ monitoring network over years is depicted in Figure 1.

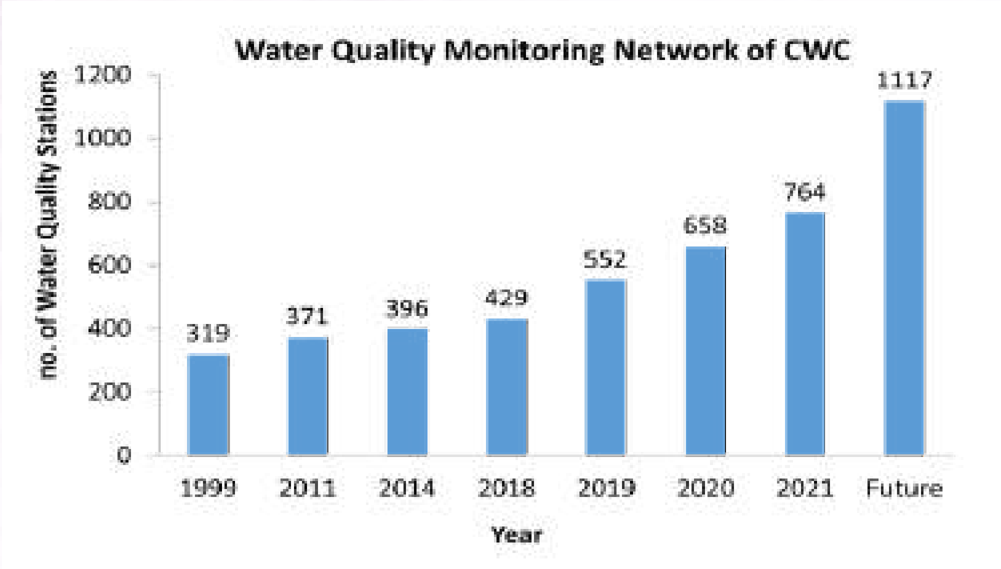


Fig. 4: Expansion of WQ monitoring network

Objectives of Water Quality Monitoring

Being the apex national body for development of water resources in the country, CWC is responsible for assessment of water resources in general. As a part of the objectives, following works are primarily undertaken with respect to water quality monitoring:

- Establishment of baseline water quality
- Assessment of suitability of water for various uses
- Detection of trends in water quality changes.
- Dissemination of water quality information upon request

Water Quality Monitoring Network in CWC at Present

At present, CWC follows a three-tier laboratory system which consists of Level I, II and III types of laboratories for providing analytical facilities for the analysis of river water samples collected from water quality monitoring stations covering all the important river basins of India.

The three-tier laboratory system consists of:

1. **Level-I Laboratories:** There are 378 level-I laboratories located at field water quality monitoring stations on various rivers of India for monitoring of 6 in-situ parameters (Colour, Odour, Temperature pH, Electrical Conductivity and Dissolved Oxygen).
2. **Level-II Laboratories:** There are 18 level-II laboratories located at division offices to analyse 25 physico-chemical and bacteriological parameters of river water.
3. **Level-III Laboratories:** There are 5 regional level-III laboratories for analysis of 41 parameters including trace & toxic metals and pesticides.

A list of parameters analysed at each level(I/II/III) is given at **Table 1** and list of level-II& III laboratories in CWC is given at **Table 2**.

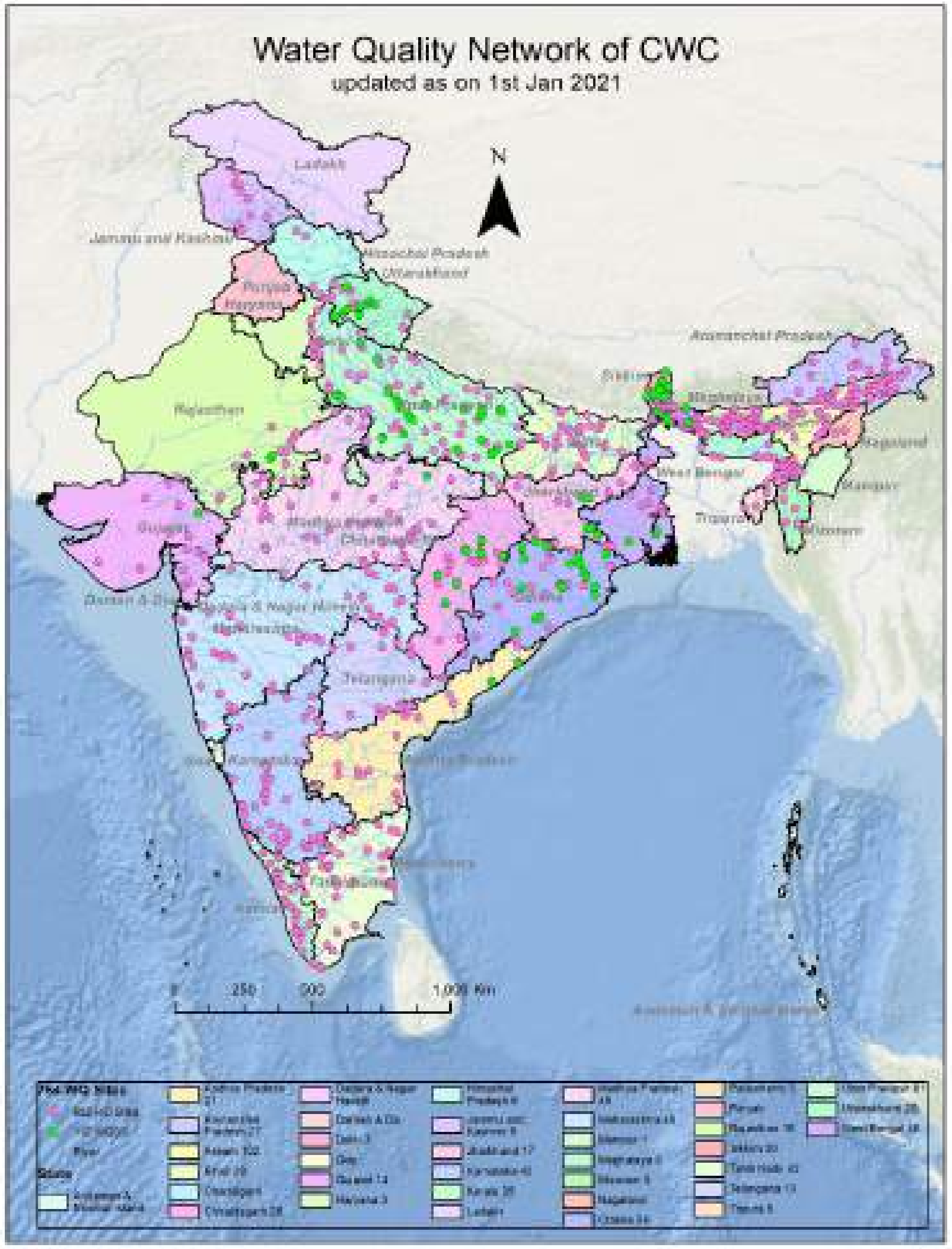


Fig. 5: Water Quality Network of CWC

Classification of Water Quality Monitoring Stations

In accordance with the definition given in the "Uniform Protocol on Water Quality Monitoring Notification" 2005, subsequently updated during 2017, water quality monitoring stations are classified as follows:

- **Baseline stations:** Baseline stations mean the monitoring location where there is no influence of human activities on water quality.
- **Trend stations:** "Trend station" means the monitoring location designed to show how a particular point on a watercourse varies over time due, normally, to the influence of man's activities.
- **Flux stations or Impact stations:** "Flux stations or Impact stations" means the location for measuring the mass of particular pollutant on Main River stem for measuring the extent of pollution due to human interference or geological feature at any point of time and is necessary for measuring impact of pollution control measures adopted.

***At present, samples have been collected thrice in a month from all sites for water quality analysis (from last year, 2021).**

Table 1: List of Water Quality Parameters

Sl. No.	Level-I	Level-II	Level-III
1	Temperature	Temperature	Temperature
2	Colour	pH	pH
3	Odour	Electrical Conductivity	Electrical Conductivity
4	pH	Dissolved Oxygen (DO)	Dissolved Oxygen (DO)
5	Electrical Conductivity	Turbidity	Turbidity
6	Dissolved Oxygen (DO)	Biochemical Oxygen Demand (BOD)	Biochemical Oxygen Demand (BOD)

Sl. No.	Level-I	Level-II	Level-III
7		Chemical Oxygen Demand (COD)	Chemical Oxygen Demand (COD)
8		Total Dissolved Solids (TDS)	Total Dissolved Solids (TDS)
9		Sodium	Sodium
10		Calcium	Calcium
11		Magnesium	Magnesium
12		Potassium	Potassium
13		Carbonate	Carbonate
14		Bicarbonate	Bicarbonate
15		Chloride	Chloride
16		Sulphate	Sulphate
17		Fluoride	Fluoride
18		Boron	Boron
19		Ammoniacal Nitrogen	Ammoniacal Nitrogen
20		Nitrate	Nitrate
21		Nitrite	Nitrite
22		Phosphate	Phosphate
23		Silicate	Silicate
24		Total Coliform	Total Coliform
25		Fecal Coliform	Fecal Coliform
26			Arsenic
27			Cadmium
28			Chromium
29			Copper
30			Iron
31			Lead
32			Nickel
33			Mercury
34			Zinc
35			Alpha Benzenehexachloride (BHC), Beta BHC, Gama BHC (Lindane)
36			OP-Dichlorodiphenyl trichloroethane (OP DDT), PP-DDT
37			Alpha Endosulphan, Beta Endosulphan
38			Aldrin, Dieldrin
39			Carbaryl (Carbamate)
40			Malathion, Methyl Parathion
41			Anilophos, Chloropyriphos

NABL accreditation of Water Quality Laboratories in CWC

As on February 2022, 17 out of 23 laboratories in CWC, functioning under different divisional offices, got accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) in the field of testing in accordance with ISO/IEC 17025:2017 and 6 are under the process of accreditation. All Level-III labs are accredited. The details of accreditation status can be seen at **Table 2** and **Figure 4**.

Table 2: List of Water Quality Laboratories in CWC

S. No.	Location of laboratory	Level of Lab	Organisational Jurisdiction	NABL Accreditation Status as on February, 2022
1	National River Water Quality Laboratory, New Delhi	III	YBO, New Delhi	Accredited

S. No.	Location of laboratory	Level of Lab	Organisational Jurisdiction	NABL Accreditation Status as on February, 2022
2	Lower Cauvery Water Quality Laboratory, Coimbatore	III	C&SRO, Coimbatore	Accredited
3	Upper and Middle Ganga Water Quality Laboratory, Varanasi	III	LGBO, Patna	Accredited
4	Krishna and Godavari River Water Quality, Hyderabad	III	K&GBO, Hyderabad	Accredited
5	Upper Cauvery Water Quality Laboratory, Bangalore	II	C&SRO, Coimbatore	Accredited
6	West Flowing Rivers Water Quality Laboratory, Kochi	II	C&SRO, Coimbatore	Accredited
7	Upper Krishna Division Water Quality Laboratory, Pune	II	K&GBO, Hyderabad	Accredited
8	Mahi Division Water Quality Laboratory, Gandhinagar	II	MTBO, Gandhinagar	Accredited
9	Lower Yamuna Water Quality Laboratory, Agra	II	YBO, New Delhi	Accredited
10	Eastern Rivers Water Quality Laboratory, Bhubaneswar	II	M&ERO, Bhubaneswar	Accredited
11	East Flowing Rivers Water Quality Laboratory, Chennai	II	C&SRO, Coimbatore	Accredited
12	Wainganga Divisional Water Quality Laboratory, Nagpur	II	MCO, Nagpur	Accredited
13	Indus Basin Rivers Water Quality Laboratory, Jammu	II	IBO, Chandigarh	Accredited
14	Mahanadi Basin Rivers Water Quality Laboratory, Raipur	II	M&ERO, Bhubaneswar	Accredited
15	Middle Ganga Divisional Water Quality Laboratory, Lucknow	II	UGBO, Lucknow	Accredited
16	Middle Brahmaputra Divisional Water Quality Laboratory, Guwahati	III	BBO, Guwahati	Accredited
17	Lower Brahmaputra Divisional Water Quality Laboratory, Jalpaiguri	II	T&BDBO, Kolkata	Accredited
18	Lower Ganga Divisional Water Quality Laboratory, Berhampore	II	T&BDBO, Kolkata	Non-Accredited
19	Middle Ganga Divisional-V Water Quality Laboratory, Patna	II	LGBO, Patna	Non-Accredited

S. No.	Location of laboratory	Level of Lab	Organisational Jurisdiction	NABL Accreditation Status as on February, 2022
20	Upper Brahmaputra Divisional Water Quality Laboratory, Dibrugarh	II	BBO, Guwahati	Non-Accredited
21	Narmada Divisional Water Quality Laboratory, Bhopal	II	NBO, Bhopal	Non-Accredited
22	Tapi Divisional Water Quality Laboratory, Surat	II	MTBO, Gangdinagar	Non-Accredited
23	Himalayan Divisional Water Quality Laboratory, Haridwar	II	UGBO, Lucknow	Non-Accredited

Important Publications

1. Water Quality "HOT-SPOTS" in Rivers of India: 2013/2017/2021
2. Status of Trace and Toxic Metals in Indian Rivers: 2014/2018/2019/2021
3. Effect of Time and Temperature on DO Levels in River Waters: 2019
4. Field Water Analysis Manual: June, 2020
5. Water Quality Monitoring of Indira Gandhi Canals: 2020
6. Water Quality Monitoring of Rivers: The Nationwide Lockdown: 2021

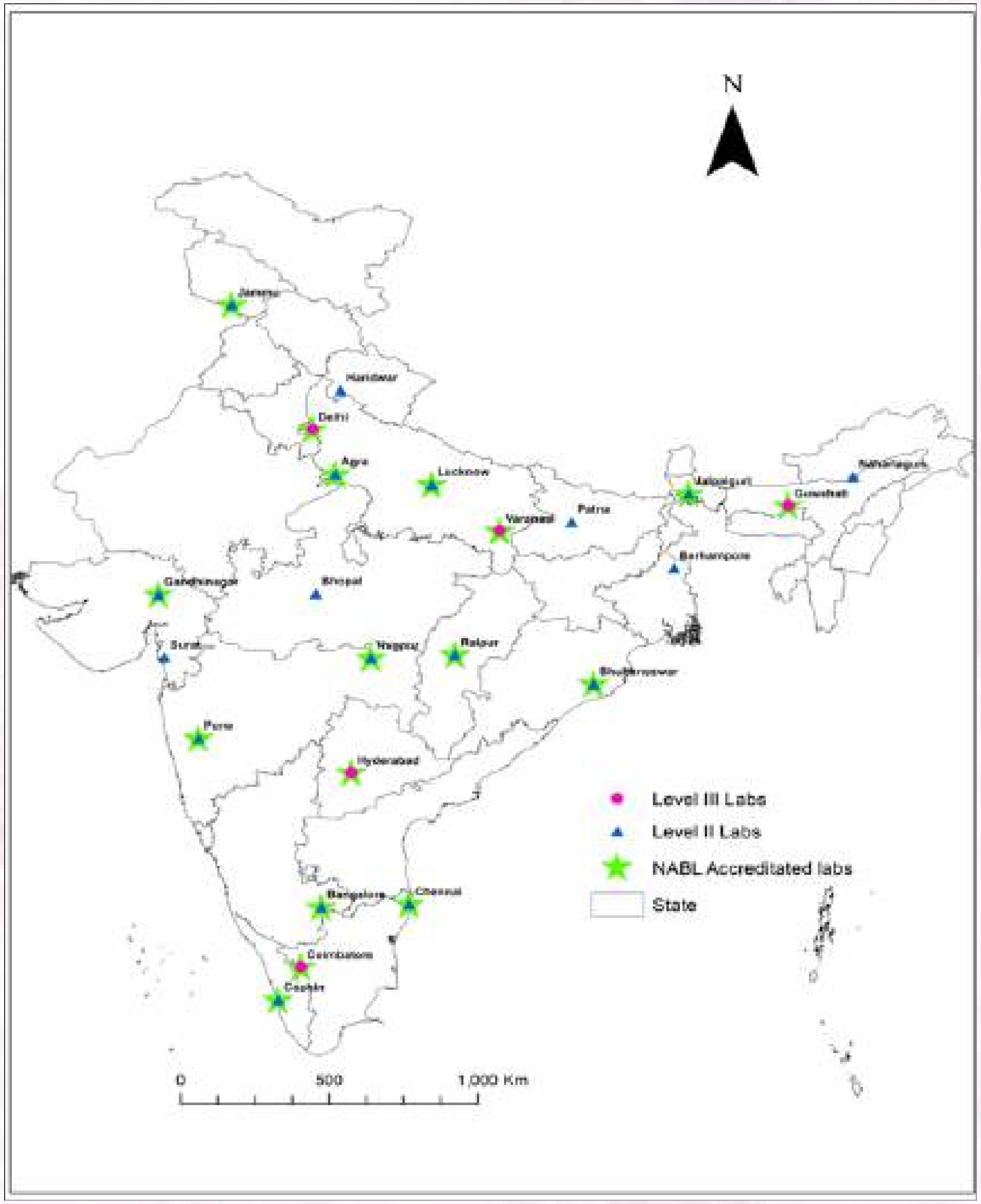


Fig. 6: NABL accreditation status of laboratories

Way forward in the field of Water Quality

- **Expansion of water quality network**

  As on September 2021, CWC has a network of 764 sites of water quality monitoring covering all important river basins of India. Further, there is future plan to expand the network sites across the country.

- **Uses of New Technologies/Software and Advanced Instruments in Water Quality Field**

  Modern, automated equipment and instruments can be used for sampling and analysis. This will reduce the manual efforts and enhance the speed and will improve data quality. Further, specially designed software can be used for data analysis and its management, data interpretation and data reporting.

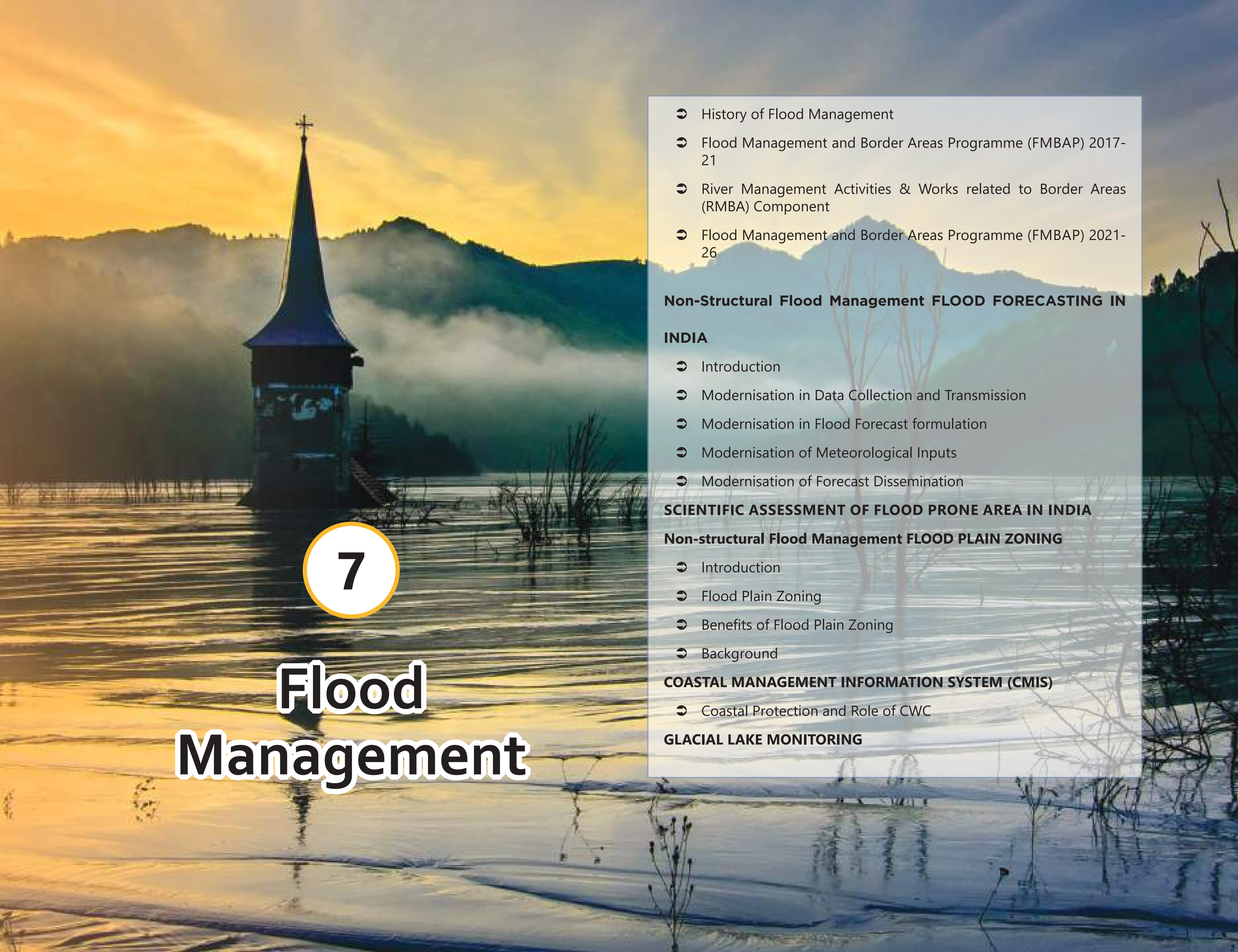
- **Future Research and Analysis of emerging contaminants**

  Detailed analysis regarding the cause/effect of emerging contaminants like pharmaceutical products, cosmetics etc. in water quality of rivers is a need of the hour as recent studies have revealed that river water is polluted with a range of emerging contaminants from pharmaceutical products, cosmetics, personal care products, insect repellents etc.

- **Water quality modelling centre for forecasting the water quality**

  It is a need of the hour to shift from the historical data collection approach to a more systematic approach with a clearly defined purpose to facilitate actual improvements on grounds. Accordingly, for analysis & prediction of Water quality, usage of technologies like Machine Learning, Artificial Intelligence and Mathematical Modeling shall be explored with the help of historical data and trends and hence accurately predict future variations in parameters.


River Bund
Barrage
Pump House
Structural Measures
Dam
Diversion
Infrastructure Works
Pond
River Improvement Works



7

Flood Management

Flood Management

Floods are natural calamity that India faces almost every year, in varying degrees of magnitude. On an average, India suffers a loss of about Rs. 6200 Crore annually besides the precious human lives. The frequent occurrence of floods can be attributed to various factors, including wide variations in rainfall both in time and space with frequent departures from the normal pattern, inadequate carrying capacities of rivers, river bank erosion and silting of river beds, landslides, poor natural drainage in flood prone areas, snowmelt and glacial lake out bursts.

Main causes of floods

The main causes of floods are as under:

(i) High intensity rainfall in short duration

(ii) Poor or inadequate drainage/channel capacity

(iii) Unplanned reservoir regulation

(iv) Failure of flood management structures

History of Flood Management

The disastrous floods experienced in large parts of the country in 1954 brought into focus the needs of tackling the flood problem on national basis. Accordingly a flood control programme was launched by the Government of India in the year 1954. Apart from creating administrative machinery for dealing with flood problems in the various States, suitable organizational set up was also created in the Commission in October 1954 under a new Wing called Flood Wing, for aiding and advising the States in flood control measures and in planning and preparing suitable Master Plans for control of floods and improving drainage system. Since then the Flood Wing as an important adjunct of the Commission had made significant contribution in evolving and implementing various flood control schemes and measures to control floods, minimize flood damage and improve drainage system. Central Flood Control Board was set up to draw up a comprehensive plan of flood control.

Integrated Flood Management Approach

- Complete immunity not possible - can be partially **controlled**
- Impacts can be minimised - **managing** to reduce losses

Permanent immunity against floods is not techno-economically feasible. However, impacts of floods can be mitigated to a certain degree by adopting appropriate structural and non-structural measures as listed below:

Structural Measures:

(i) Reservoirs

(ii) Detention basins

(iii) Embankments

(iv) Channelization of rivers

(v) Channel improvement

(vi) Drainage improvement

(vii) Diversion of flood waters

(viii) Watershed Management

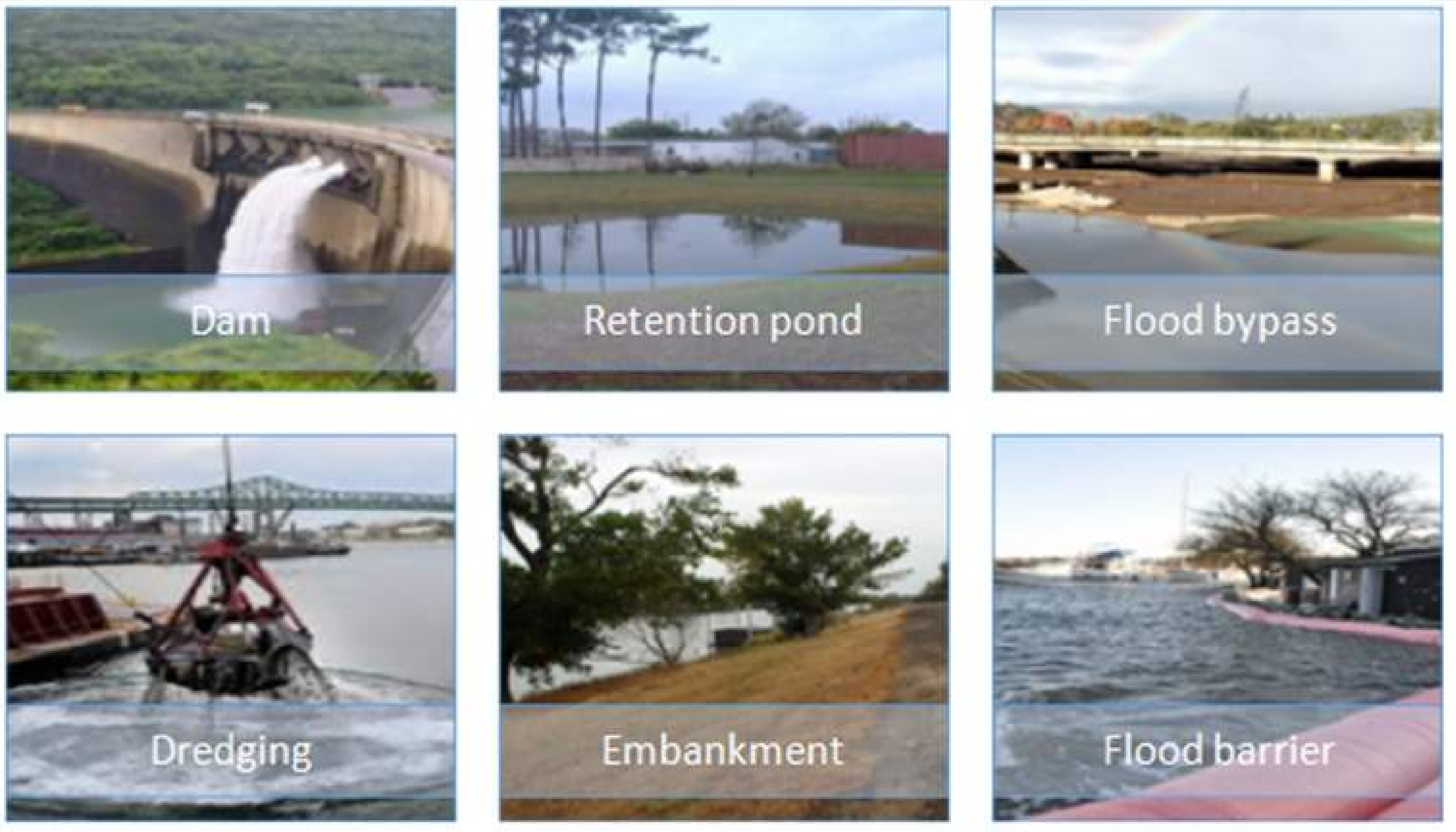


Fig. 1: Structural measures of Flood Management.

Non-Structural Measures:

(i) Flood forecasting

(ii) Flood plain zoning

As per constitutional provisions, the subject of Flood Management including erosion control falls within the purview of the States. The flood management & anti-erosion schemes are planned, investigated and implemented by the State Governments with own resources as per priority within the State. The Union Government only renders assistance to States which is technical, advisory, catalytic and promotional in nature.

At present Central Water Commission (CWC) performs flood forecasting activities on major rivers and their tributaries in the country and issues flood forecast at 331 stations. The forecasts issued by CWC are utilized by local administration in taking suitable administrative measures including evacuation of people from flood affected areas to safer locations during floods. The inflow forecasts issued by CWC are utilized by the project authorities in proper operation of reservoirs in order to mitigate flood impact in the downstream areas.

Dissemination of flood forecasts have also been modernised by having a dedicated website *http://india-water.gov.in/ffs*. The flood information is also loaded in Facebook Page, Twitter of CWC Flood Forecast dissemination system.

CWC has started formulating 3 Day Advisory Flood Forecast for 20 major flood prone river basin in the country since monsoon 2016 which was upgraded to 5 Day Advisory Flood Forecast during 2021. This activity has been developed in-house and utilizes global rainfall products like GPM (Global Precipitation Measurement), GsMAP (Global Satellite Mapping of Precipitation- a product of Japan Aerospace Exploration Agency) and IMD (India Meteorological Department) observed gridded rainfall & forecasted rainfall such as GFS (Global Forecast System), WRF (Weather Research and Forecasting). For formulation of flood forecasts based on these rainfall products, 1-D MIKE-11 Flood forecast models have been developed for basins viz Indus & its tributaries, Ganga & its tributaries, Brahmaputra & its tributaries, Barak System, Subarnarekha (i/c Burhabalang), Brahmani & Baitarni, East flowing (Mahanadi to Pennar), Narmada, Tapi, Mahi, Sabarmati, Mahanadi, Godavari, Krishna, West Flowing Rivers (Kutch & Saurashtra), West Flowing Rivers (Tapi to Tadri), Cauvery & its tributaries, Pennar, East Flowing Rivers (Pennar to Kanyakumari) West Flowing Rivers (Tadri to Kanyakumari). These advisories are shared with concerned stake holders on a public domain GIS dashboard which can be accessed at *https://120.57.99.138/*. The model outputs (water level, catchment rainfall and inflow forecast etc.) are updated on the website every three hourly during the monsoon season.

The development of Early Flood Warning System (EFWS) including Inundation Forecast (IF) in Ganga Basin has been taken up by CWC through Consultancy under NHP. CWC has signed a contract with M/s AECOM Asia Company Ltd in Joint Venture with M/s URS Scott Wilson India Private Ltd & M/s AECOM India Private Ltd on 11.8.2021 for this consultancy work. The objective of the consultancy is to develop an Early Flood Warning system (EFWS) including Inundation Forecasting (IF) and its integration with WRIS/e-SWIS/WIMS with a customized GIS tool for the real time dissemination of water level forecasts, inundation forecast &development of dashboard for the query-based flood warning/ flood inundation maps for all stakeholders. The scope of consultancy includes development of the system in 2 years (Part A) and Operation & maintenance of the system for 5 years after development (Part B). The high resolution DEM being developed / developed by Survey of India & NRSC will be utilized for inundation model.

High Resolution Digital Elevation Model (DEM) developed by NRSC in some flood prone river reaches are being used for inundation forecast modelling in Godavari & Tapi basin by NRSC and for inundation forecasting modelling in Mahanadi Basin by CDAC with support from CWC.

The Government of India set up Ganga Flood Control Commission (GFCC) at Patna in 1972 and Brahmaputra Board in 1980 for advising the Ganga Basin States and NE-States respectively on Flood Management measures. These Organizations have prepared master plans for flood management in respective Basin States.

It was felt by Government that worldwide advances in technology necessitated a study in depth of our future approach and programmes of Flood control measures. So the Government of India constituted Rashtriya Barh Ayog (National Flood Commission) in July 1976. Member (Floods), CWC was a member of this Committee and an officer of CWC was its Member-Secretary. The Commission submitted its report in March 1980, its recommendations covering the entire gamut of flood control activities. These recommendations and the comments received thereon from the State Governments were considered and guidelines and instructions for the implementation of these recommendations were circulated in September 1981.

The Government of India issued National Water Policy-2012 which emphasizes construction of large storage reservoirs and other non-structural measures for integrated flood management.

Long term solution to the flood problem lies in creation of storage reservoirs on rivers and their tributaries with dedicated/specific flood cushion by reducing the flood peaks and levels, integrated reservoir operation, interlinking of rivers etc. Short term solutions in form of embankments, anti erosion measures, etc to manage floods and erosion problem are necessary to safeguard the flood prone areas, properties and population. Central Government is providing assistance to State Governments for tackling the devastation caused by floods through various funding mechanism. Short term solutions in form of flood and erosion management worksare being taken up by respective States Govts as well as Brahmaputra Board and supported by various schemes/plans of Central Govt from time to time.

During X Plan, following four schemes were sanctioned to provide central assistance to the flood prone states to take up flood control and river management works in critical areas:

(a) Critical Anti-erosion works in Ganga Basin States (a Centrally Sponsored Scheme),

(b) Critical Flood Control and Anti Erosion Schemes in Brahmaputra and Barak Valley States (a State Sector Scheme),

(c) Improvement of Drainage in critical areas in the country (a State Sector Scheme) and

(d) Critical Anti-erosion Works in Coastal and other than Ganga Basin States (a State Sector Scheme).

The above schemes were merged together and a restructured scheme, namely, "Flood Management Programme" under State Sector in Central Plan was approved for XI Plan period and continued during XII Plan. CWC was involved in techno-economic appraisals of these projects which were proposed by respective States Governments as well as Brahmaputra Board.

Flood Management Program (FMP):

"Flood Management Programme (FMP)" a State Sector scheme amounting to Rs. 8,000 crore under Central Plan proposed by MoWR, RD & GR was approved by Government of India during XI Plan (Nov. 2007). The continuation of flood management programme was approved by the Government of India during XII Plan with an outlay of Rs 10,000 crore. An outlay of Rs 2642 Cr was kept for period 2017-20 under this component.

River Management Activities & Works related to Border Areas (RMBA) Component

River Management Activities & Works related to Border Areas (RMBA) started as a Central Sector Scheme with an outlay of Rs 820 Cr in XI plan for taking up non-structural measures such as Hydrological Observation and Flood Forecasting works on common border rivers, payment to neighboring countries (China) for supplying HO data on common rivers, investigation of WR projects in neighbouring countries, activities of GFCC and Pancheswar Development Authority (PDA) was funded through this scheme. In addition to above activities, 100% Central Assistance was also provided for taking up structural measures such as Anti Erosion/Flood Management schemes on rivers on international borders and Union Territories. The scheme with an outlay of Rs 740 Cr was also continued during XII Plan.

An outlay of **Rs700** Cr was kept for period 2017-20 under this component.

These structural works implemented have resulted in protecting area of about 20.54 mha till end of XII Plan against 40 mha flood prone area assessed by Rashtriya. The details of flood management measures taken up till end of XII Plan are as under:

S. No.	Flood management measures	Extent
1	Embankment	37072.659 km
2	Drainage channel/channel improvement	39726.700 km
3	Village raised/protected	7713 nos
4	Town/Villageprotection works	2906 nos
5	Raised Platforms	65 nos

Flood Management and Border Areas Programme (FMBAP) 2017-21

A comprehensive scheme titled "**Flood Management and Border Areas Programme (FMBAP)" with an outlay of Rs 3342.00 Cr (FMP-Rs 2642 Cr & RMBA-Rs 700 Cr)** for period 2017-2020 with merged components from the existing Flood Management Programme (FMP) and River Management in Border Areas (RMBA) schemes during XII Five Year Plan was approved by the Union Cabinet on 07-Mar-2019. It aimed at completion of the on-going projects already approved under FMP. The scheme was extended till March, 2021.

A total 522 schemes costing Rs 13238.37 Cr were approved during XI Plan (420 projects costing Rs 7857.08 Cr) and XII Plan (102 projects costing Rs 5381.29 Cr) . Out of these 522 schemes, 421 schemes have been completed; 64 schemes foreclosed, dropped and shifted (47-foreclosed; 16-dropped & 1 shifted to RMBA component) and 37 schemes are ongoing. Out of these 37 ongoing schemes; 21, 13 & 3 schemes are being monitored by CWC, GFCC & Brahmaputra Board respectively. These 421 completed schemes have given protection to an area of around 4.991 mha and protected a population of about 53.475 million.

Brief about both components are as under:

Flood Management and Border Areas Programme (FMBAP) 2021-26

The total amount recommended by EFC for FMBAP 2021-26 for XVth Finance Commission Cycle is Rs. 4,500 Crores.

As apparent from the above, heavy responsibility was placed on the Central Water Commission. A separate Flood Wing headed by a Member of the Central Water Commission started Functioning in 1970. The scope of work in the Central Water Commission increased progressively from a mere liaison or coordination of activities in the fifties to active participation in the State Flood Control Boards and technical advisory committees and then to preparation of master plans, comprehensive planning of inter-state flood control works, providing guidance to States, and expansion of the flood forecasting and advance warning network with state of the art technology in the country.

Introduction

Flood causes considerable damage to human lives and property almost every year. About 50% of total area liable to flood (40 mHa assessed by the Rashtriya Barh Ayog) in the country has been provided with reasonable protection against flood of a low to moderate magnitude due to technological and economic constraints. It is not possible to provide protection against all magnitude of flood. Flood Forecasting & warning has been recognized as the most important, reliable and cost effective non-structural measures for flood mitigation. The Journey of Flood Forecasting Activities of CWC is as follows:

1957	1969	1974	2001	2017
"High Level Committee on Floods"- Emphasis on Non-structural Measures	Started Flood Forecasting in Ganga, Brahmaputra, Narmada, Teesta, Mahanadi and Coastal rivers of Orissa	Extended Forecasting Network to Godavari	Extended Forecasting Network to Pennar	By the End of 12th plan 226 Flood Forecasting Stations Across the Country
1958	**1970**	**1978**	**2012**	**2021**
First Forecating Station at Old Delhi Bridge on Yamuna River	5th Conference of State Minister's of Irrigation and Power- Emphasis of Extentson and Modernisation of Forecasting Network	Extended Forecasting Network to Krishna	By the End of 11th plan 175 Flood Forecasting Stations All Over the Country	331 Flood Forecasting Stations Across the Country

Timeline for CWC flood Forecasting Network Expansion

Presently, CWC has 331 (199 Level and 132 Inflow) operational flood forecast stations and it is planned to increase the forecasting network to 375 stations by 2025 as shown below:

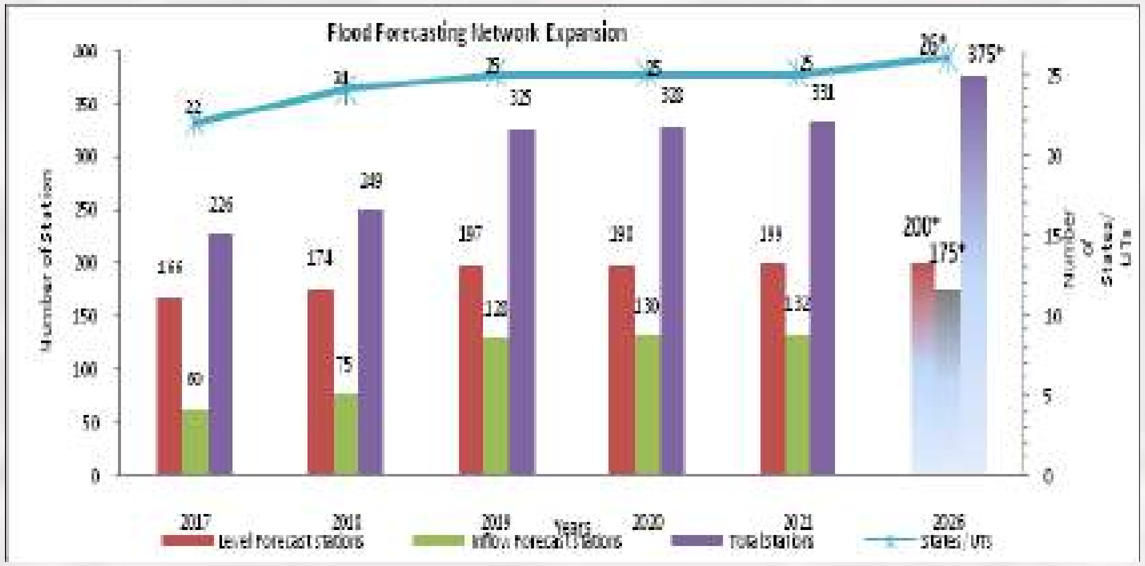


Fig. 2: CWC Flood Forecasting Network Expansion

Modernisation in Data Collection and Transmission

1958-1980	1990s
Data Collection- Manual Gauges Data Communication- Crystal Based HF Wireless Only Site to Divisional Control Room	Satellite Based Data Communication Started
1980-1990	**1999**
Data Collection- Automatic Sensor Based Obervation (14 station in Upper Yamuna -Pilot Basis) Data Communication- Tunable Transmitters, Antenna System, Power System Inter-Divisional Communication	First satellite based communication with automated data aquisition under Dam Safety Assurance and Rehabilitation Project (DSARP) Modernisation of 35 Station in Mahanadi and 20 Stations in Chambal Basin Two Earth Receiving Stations Established - Burla (Odisha) and Jaipur (Rajasthan).

Timeline for Modernisation of CWC Data Collection and Communication

Fig. 3: Manual Gauge and Radar Based Water Level Sensor

Fig. 4: Natural Siphon Rain Gauge and Automatic Weather Station

This modernisation activity continued during different plan period viz. X (168 Stations), XI (222 stations), XII (523 Stations). CWC is presently getting data on real-time basis from 1014 stations in various river basins in 29 modelling centres. This number is likely to reach 1188 by 2026.

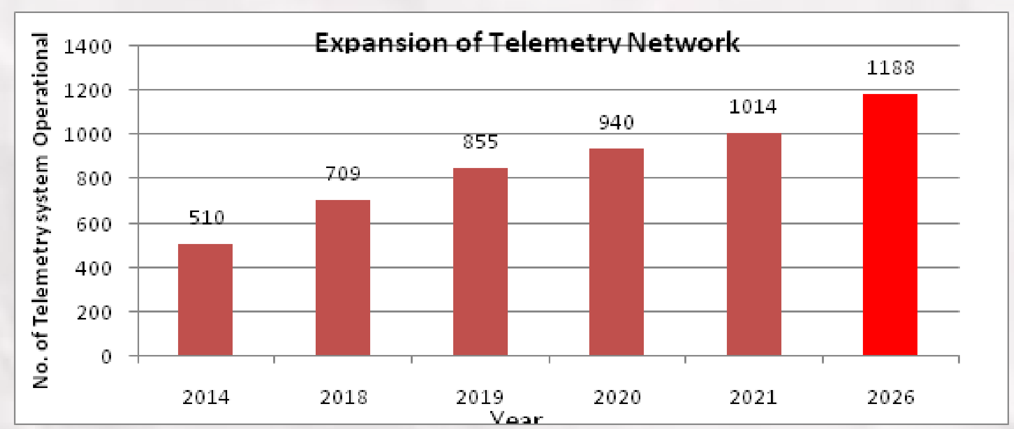


Fig. 5: Expansion of Telemetry Network

Modernisation in Flood Forecast formulation

1958-1990s	2007	2017
Forecasting Using Hand Calculated Statistical Correlation and Regression Equations	Mike 11 software Purchased for all Modelling Centres Models for Brahmaputra and Krishna Basins were Developed	3-day Advisory Started for Pan India using Mathematical Modelling

Mid 1980s- 990s	2012-2017	2021
Use of Spreadsheets and Tables to Generate Coorelation and Regression Equaitons Use of Mathematical Models Initiated, System 11F of DHI used for Developing Models for Chambal and Mahanadi Basins	All new Forecasting Stations were Braought under Mathematical Modelling Mike-2016 Used for Modelling	5-day Advisory Started for Pan India using Mathematical Modelling

Timeline for Modernisation of Flood Forecasting

Present 5-day advisory portal of CWC is shown below:

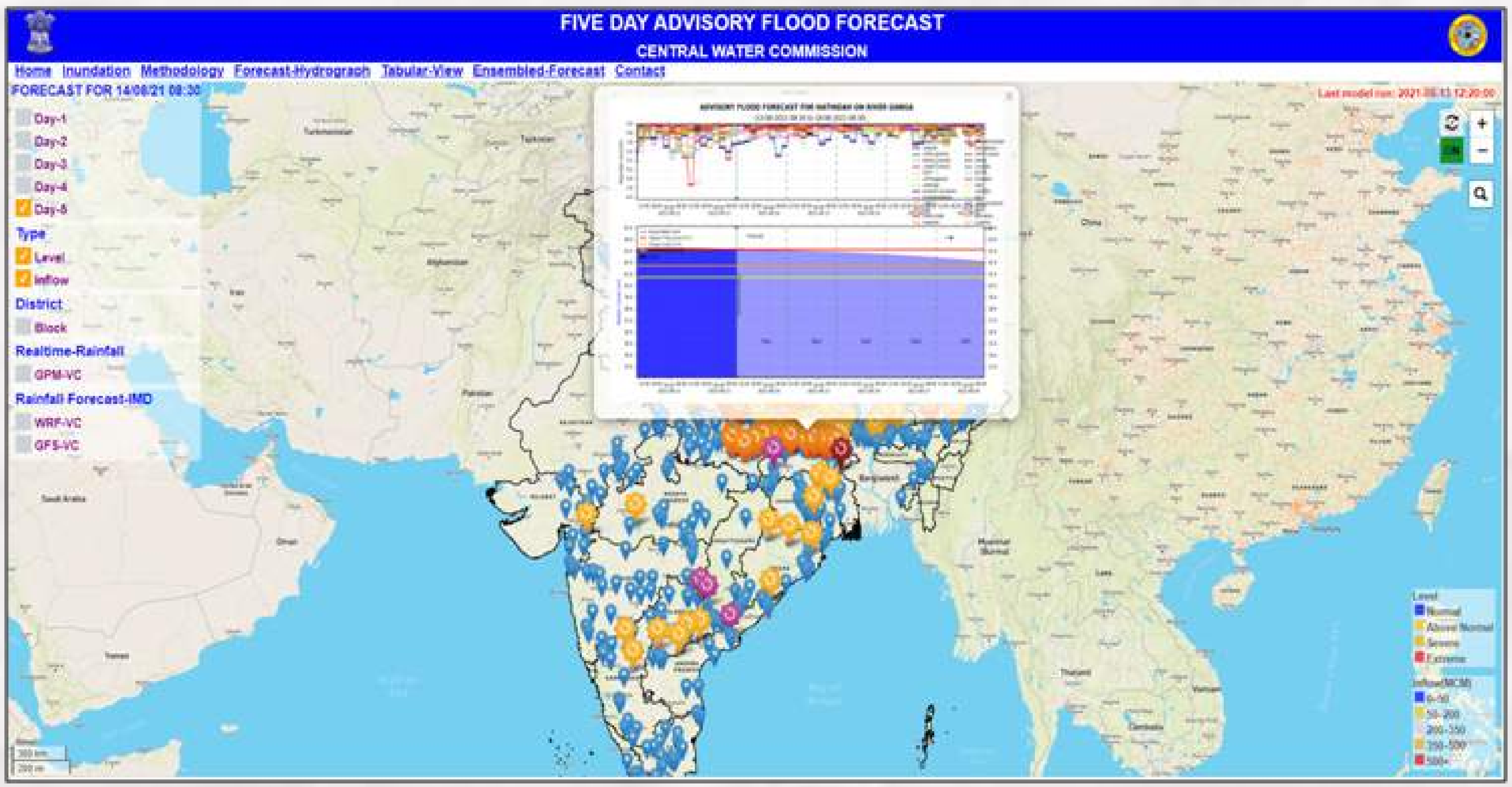


Fig. 6: CWC 5-day advisory Flood advisory portal (http://120.57.99.138)

Modernisation of Meteorological Inputs

After the recommendation made by 5th Conference of State Minister's of Irrigation and Power held at Ooty in September 1970, IMD started FMOs in various locations to cater to the needs of Flood Forecasting. These FMOs provide Quantitative Precipitation Forecasts (QPF) to concerned Flood Forecasting Divisions. These QPF were prepared and sent to concerned CWC Division by hand during 1970s to 1990s. With the advent of internet in the 1990s, e-mails were utilised to send these QPFs. From 2007 onwards, the QPF bulletins were published in the website of the concerned Meteorological Centre. Numerical Weather Prediction (NWP) model outputs were provided in PDF through the website from 2009 onwards. With advent of automatic 3 day advisories by CWC, IMD has started sharing the data seamlessly using ftp servers from 2017 onwards and is also providing map based sub-basin wise QPFs from 2017 onwards.

Modernisation of Forecast Dissemination

CWC Flood Forecasting Website

After formulation of flood forecasts, the flood forecasts have to be disseminated immediately to the concerned first responders who will in turn warn the general populace regarding the impending floods. Upto 1990s, these flood forecasts were sent through wireless to the concerned flood forecasting stations and the personnel available in the CWC FF stations would manually hand over the forecast to its beneficiary. With the advent of internet, e-mail was used for dissemination of flood forecast. From 2006, a web based flood forecasting web site under domain in name http://india-water.gov.in/ffs started functioning. However, it was upgraded and made more user friendly from 2014 and is being used till date. This has been further upgraded using Water Information Management System (WIMS) through which better data entry system, report generation and user friendly web functions have been operational from 2020 Flood Season.

CWC Flood Forecast Dissemination website is shown below:

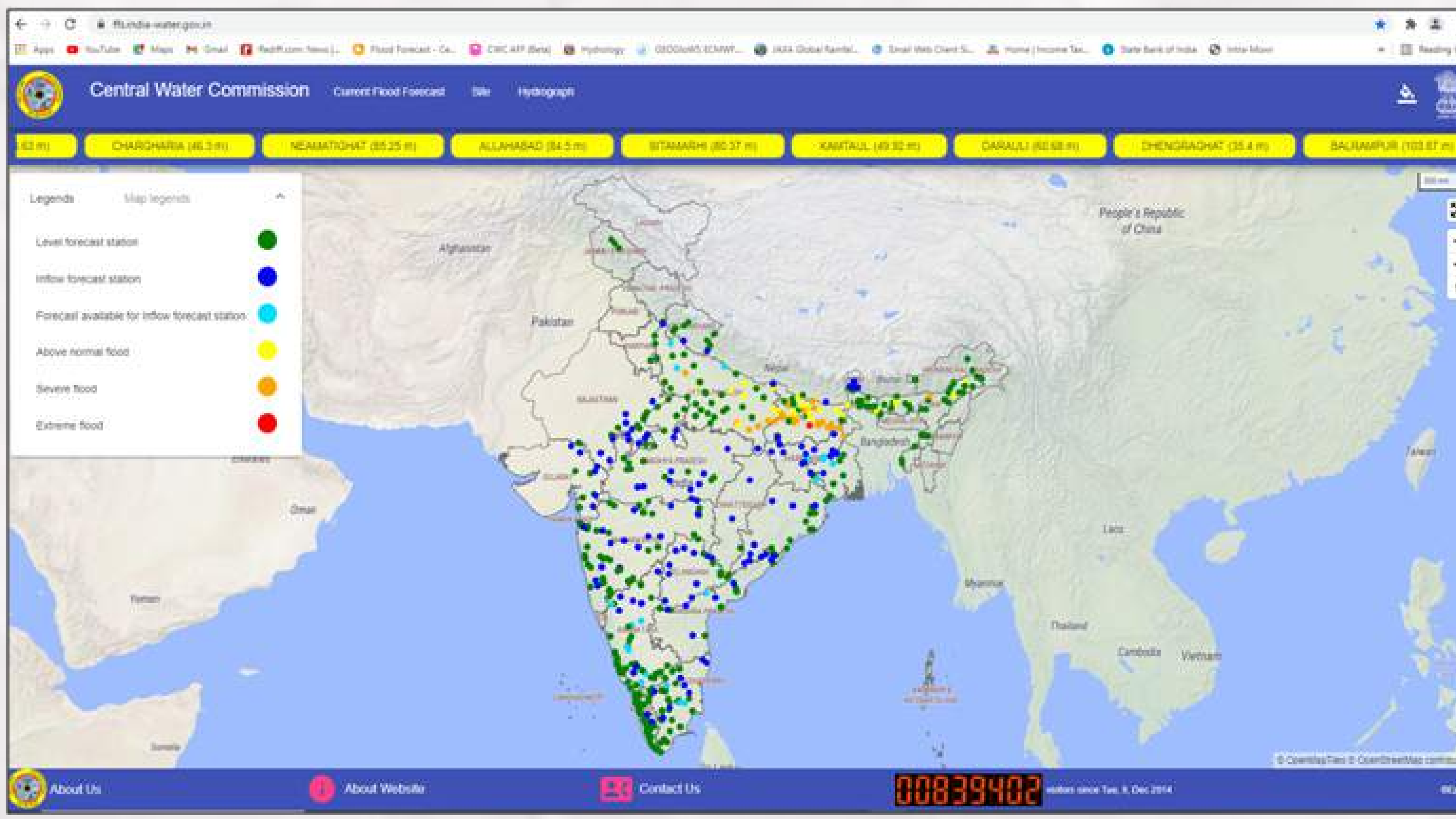


Fig. 7: CWC Flood Forecast Dissemination Website (http://india-water.gov.in/ffs)

Collaboration with M/s Google Inc.

CWC is working in collaboration with M/s Google Inc., for generating Common Alerting protocol (CAP) for sending CWC's Flood Forecasting information to general populace in the affected areas through Google enabled android smart phones or through various Google platforms from 2015 onwards. National Disaster Management Authority through Centre for Development of Telematics (C-DoT) under MoCIT is also developing its own CAP alert systems through which priority call routing will be given from the concerned mobile towers. Radio and TV broadcast of alerts are also being envisaged. The system is being tested on pilot basis in Tamilnadu in March 2020 onwards.

CWC has also collaborated with M/s Google Inc., to provide inundation alerts based on the Flood Forecast available in CAP platform using high quality Digital Terrain Models available with Google using Artificial Intelligence and Machine Learning. The system started functioning from 2018 when inundation alerts were provided for Patna Gandhighat forecast station. This expanded to around 11,000 sq.km. covering 7 FF stations (Patna Gandhighat & Kahalgaon in Bihar, Neamatighat, Tezpur, Guwahati & Goalpara in Assam and Ayodhya in Uttar Pradesh) during 2019. Presently, this inundation alert mechanism is functional on all 199 level forecast stations of CWC.

Inundation alert portal of CWC and Google collaboration is shown in below:

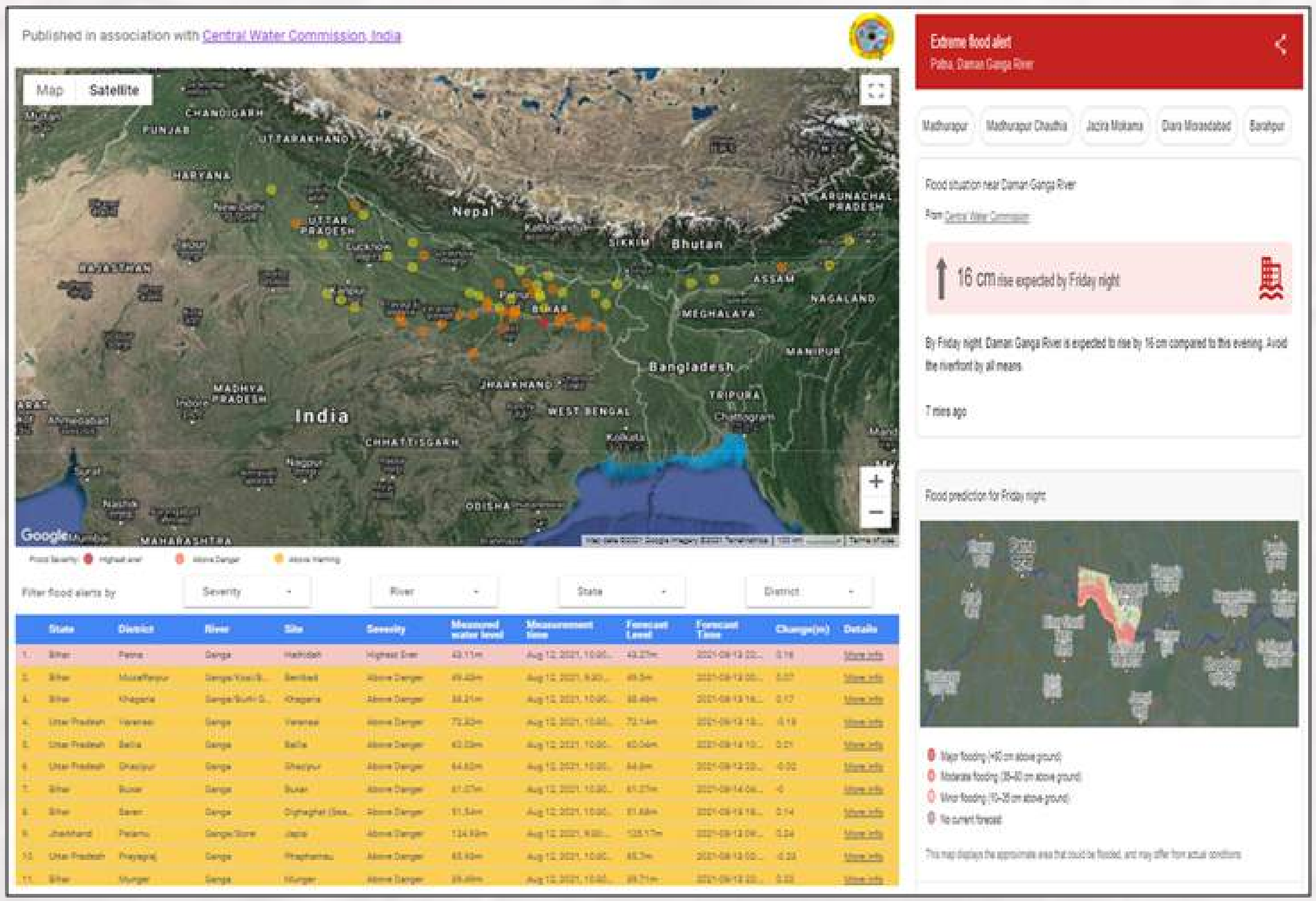


Fig. 8: CWC-Google inundation alert portal (http://g.co/indiafloods)

SCIENTIFIC ASSESSMENT OF FLOOD PRONE AREA IN INDIA

Floods are the leading cause of natural-disaster losses in India. Every year, flood events cause great socio-economic losses. For this reason, precise flood mapping and modeling are essential for flood hazard assessment, damage estimation and sustainable urban planning to properly manage flood risk. Although the amounts of fatalities have declined due to improved early warning systems, economic losses have continued to rise with increased urbanization in flood-hazard areas. Identification of flood prone areas is one of the most important tasks before adopting appropriate measures for mitigation of floods.

The Rashtriya Barh Ayog (RBA) defined the 'area liable to floods' in a State as maximum area damaged in any one of the years. On the basis of annual damage by floods and drainage congestion (during 1953-1978) reported to the Central Water Commission by the States, RBA had estimated in 1980, the total area liable to floods in the country as 40 MHa. The extent of maximum area affected by floods was further updated by the XII Plan Working Group (WG) on 'Flood Management and Region Specific Issues' constituted by the erstwhile Planning Commission as 49.815 MHa. It was on the basis of figures reported by the State Revenue Authorities and Ministry of Home Affairs (MHA) to CWC. The State-wise maximum area affected by floods in any year during 1953 to 2010 was taken into account. State-wise flood affected areas identified by RBA and XII Plan Working Group are given at below :

State-wise inundated area identified by RBA and XII Plan Working Group

(Area in Mha)

Sl.No.	State/UT	RBA (1980) in Mha	XII Plan WG (2011) in Mha
1	Assam	3.15	3.82
2	Andhra Pradesh	1.39	9.04
3	Arunachal Pradesh	-	0.207
4	Bihar	4.26	4.986
5	Chhattisgarh	-	0.089
6	Delhi	0.05	0.458
7	Gujarat	1.39	2.05
8	Goa	-	-
9	Haryana	2.35	1
10	Himachal Pradesh	0.23	2.87
11	Jammu & Kashmir	0.08	0.514
12	Jharkhand	-	-
13	Karnataka	0.02	0.9
14	Kerala	0.87	1.47
15	Madhya Pradesh	0.26	0.377
16	Maharashtra	0.23	0.391
17	Manipur	0.08	0.08
18	Meghalaya	0.02	0.095
19	Mizoram	-	0.541
20	Nagaland	-	0.009

Sl.No.	State/UT	RBA (1980) in Mha	XII Plan WG (2011) in Mha
21	Odisha	1.4	1.4
22	Punjab	3.7	2.79
23	Rajasthan	3.26	3.26
24	Sikkim	-	1.17
25	Tamil Nadu	0.45	1.466
26	Telangana	-	-
27	Tripura	0.33	0.33
28	Uttar Pradesh	7.336	7.34
29	Uttarakhand	-	0.002
30	West Bengal	2.65	3.08
31	A&N	-	0.03
32	Lakshadweep	-	-
33	Puducherry	-	0.05
	Total	40 Mha	49.815 Mha

Earlier, efforts were made to assess flood prone areas in India, however due to constraints of time and data, any identification of Flood Prone Areas could not be evolved scientifically. Hence, to achieve this objective and in line with the suggestions of erstwhile Planning Commission, the then MoWR, RD & GR had constituted an Expert Committee in 2012 under Chairman, CWC with members from NDMA, SoI, NRSC, IMD, GFCC, and IITs etc. for scientific assessment of flood prone areas in India. The Expert Committee has held 6 meetings so far. During the 2nd meeting of the Expert Committee, it was also decided to constitute Regional Committees for each state with Principal Secretaries of Water Resources Department as its Chairman and Regional Chief Engineer/ Director of CWC as its Member Secretary.

Various methodologies for arriving at the scientific assessment of flood prone areas were deliberated by the Expert Committee. The Expert Committee took note that satellite remote sensing is a powerful tool to map flooded areas and is also currently a low-cost tool that can be profitably exploited for flood mapping.

After thorough and extensive deliberations, the Committee directed that, the state-wise flood prone areas delineated by CWC shall be sent to the regional committees for ground truth verification by States/UTs.

Accordingly, flood prone area maps have been sent to respective States/ UTs for ground truth verification through Regional Committees. After receiving the ground truth verified final layers from all the States/ UTs, the aggregated extent of flood prone area in India will be derived and will be submitted for the acceptance of Expert Committee.

However, some of the limitations of the study are (a) the time of the satellite pass with respect to the time of the flood peak; (b) the spatial resolution of satellite; (c) the sensors type (e.g., SAR or multispectral); (d) the sky conditions; (e) the land-use and morphology of the flooded area; (f) the type of data processing.

FLOOD PLAIN ZONING

Introduction

To understand the importance of Flood Plain Zoning, it is essential to understand flood plain and its importance. Usually during lean season, a river is mainly confines to its main channel, but as the water level rises during monsoon, the river spread laterally and its water inundates the area on both side of the main channel forming its floodplain. The flood plain may be defined as any area susceptible of being inundated by flood waters. It includes water channel (floodway) and flood channel inundated during high flows (flood fringes). Flood Plain is, therefore, the area of river spread during high stages.

Flood Plain Zoning

The Flood plain zoning is a non-structural measure aiming at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones. Basic concept of Flood Plain Zoning is to regulate land use in flood plain to restrict damage caused by flood. It aims at determining location and extent of area for development activity. Flood plain zoning includes mapping of all the vulnerable floodplains with clearly defined, no-development and regulatory zones.

Benefits of Flood Plain Zoning

The benefits of Flood Plain Zoning include:

- Damage of Life and property is reduced
- Providing habitat for aquatic, riparian, and terrestrial plants, invertebrates, birds and animals
- Improved groundwater recharge & base flow.
- Spread of fertile silt in flood plain, thus reduction of dependence on chemical fertilisers & irrigation

Background

Central Water Commission (CWC) has been continuously pursuing the States to take follow up action to implement Flood Plain Zoning approach. A model draft bill for Flood Plain Zoning legislation was circulated in 1975. Manipur enacted the bill in 1978, however, demarcation of Flood Zone is yet to be done. Rajasthan also enacted the bill in 1997 but is yet to be enforced. The State of Uttrakhand also formulated the Act in 2012 to provide for zoning of flood plain of the rivers in Uttrakhand.

In reference to O.A. No. 200/2104, M.C. Mehta Vs UOI & Ors, Hon'ble National Green Tribunal (NGT) describes the River Ganga Matter in phased manner as under:

Phase-I	:	Gaumukh to Kanpur.
		Segment-A: Gaumukh to Haridwar.
		Segment B: Haridwar to Kanpur.
Phase-II	:	Kanpur to Uttar Pradesh Border.
Phase-III	:	UP Border to Jharkhand Border (via Bihar).
Phase-IV	:	Jharkhand Border to Bay of Bengal (West Bengal).

In pursuance to directions contained in the judgment passed by Hon'ble NGT on 13.07.2017, CWC has Identified and demarcated the flood plains of river Ganga in segment B of Phase- I (Haridwar to Unnao) on one in twenty five year's cycle or appropriately also has Identified no development/construction zone, regulatory zone and the activities that can be/cannot be carried on in the regulatory zone of the floodplain.

Fig. 9: Different Flood Plain Zones & Respective Activities

S. No.	Priority	LAND USE
1	Priority 1 (Above Warning Zone)	Defence installations Industries Public utilities like hospitals, electricity installations, water supply, telephone exchange, aerodromes, railways stations, commercial centres, etc. Buildings should be located in such a fashion that they are above the levels corresponding to a 100 year flood frequency or the maximum observed flood levels.
2	Priority 2 (Restrictive Zone)	Public institutions Government offices, universities, public libraries and residential areas. Buildings should be above a level corresponding to a 25-year flood or a 10-year rainfall with stipulation that all buildings in vulnerable zones should be constructed on columns or stilts.
3	Priority 3 (Prohibitive Zone)	Parks and playgrounds-Infrastructure such as playgrounds and parks can be located in areas vulnerable to frequent floods.

'Prohibitive zone' is also termed as 'No Development Zone' and 'Restrictive Zone as 'Regulatory Zone'. For Flood Plain Zoning broad demarcation of area is carried out in reference to inundation of area by flood of different return period i.e. 5, 10, 25 & 50 year return period.

Coastal Protection and Role of CWC

As per allocation of business rule 1961, Sea Erosion is one of the mandate of DoWR, RD&GR under Ministry of Jal Shakti. Realizing the need of overall planning and cost effective solution to the coastal problems, the Govt. of India constituted the Beach Erosion Board in the year 1966 under the Chairmanship of Chairman, CWC (erstwhile CW&PC) initially, to guide and implement the programme of anti-sea erosion works in Kerala only. The Govt. of India reconstituted the Board in 1971 and further in 1989 extending its jurisdiction to the entire coastline of the country.

With the objective of the development in the protected coastal zone and the pressure of population in the densely populated area in the coastal zone, the Beach Erosion Board was reconstituted and renamed as "Coastal Protection and Development Advisory Committee" (CPDAC) with its Secretariat at the CWC to identify and develop the various resource potential available behind the protected areas.

Coastal Protection and Development Advisory Committee provides a common platform to all concerned maritime States/UTs to discuss issues related to coastal protection and development. The Committee has given its recommendations in the past on various coastal related issues. **Under the aegis of the CPDAC, various initiaves have been taken in the past by CWC.**

1. **National Coastal Protection Project and External Assistance**

   With the discontinuation of Central Loan Assistance, the State Govts/Union Territories started facing financial difficulties in funding the anti-sea erosion works. The beach protection works suffered serious setback due to paucity of funds with the State Govts. The State Govts. approached the Govt. of India for locating source of funding for anti-sea erosion works. Realizing the setback received in the progress of coastal protection works in the maritime States, the Beach Erosion Board, in its 23rd meeting, held in July, 1994, requested the maritime States to formulate the proposals for protection of coastal reaches from sea erosion at vulnerable reaches in their respective states and send the proposals to Central Water Commission who will coordinate and prepare a consolidated National Coastal Protection Project (NCPP) based on their proposals, for posing the same for external Assistance.

   After discussion between GoI and Asian Development Bank (ADB) for funding on coastal protection works, ADB approved grant for Project Preparatory Technical Assistance (PPTA). The PPTA was used to prepare an investment programme for Sustainable Coastal Protection and Management Project in the States of Goa, Maharashtra and Karnataka. The Terms of Reference (ToR) of PPTA also included preparation of one or two projects in each participating state for immediate implementation based on state's priority. After appraisal of CWC, the Ullal (Karnataka) and Mirya Bay (Maharashtra) pilot project were approved by Advisory of Committee of DoWR, RD&GR. Further to above, the Government of India and the Asian Development Bank (ADB) signed an agreement for $51.555 Million loan under the Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) in year 2011 for these two projects. The Ullal Project (Karnataka) proposed a hybrid solution, comprising of several components like Beach nourishment, two offshore reefs, near shore berms etc. Two submerged offshore reefs were constructed to dissipate incoming wave energy and stabilize the beach nourishment placed on shore. This was new concept of coastal protection in India. The additional projects for the State of Karnataka were appraised by CWC and after acceptance of Advisory Committee of DoWR, RD&GR, these were implemented under the Tranche-II loan for SCP&MIP.

2. Climate Resilient Coastal Protection and Management Project

During the year 2014, an agreement was signed by the GoI with ADB for Technical Assistance (TA) programme namely Climate Resilient Coastal Protection and Management Project (CRCP&MP) to support mainstreaming of climate change consideration into coastal protection and management at the national level and in the two focal states (of Karnataka and Maharashtra) where the Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) was already operational under external assistance from ADB. This TA was financed by grant from Global Environment Facility (GEF) & administered by Asian Development Bank (ADB). CWC was the overall coordinator of the Project and apart from other activities, the Guidelines for Climate Change Adaptation for the Indian coast was prepared under the programme. Impact of climate change was also analysed through various institutes for parameters such as Wave, Sea Level Rise, Storm Surge and other meteorological parameters.

3. Shoreline Change Atlas of Indian Coast

There was no systematic inventory of shoreline changes occurring along the entire Indian coast on 1 : 25,000 scale, which is required for planning measures to be taken up for protecting the coast at the national level. Under the aegis of CPDAC, a project namely "Shoreline Change Atlas of the Indian Coast" was funded by CWC in year 2010 in collaboration with Space Applications Centre (ISRO), Ahmedabad. Firstly the assessment of the Shoreline change was done based on the timeframe from 1989-91 to 2004-2006. The latest assessment was updated for the timeframe during 2004-06 to 2014-16. Their findings have been summarized in the Table as under.

Sl No.	State	Erosion Area (in ha)	Erosion Length (in km)	Accretion area (in ha)	Accretion Length (in km)	Stable Length (in km)	Total Length (in km)
1	Gujarat, Daman & Diu	313.6	109.76	207.75	49.18	1051.44	1210.4
2	Maharashtra	104.75	75.16	209.94	60.27	588.64	724.07
3	Goa	28.78	21.7	13.6	7.13	116.73	145.56
4	Karnataka	72.05	40.19	111.39	47.74	230.86	318.78
5	Kerala	285.02	137.33	303.3	121.13	327.17	585.63
6	Tamil Nadu and Puducherry	358.35	128.88	470.68	188.6	531.57	849.07
7	Andhra Pradesh	795.67	188.95	807.88	208.15	413.33	810.4
8	Odisha	831.35	143.6	753.5	98.77	208.19	450.53
9	West Bengal	393.67	56.3	141.18	33.9	67.24	157.45
10	Lakshadweep Islands	16.59	11.65	18.4	13.15	115.84	140.66
11	Andaman-Nicobar Islands	480.08	230.77	1004.01	256.31	1669.7	2156.79
	Total	**3679.91**	**1144.29**	**4041.63**	**1084.33**	**5320.71**	**7549.34**

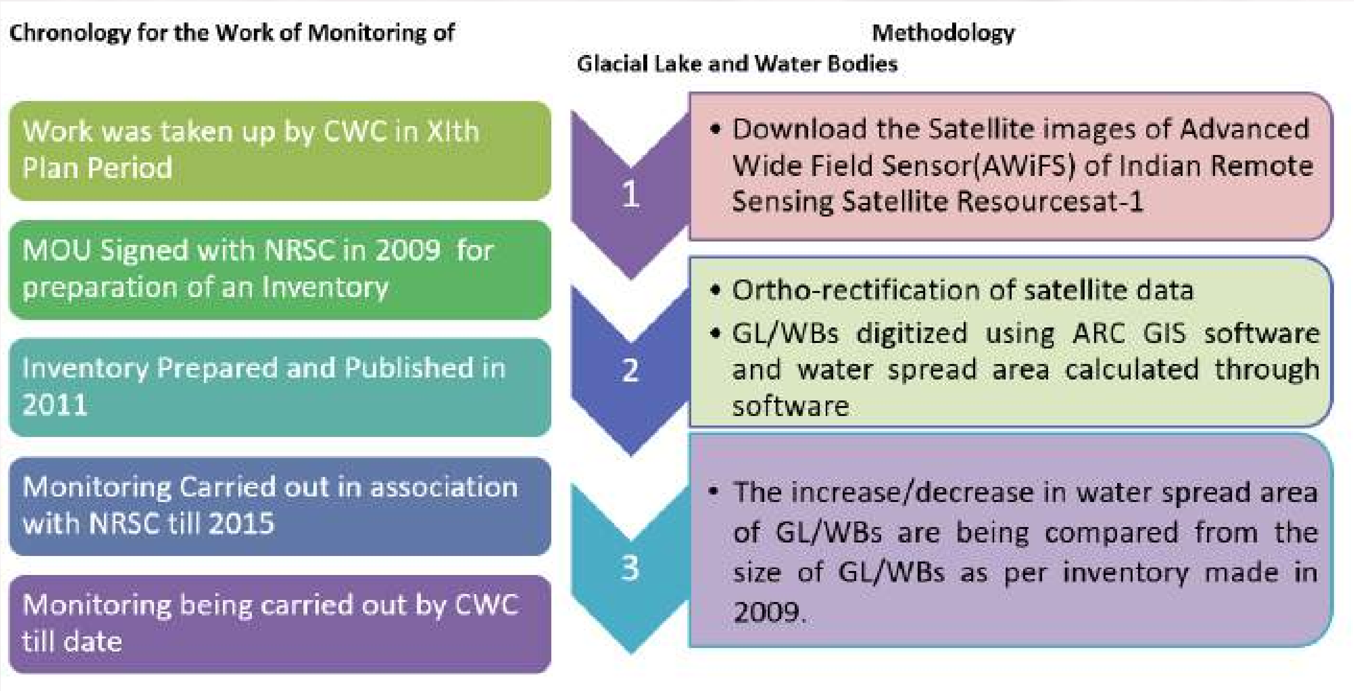
4. **Coastal Management Information System (CMIS)**

CWC has vast data collection network and data for Riverine Processes. However, such data/network is not available for coastal processes. For proper Coastal Protection, understanding of various coastal processes and cause of erosion need to be identified first. Vast set of data on Sediment transport, wave, tides, bathymetry, geological data, satellite imageries etc. is required to analyze the problem. Hence, need for a comprehensive Coastal Management Information System (CMIS) was keenly felt. In this regard, CWC streamlined the coastal data collection process and guidelines and collaborated with various institutes for setting up the sites. Presently establishment of three sites has been completed and five sites are in progress. Further an expansion of sites is proposed in present plan period (2021-26) to establish a network of Coastal sites covering to most of maritime states.

GLACIAL LAKE MONITORING

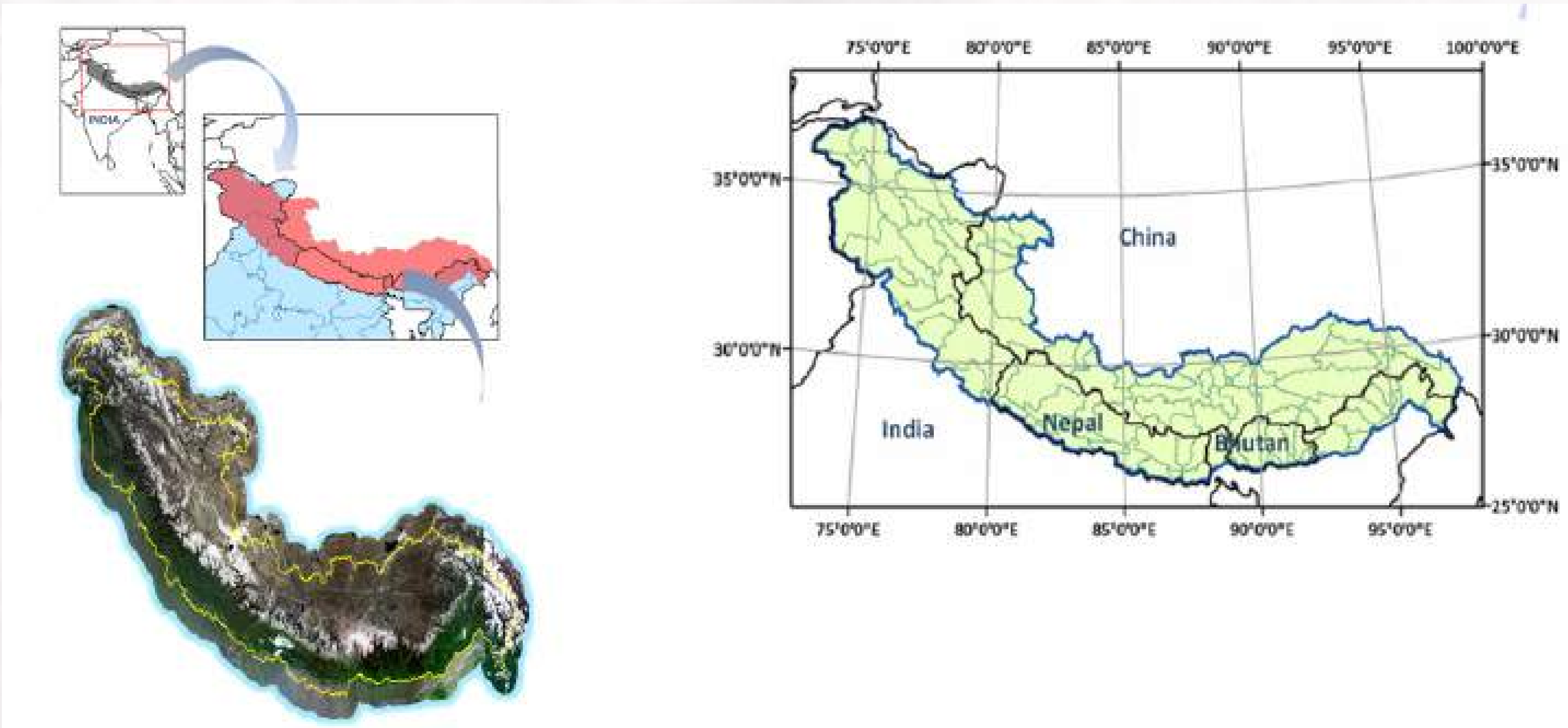
- When glacial ice or moraines impound water, glacial lakes are formed.
- The moraine creates topographic depression in which the melt water is generally accumulated leading to formation of glacial lake. When this lake is watertight, melt waters will accumulate in the basin until seepage or overflow limits the lake level. Such moraine-dammed lakes appear to be the most common type of glacial lakes.
- The impoundment of the lake may be unstable, leading to sudden release of large quantities of stored water.
- Flash floods caused by the outburst of glacial lakes, called as Glacial Lake Outburst Flood (GLOF), and are well known in Himalaya.

Fig. 10: Glacial Lakes, dammed by rocks and/or ice jams, can burst suddenly and cause catastrophic damage in nearby communities. Photo: National Park Service

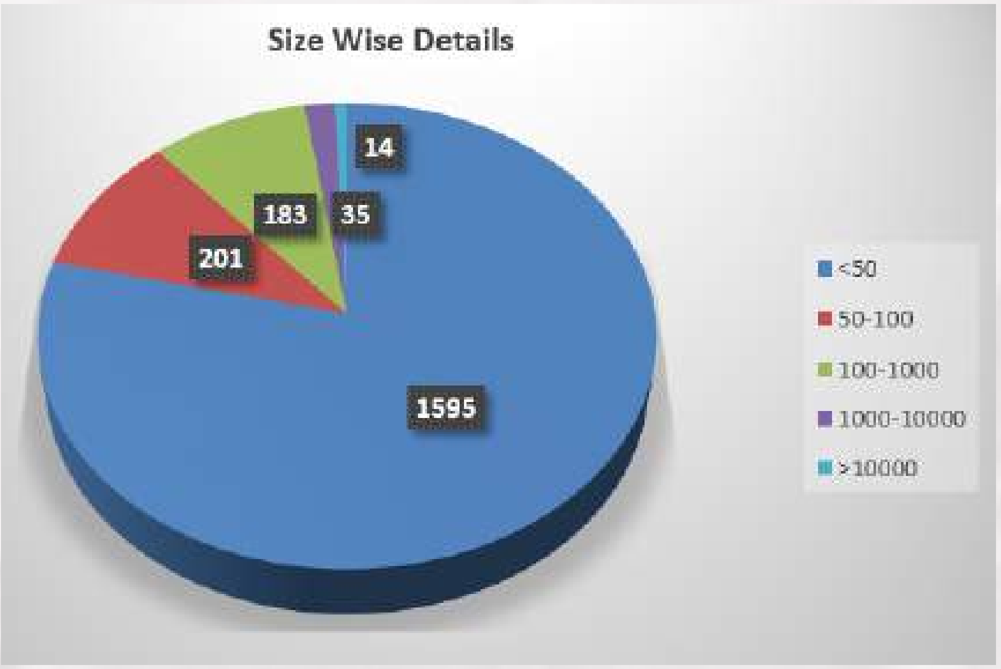


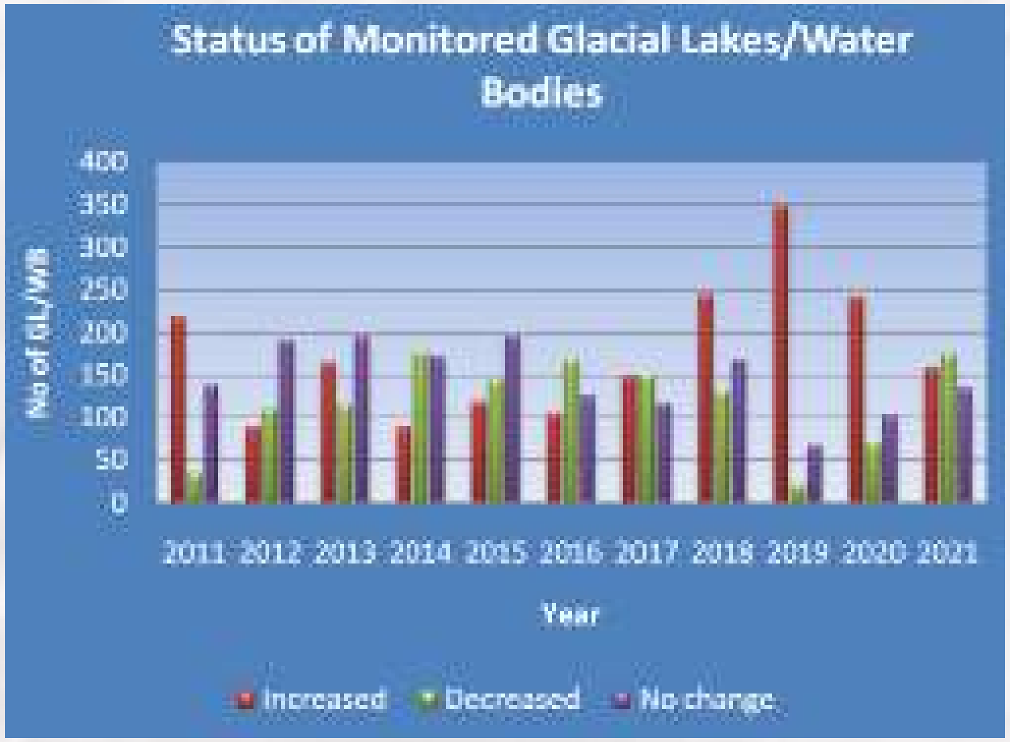
Study Area:

The present study is carried out for the area covering Indian Himalayas. The study area extends across different countries namely India, Nepal, Bhutan and China. The index map showing study area is given in Figure below:



Details of Glacial Lakes / Water Bodies (having water spread area more than 10 Ha) in the Himalayan region catchment which contributes to rivers flowing in India





8

Planning of Water Resources Projects

APPRAISAL OF MAJOR, MEDIUM AND MULTIPURPOSE PROJECTS

- Preparation of Guidelines
- E-PAMS

MONITORING OF THE PROJECTS

NATIONAL PROJECTS

- LIST OF NATIONAL PROJECTS

ROLE OF CW&PC / CWC IN ACHIEVING INTER-STATE COOPERATION IN WATER RESOURCES SECTOR

- Achievements
- Status of Tribunals

PERFORMANCE ASSESSMENT OF IRRIGATION PROJECTS

NEW INITIATIVE SUPPORT FOR IRRIGATION MODERNIZATION PROGRAMME (SIMP)

RESERVOIR STORAGE MONITORING IN THE COUNTRY

Planning of Water Resources Projects

APPRAISAL OF MAJOR, MEDIUM AND MULTIPURPOSE PROJECTS

Irrigation and Multipurpose Projects are investigated, formulated and implemented by the concerned State Governments. However, these used to be accepted by the erstwhile Planning Commission for inclusion in the Plans before they were taken up for implementation by the concerned States.

A committee for recommending projects to be included in 2nd FYP was set up by the Planning Commission in 1954. CWC was entrusted with the responsibility of examination of technical and economic feasibility of Multipurpose, Major and Medium Irrigation Projects since 1954.

Later, Planning Commission constituted an Advisory committee for Irrigation, Flood Control and Multipurpose projects in 1976. The Committee was entrusted with the function of getting the project examined by the Central Water Commission and Central Electricity Authority, as required to determine their techno-economic viability. Subsequently, in 1987, Advisory Committee of Planning Commission was replaced by an Advisory Committee in Ministry of Water resources under the chairmanship of Secretary (WR)

Since then, in past 68 years, CWC has examined and is examining techno economic aspects of all important water resources projects in India and thereby developed in-house expertise in all important aspects of the water resources projects viz., hydrology, irrigation planning, inter-state matters, design of Dams, Barrages, Power Houses and Canals, basin planning, construction methodology and cost engineering. Besides the projects of India, CWC also provides techno-economic inputs for International Projects from countries like Nepal, Bhutan, Afghanistan. Myanmar and Africa etc. on need basis.

The first meeting of the Advisory Committee of Planning Commission was held on 18.12.1976. Since then till date 149 meeting of the Advisory Committee of both Planning Commission and MoWR, RD & GR took place and **1580** project proposals including flood control and coastal erosion projects were considered and approved by the Advisory committee.

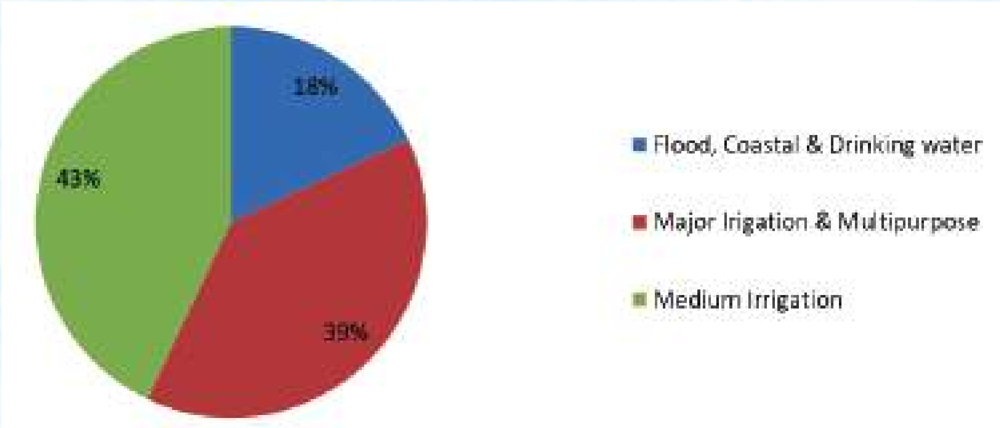


Fig. 1: Distribution of different category of projects accepted by Advisory committee of DoWR, RD & GR.

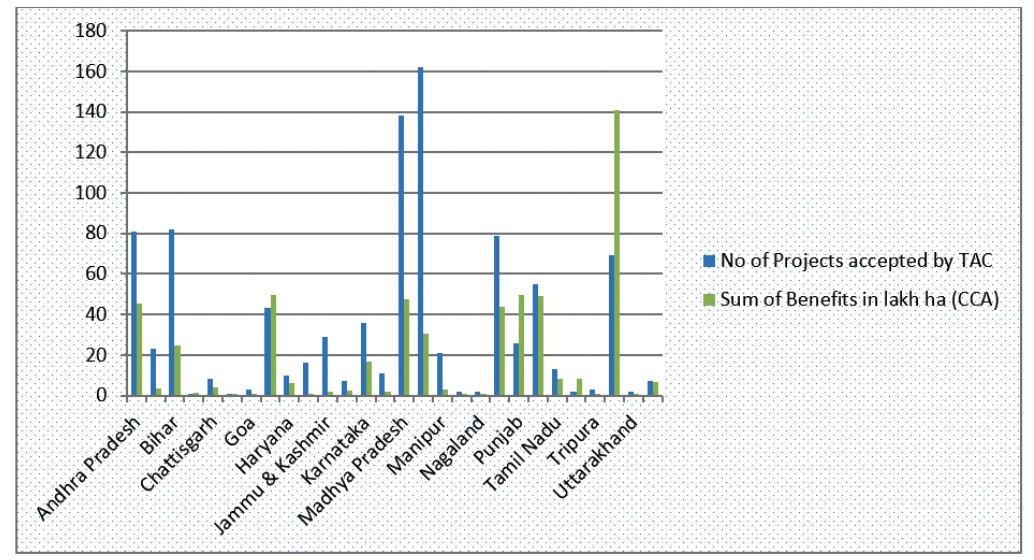


Fig. 2: No of Irrigation Projects and its corresponding CCA coverage as accepted by the Advisory Committee of DoWR, RD & GR.

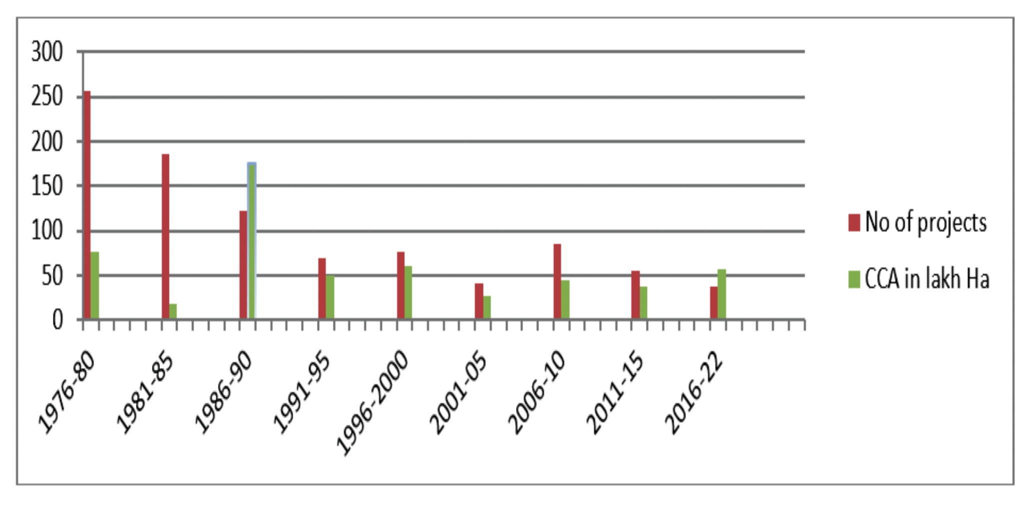


Fig. 3: No of projects and corresponding CCA (in 5yrs span) accepted by the Advisory Committee of DoWR, RD & GR.

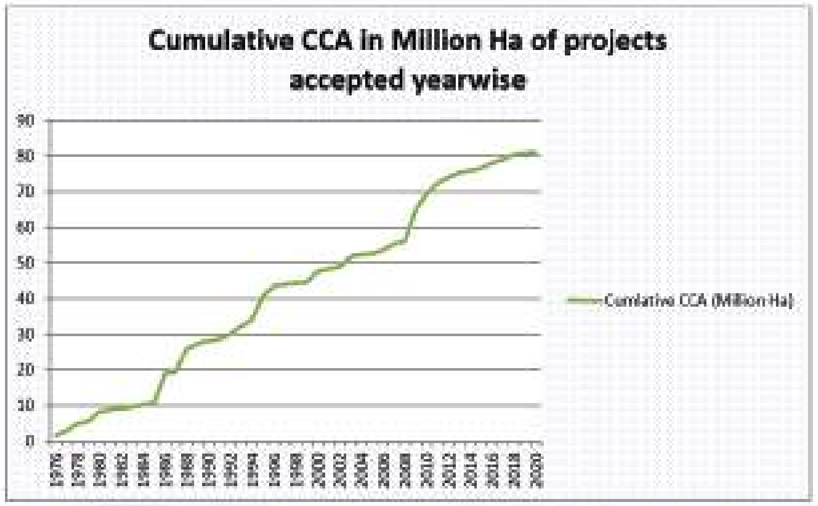


Fig. 4: Year-wise cumulative CCA of projects accepted by the Advisory Committee of DoWR, RD & GR.

Preparation of Guidelines

In 1973, Expert Committee on rise of cost of Irrigation and Multipurpose Projects recommended for a guidelines by the CW&PC for the investigations to be carried out and preparation of the Project Report for approval of Planning Commission. Subsequently, the first guidelines for Preparation of Detailed Project Report of Irrigation and Multipurpose Projects were finalized in 1980. These Guidelines f have been revised lastly in 2010.

Further, the Guidelines for Submission, Appraisal and Clearance of Irrigation and Multipurpose Project were prepared by CWC in 1989 which have been revised in 2017.

E-PAMS

Online submission of project proposals (PFR/DPR) through the web-enabled e-PAMS (Project Appraisal Management System) has been launched in 2019 is an effort for transparent and both way communication between CWC & State Government in appraisal process.

Fig. 5: E-PAMS Portal for submission and appraisal of Irrigation & Flood control projects

Fig. 6: E-PAMS Portal - Dashboard

MONITORING OF THE PROJECTS

- CWC has been entrusted with the responsibility of monitoring projects as recommended by the State Irrigation Ministers in the conferences of 1975 & 1976. CWC monitors inter-state/externally assisted/centrally sponsored projects with the objective of their timely completion.
- Since Independence many new irrigation projects have been taken up to create water and food security in India. However, the completion of projects got delayed due to various reasons and paucity of funds. This resulted in the locking up of the huge investment. Central Government, during 1996-97, launched an Accelerated Irrigation Benefits Programme (AIBP) to provide Central Loan Assistance (CLA) to major/medium irrigation projects in the country, with the objective to accelerate the implementation of those projects which were beyond resource capability of the states or were in advanced stage of completion. While selecting the projects, special emphasis was to be given to Pre-fifth and Fifth Plan projects. Priorities were also given to those projects which were benefiting Tribal and Drought Prone Areas.
- Since inception altogether 297 major and medium irrigation projects have been included under AIBP out of which 143 projects have been completed and five projects have been deferred, leaving 149 projects as ongoing as on March, 2015. During 2015-16, the AIBP was subsumed in the umbrella scheme of PradhanMantriKrishiSinchayeeYojana (PMKSY). Under PMKSY-AIBP, 99 ongoing AIBP projects (and 7 phases) from different States and UTs were identified and prioritized for completion in phases in a Mission Mode with cost estimate of Rs. 77595 Crore. The balance irrigation potential of these projects was 3.464 million hectare as on 1st April, 2016.
- Central Water Commission with the help of its regional offices conducts the monitoring of these projects covered under the PMKSY-AIBP spread all over the country as was case with AIBP Projects earlier. Extensive review & monitoring mechanism has been put in place to ensure that the bottlenecks encountered in the execution of these projects are timely addressed. All major and medium projects where funds have been released in the previous year are to be monitored twice in a year and a monitoring report is to be prepared by concerned field office of CWC. CWC also highlights the bottlenecks in the projects and regular follow up is done with the State Government for their timely resolution.
- Central Water Commission (CWC) had also used the satellite data and web services through ISRO-Bhuvan and publicly available software for online monitoring of ongoing AIBP projects biannually (pre monsoon & post-monsoon). It facilitated in identifying the critical gaps and bottlenecks in the projects.
- During 2016-2021, Central assistance of Rs. 12,999 crore were recommended by the CWC for the release to the prioritized AIBP Projects. Dedicated efforts resulted into the completion of forty-six (46) of these prioritized projects. Further, out of balance projects, 21 projects have progress of more than 90 % and 14 projects have progress between 80 to 90 %.During 2016-21, additional irrigation potential of 2.274 million hectare has been created through these projects.
- Out of these 99 projects and 7 phases (Total- 106), 59 projects benefit Drought prone areas (DPAP) whose Ultimate Irrigation Potential is 4.703 million hectare. Out of which 2.656 million hectare had been created upto 31st March, 2016. During 2016-2021, additional potential of 1.337 million hectarehas been created through these projects, 24 of these projects have been completed so far.

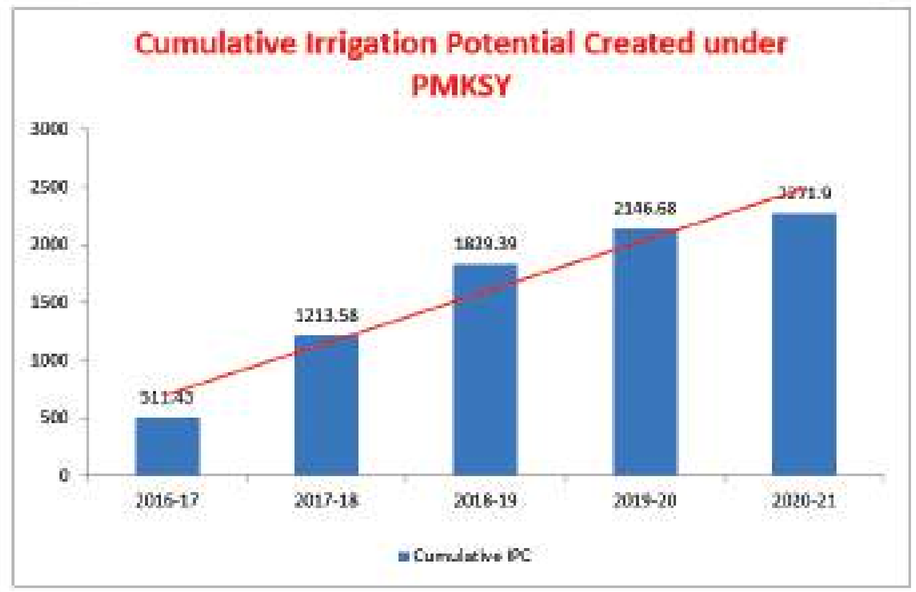
- Various reforms measures have been undertaken under PMKSY-AIBP since inception; for streamlining the process which are as under:
- a. Fast Track Performa Clearance (FTPC) has been introduced for approving the revision in cost of the prioritized projects where cost revision is in excess of 20% of the originally approved cost. It has considerably reduced the time taken earlier in the approval of revised cost estimates of the project.
- b. Innovation in Funding Mechanism was implemented by making the arrangements of funds for both Central Assistance (CA) and State Share component through National Bank for Agriculture and Rural Development(NABARD) under Long Term Irrigation Fund (LTIF). States can borrow their share of cost from NABARD at a reduced rate of interest of 6% p.a. Central Government bears the cost of interest subvention on loan availed by States so as to make the lending rate 6% p.a.
- c. Modifications in the guidelines of the scheme have been made to make the process of fund releases more expeditious.
- PMKSY-AIBP (including CADWM) scheme was valid till March, 2021. The proposal for its extension for the period 2021-26 has been approved. The continuation of Pradhan Mantra Krishi SinchaiYojana (PMKSY) for 2021 to 2026 with an outlay of Rs. 93,068.0 crore including Rs. 37,454 crore Central Assistance to States. Under the continuing scheme it is planned to provide financial assistance for completion of 60 ongoing Major/Medium Irrigation projects under PMKSY-AIBP, 85 ongoing CADWM projects and financial assistance to new Major/Medium irrigation projects including ERM projects. In the March 2022, five (05) more projects have been included in the AIBP scheme.
- In September, 2018, Government of India approved the implementation of "Relining of Sirhind Feeder (RD 119700 to 447927) and relining of Rajasthan Feeder (RD 179000 to 496000)" with the approved cost of Rs. 1976.75 crore (Rs. 671.478 Cr for Sirhind Feeder and Rs. 1305.267 Cr for Rajasthan Feeder). Out of the total estimated cost, Rs. 826.168 crore would be provided as Central Assistance (Rs. 205.758 crore for Sirhind Feeder and Rs. 620.41 crore for Rajasthan Feeder) in addition to Rs 155.84crore of central assistance earlier released for these projects.
- Relining of Rajasthan Feeder envisages to save560 cusec of water leading to stabilization/ improvement of irrigation in 98,739 ha of area in Rajasthan. Relining of Sirhind Feeder envisages saving 256 cusec of water leading to stabilization/ improvement of irrigation in 69,096 ha of area (20740 ha. in Rajasthan and 48356 ha. in Punjab). Completion of relining works would address water-logging in 84800 ha of land in Muktsar, Faridkot and Ferozpur districts in South-West Punjab.
- An Expert Project Review Committee has been constituted in May 2019 under Chairmanship of Member (WP&P), CWC to guide/ oversee the overall implementation of "Relining of Sirhind Feeder from RD 119700 to 447927 and Relining of Rajasthan Feeder from RD 179000 to 496000 of Punjab" till completion and to examine the progress of the work from all angles. The Committee has visited the project site twice and last visit was held on 10-12-2021. Further, 4 meetings of the Committee has been held so far. The last meeting was held on 01-08-2022, during which discussions were held to firm up need for extension of project completion timeline, revised work plan for balance relining work of Rajasthan Feeder and Sirhind Feeder and revision of cost of the project.
- The total expenditure incurred for Relining of Sirhind Feeder up to July, 2022 is Rs 499.53 cr and Overall progress is 74% up to July, 2022(approx. 84 km relined out of 100 Km). The total expenditure incurred for relining of Rajasthan Feeder up to July 2022 Rs735.3 cr and Overall progress is approx. 55% up to July/2022 (approx. 63.12 km relined out of 96.65 Km).

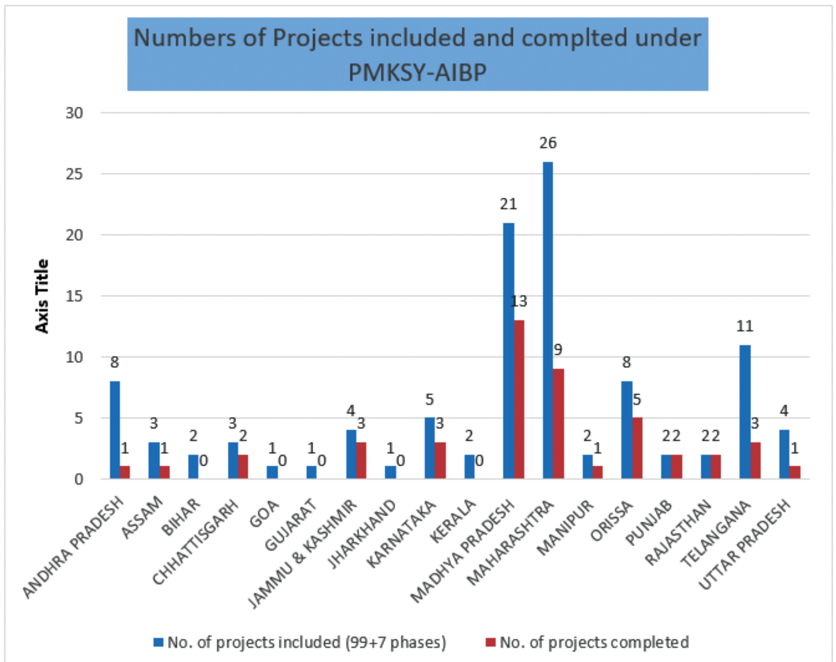
Fig. 8: Photographs of 2nd visit of Expert Project Review Committee to Rajasthan Feeder and Sirhind Feeder Project

- Apart from PMKSY, a Special Package for completion of irrigation projects to address agrarian distress in Vidarbha, Marathwada and other chronically drought prone areas of Rest of Maharashtra has been approved during 2018-19. Under the Special Package, 8 MMI projects and 83 SMI projects with a balance cost of Rs. 13,651.607 crore as on 1st April, 2018 are planned to be completed in a phased manner up to 2022-23. The targeted additional potential through these projects is 3.77 lac ha. These projects have created 1.114 lac ha of potential during 2018-19 to 2020-21. Twenty six (26) SMI projects have been completed.of Underground Pipelines (UGPL) in the Distribution Network of the projects has been actively promoted for increasing the water conveyance efficiency and overcoming the issues related to Land Acquisition. Use of UGPL has also resulted in cost saving in comparison to the conventional open canal system because of doing away with the requirement of acquiring the land. Guidelines for Piped Irrigation Network were issued in July'2017 for promoting its use in the DISNET of Irrigation projects. More than 25 projects out of prioritized PMKSY-AIBP projects have used the UGPL in their DISNET.
- The use of Modern Technology has also been made for review of the progress of works in projects. An online Management Information System (MIS) has been developed to review the progress of works in projects. A nodal officer for each of the prioritized projects has been nominated by the concerned project authority,who is responsible for regular updating the progress on the MIS.
- Remote Sensing techniques have been used to assess the cropped area in the command area of the prioritized projects. It depicts the land under cultivation in the project command thus indicating the water actually reaching the farms of the farmer.
- A mobile application has been developed for geotagging the project components.
- Project command along with the canal network of all the prioritized projects has been digitized on a GIS platform using satellite imageries.

It shows the year-wise status of completion of canal network. It also hosts the geo-tagged data from the mobile application.

- CADWM Programme aims for bridging the gap between irrigation potential created and that utilized through micro level infrastructure development directed at bringing hydraulic connectivity to the tail-end farms through greater penetration of lined field channels.In addition, Structural intervention also envisages improvement in water use efficiency through creation of infrastructure for micro-irrigation in an area of about 10% of the canal irrigated command. Field units of central water Commission are also responsible for the monitoring of CADWM Projects.
- In addition, Surface Minor Irrigation Schemes arealso monitored periodically on sample basis (at least 20% of MI Schemes) by the concerned Regional Offices of Central Water Commission and assessed against predetermined targets set by the Ministry of Jal Shakti.





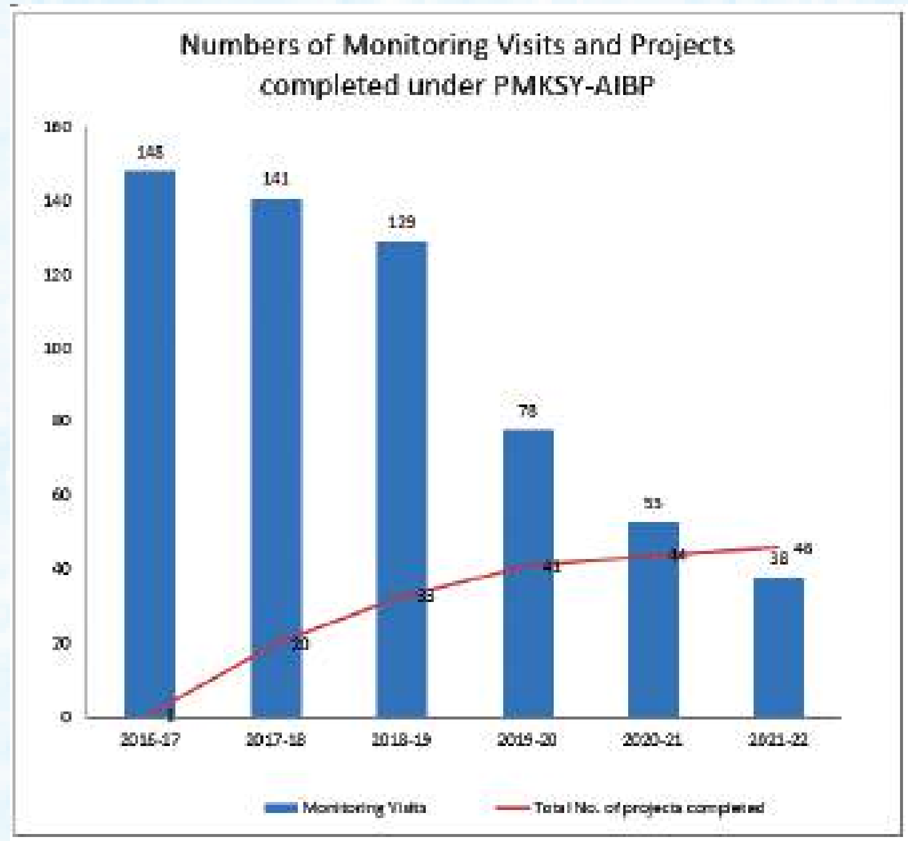


Fig. 7: Sardar Sarovar Multi Purpose Project, Gujarat

Fig. 8: Punasa Dam, Indira Sagar Irrigation Project, Madhya Pradesh

Fig. 9: Bham Dam, Nandur Madhmeshwar Project, Maharshtra

Fig. 10: Narmada Tapti Kachhar, Indore

Fig. 11: Girija Barrage Uttar Pradesh

Fig. 12: Saryu Nahar Pariyojana Uttar Pradesh

Fig. 13: Rani Avanti bai Lodhi Sagar Project, Jabalpur (Bargi Dam)

Fig. 14: Dongargaon Irrigation Project, Maharashtra

Fig. 15: Bargi Dam Project Phase-I

Fig. 16: Lower Panzara (AKKALPADA) Medium Irrigation Project

Fig. 17: Mahuar Irrigation Project, M.P.

Fig. 18: Cross Regulator at Main Canal Rd 140.085 Km, ISP Phase I & II Project, M.P

Fig. 19: Sagad Dam, M.P.

Fig. 20: Satak Aquaduct at Main Canal Rd 140.140 Km, ISP Phase I & II Project, M.P.

In February 2008, the Government of India approved a scheme of National Projects with a view to expedite completion of identified National Projects for development of Water Resources in the Country and for the benefit of the people.

The Government of India initially declared 14 projects as National Projects in February 2008.

Later, Cabinet Committee on Infrastructure approved inclusion of Saryu Nahar Pariyojana of Uttar Pradesh in the scheme of National Project on 3rd August, 2012. Polavaram Irrigation Project of Andhra Pradesh was included under the scheme of National Projects vide Gazette notification dated 01.03.2014 under Section 90 of 'Andhra Pradesh Re-Organization Act'

Out of 16 projects included in the scheme of National Projects, eight projects, namely, Gosikhurd Project of Maharashtra, Shahpur Kandi of Punjab, Teesta Barrage Project of West Bengal, Saryu Nahar Pariyojana of Uttar Pradesh, Polavaram Irrigation Project of Andhra Pradesh, Lakhwar Multi-Purpose Project of Uttarakhand, Renuka Dam Project of Himachal Pradesh and Ken-Betwa Link Project of Madhya Pradesh & Uttar Pradesh are under execution.

The provision of Central Assistance for National Projects has been included in the PMKSY. Accordingly, Government of India provides Central Assistance for the cost of irrigation & drinking water component of these National Projects in the form of central grant for their completion in a time bound manner. Central Water Commission examines and recommends Central Assistance Proposal as submitted by the Project Authorities to DoWR, RD & GR, MoJS. Further, these projects are given technical advice and are being regularly monitored by Central Water Commission.

Brief of achievements for following National Projects are as under:

1. Saryu Nahar Pariyojana (Uttar Pradesh):

- The Saryu Nahar Pariyojana was originally conceived as Left Bank Ghaghara Canal project in the year 1974 to irrigate 267.00 Th. ha in the districts of Bahraich and Gonda. It was reformulated in 1980by changing and enlarging its scope and was renamed as Saryu Nahar Pariyojana.
- Gross Command Area (GCA) under entire Saryu Nahar Pariyojana is 16.0 Lakhs Ha while the Culturable Command Area (CCA) is 11.29 Lakh Ha. The Ultimate Irrigation Potential of the whole project is 14.04 Lakh ha with Irrigation intensity of 124%.
- Implementation of this project has been done in three phases. Two phases have been completed and the 3rd Phase is being implemented at present. In third phase, balance works of Saryu System and new works in Rapti System with total IP of 4.73 lakh ha are covered which are being funded under National Project Scheme of PMKSY from August, 2012.
- The project interlinks 5 rivers i.e. Ghaghra, Saryu, Rapti, Banganga and Rohini in the Ghaghrabasin and provide benefits to nine Districts of Uttar Pradesh (Bahraich, Shrawasti, Balrampur, Gonda, Basti, Sant-kabirnagar, Gorakhpur, Sidharthnagar, Maharajganj) with Irrigation Potential envisaged as 4.73 Lac Ha (under National Project) after completion.
- The Cost of the project is Rs. 9802.67 Cr at PL 2016 includes the cost of National Project component of Rs. 5803.61 Cr.

- Apart from technical advice, the project is being monitored time to time by CWC. As on 31.03.2022, Central Assistance of Rs. 2272.123 Cr has been recommended by CWC to DoWR, RD & GR, MoJS
- The project was inaugurated by Hon'ble PM on 11.12.2021. The formal completion of the project is expected in December 2022.

Fig. 21: Inauguration of Saryu Nahar Pariyojana in Uttar Pradesh by Hon'ble Prime Minister

Hon'ble PM with Hon'ble Minister of Jal Shakti and Hon'ble CM of Uttar Pradesh at inaugural function of Saryu Nahar Pariyojana in Uttar Pradesh

2. Gosikhurd Irrigation Project in Maharashtra:

- Gosikhurd National Project was declared National Project in Feb 2008. The project envisages construction of an earthen dam across River Wainganga, a tributary of river Godavari in Maharashtra.
- The project will provide irrigation benefits to 2,50,800 ha (Ultimate Irrigation potential) along with other benefits.
- The districts benefitted are Bhandara, Nagpur and Chandrapur.
- Fast Track Proforma Clearance of Revised Cost Estimate (RCE) in respect of Gosikhurd Irrigation Project (National Project), Maharashtra, Estimated Cost Rs. 18494.57 Cr (Cost of component National Project = Rs 12770.09 Cr) at PL 2012-13 of WRD and 2013-14 of PWD had been appraised in CWC and was accepted with certain conditions vide CWC OM date 11.12.2017.
- Apart from technical advice, the project is being monitored time to time by CWC in Nagpur.

Visit of CWC team to Gosikhurd Irrigation Project in Maharashtra

Spillway of Gosikhurd Irrigation Project in Maharashtra

View of Spillway of Polavaram Irrigation Project in Andhra Pradesh

3. Polavaram Irrigation Project in Andhra Pradesh

- The Polavaram Irrigation Project envisages construction of a dam across river Godavari in West / East Godavari District of Andhra Pradesh.
- The project had been declared as National Project through Gazette Notification dated 01st March 2014 regarding "Andhra Pradesh Re-Organization Act 2014".
- The project would create ultimate irrigation potential of 4.36 Lakh Ha (Kharif-2.91 + Rabi-1.45), power generation with installed capacity of 960 MW, supply 23.44 TMC of water to meet the needs of drinking water and industrial areas in and around Visakhapatnam and divert 80 TMC of water to Krishna basin upstream of Prakasam Barrage.
- The estimated cost of the project is Rs. 29,027.95 Cr @ 2013- 14 PL (for quantities as per 1st RCE (2010-11) and Rs. 47,725.74 Cr @ 2017-18 PL (for revised quantities as per2nd RCE (2017- 18). Total CA released to the Project is Rs 13045.148 Cr till 31.08.2022.
- An Expert Committee headed by Member (WP&P) and officers from CWC has been constituted on 10.03.2017 (reconstituted on 07.06.2017) for overall implementation of Polavaram Irrigation Project. Till date Expert Committee has made seven visits / meetings (virtual) to the project.
- Further, Dam Design and Review Panel (DDRP) under the chairmanship of Shri A.B. Pandya, (former Chairman, CWC) have been constituted on 13.06.2016 respectively to carry out regular monitoring of the project and to strive better coordination with DDRP/Contractor/PPA/CWC design units/ Central Water and Power Research Station (CWPRS) in respect of various issues related to design and implementation of the project. DDRP has met 20 times so far.

Visit of Hon'ble Minister, Ministry of Jal Shakti, Government of India to Polavaram Project Irrigation in Andhra Pradesh during the month of March, 2022

4. Shahpurkandi Dam Project in Punjab

- The project was declared as National Project in Feb, 2008.The Project is on river Ravi, 11 Km downstream of Ranjit Sagar Dam and 8 Km upstream of Madhopur Headworks. The project is situated in Pathankot district of Punjab State.
- At present, a lot of water of river Ravi is going waste to Pakistan. As per the Indus Waters Treaty 1960, India is entitled to utilize all the waters of river Ravi. After the completion of this project, India would be able to utilize most of the waters of river Ravi for irrigation and power generation.
- The Project will act as a balancing reservoir for Ranjit Sagar Dam Power House and ensure uniform water supply to the Upper Bari Doab Canal in Punjab and Ravi Canal in J&K and also optimum utilization of Ravi waters for irrigation and power production during peaking hours from Ranjit Sagar Dam Power Houses.
- It envisages construction of 55.5 m high concrete dam, 7.70 km long Hydel Channel along the left bank of river, 2 nos. head regulators, one to feed Shahpurkandi Hydel Channel (Left side) in Punjab and the other to feed Ravi Canal (right side) in J&K.
- The Project has Irrigation benefit of 37173 ha. (32173 ha. in J&K + 5000 ha. in Punjab) and power potential of 206 MW (2x99 MW + 8 MW).
- The RCE of the project had been appraised in CWC and was accepted by Advisory Committee of DoWR, RD & GR, MoJS on Irrigation, Flood Control & Multipurpose Projects in its 138thmeeting held on 31st October, 2018 for an estimated cost of Rs. 2715.70 Cr (PL February, 2018).
- Work on the project has been restarted from November, 2018. Revised completion schedule of the project is April, 2023.
- Cabinet Committee has approved the implementation of Shahpurkandi Dam Project on 06.12.2018. Investment Clearance proposal of the project amounting to Rs. 2715.70 Cr (PL February, 2018) was examined in CWC and accepted by Investment Clearance Committee of DoWR, RD & GR in its 10th meeting held on 27.02.2019.

Visit of Monitoring Committee of CWC to Shahpurkandi Dam Project in Punjab

The Central Assistance released till 31.03.2022 (after resumption of work) is Rs 207.45 Cr.

- Further, a Monitoring Committee for Implementation of Shahpurkandi Dam Project was constituted under the Chairmanship of Member (WP&P), CWC. So far 8 visits / meetings have been made by Monitoring Committee. The 7th visit of the Monitoring Committee to the project sites was carried out during 07-09th June 2022 under Chairmanship of Sh. Kushvinder Vohra, Member (WP&P), CWC, to expedite the implementation of Shahpurkandi Dam project. Subsequently, 8th meeting of the Monitoring Committee was held on 01-08-2022 during which recommendation was made to extend timeline for completion of the project by 6 months.
- Apart from Technical Advice, the project is also being monitored time to time by CWC.

5. Lakhwar Multipurpose Project (Uttarakhand):

- Lakhwar Multi-Purpose Project was declared as National Project in Feb, 2008. The project is located at River Yamuna, Village/ Tehsil: Lohari, District Dehradun (Uttarakhand).
- Besides providing irrigation, drinking and Industrial water, the project will also provide releases as per agreement signed among the Upper Yamuna Basin States of Himachal Pradesh, Uttarakhand, Uttar Pradesh, Haryana, National Capital Territory of Delhi and Rajasthan based on MoU signed on 12.05.1994.
- Revised Cost Estimate (RCE) of the Lakhwar Multipurpose Project at Estimated cost of Rs. 5747.17 Cr @ PL July 2018, has been appraised in CWC and accepted by Advisory Committee in its 141st meeting held on 11.02.2019.Investment Clearance Proposal amounting to Rs. 5747.17 Cr @ PL July 2018 was examined in CWC for Lakhwar MPP and same was accepted by Investment Clearance Committee of DoWR, RD & GR on 02.11.2021.
- Funding of Lakhwar MPP has also been approved by Cabinet Committee on Economic Affair (CCEA) in its meeting held on 15.12.2021.
- Foundation stone for the project was laid by Hon'ble Prime Minister on 30.12.2021.

Foundation stone of Lakhwar Multipurpose Project in Uttarakhand laid by Hon'ble Prime Minister

6. Renuka Dam Project (Himachal Pradesh):

- Renuka Dam Project in Himachal Pradesh was declared as National Project in Feb, 2008.
- The project consists of construction of a dam on river Giri, a tributary of Yamuna. The entire dam complex, storage reservoir as well as catchment area falls within the territorial boundary of Himachal Pradesh.

Foundation stone of Lakhwar Multipurpose Project in Uttarakhand laid by Hon'ble Prime Minister

Foundation stone of Renuka Dam Project in Himachal Pradesh laid by Hon'ble Prime Minister

- The project when completed shall store the monsoon water of river Giri to be released later on in a regulated manner as per the drinking water requirement of Delhi [9 months from October to June – 498 MCM (Live)]. The project will also generate 40 MW of power during peak flow
- RCE of the project amounting to Rs. 6,946.99 Cr (PL October 2018) has been appraised and accepted by Advisory Committee in its 143rd meeting held on 09.12.2019.
- Investment Clearance Proposal amounting to Rs. 6,946.99 Cr (PL October 2018) was examined in CWC for Renuka Dam Project and same was accepted by Investment Clearance Committee of DoWR, RD & GR on 07.08.2020.
- Funding of Renukaji Dam Project has also been approved by Cabinet Committee of Economic Affair (CCEA) in its meeting held on 15.12.2021.

7. Ken Betwa (KB) link Project Phase (Madhya Pradesh& Uttar Pradesh):

- Ministry of Jal Shakti (erstwhile Ministry of Water Resources, River Development and Ganga Rejuvenation) formulated a National Perspective Plan (NPP) for Water Resources Development in India in 1980s. The National Perspective Plan envisages Inter-basin water transfer from water surplus to water deficit areas comprising two components, namely, (i) Peninsular Rivers Development component and (ii) Himalayan Rivers Development component.
- The National Water Development Agency (NWDA) was set up on 17th July, 1982 by the Government of India as a Society under the Societies Registration Act 1860 under this Ministry to study the feasibility of the links under National Perspective Plan.
- NWDA had identified 30 links (16 under Peninsular component& 14 under Himalayan component) for preparation of the Feasibility

A tripartite MoA signed among Govts of MP and UP with Union Government for implementation of the Ken-Betwa link project in Madhya Pradesh and Uttar Pradesh

Reports (FRs). Out of 16 peninsular links, Detailed Project Reports (DPR) of Priority Links, One Project namely, Ken Betwa Link Project (KBLP) was declared as National Project in Feb, 2008.

- The project proposes a link between Ken and Betwa rivers. The KBLP will provide irrigation in CCA of more than 7.21 Lakh ha in the districts of Chhattarpur, Panna, Tikamgarh, Vidisha, Sagar, Shivpuri & Datia of Madhya Pradesh and Mahoba, Jhansi & Banda of Uttar Pradesh. Besides, the project envisages Power generation (103 MW hydro & 27 MW Solar) and drinking water supply of 49 MCM to 13.42 Lakh Population. The DPR of the KBLP has been received in two phases.
- The DPR of KBLP (Phase-I) was appraised in CWC and was accepted for the estimated cost of Rs 18057.08 Cr. at 2015-16 price level in 129th meeting of Advisory Committee of MoWR, RD & GR on 08.07.2016.
- DPRs of KBLP (Phase-II) projects namely Lower Orr dam Project (Rs. 2657.04 Cr at 2017-18 PL), Kotha Barrage Project (Rs 709.47 Cr at 2017-18 PL) and Bina Complex Project (Rs 3353.62 Cr at 2017-18 PL) was appraised in CWC and was accepted in the meeting of 148th TAC held on 17.01.2022.
- Also, for the implementation of KBLP, funding has been approved by Cabinet Committee of Economic Affair (CCEA) in its meeting held on 08.12.2021 at an estimated cost of Rs. 44,605 Cr at 2021-22 PL.
- A tripartite MoA signed among Govts of MP and UP with Union Government for implementation of the Ken-Betwa link project on 22.03.2021 in the august presence of Hon'ble Prime Minister.
- Ken Betwa Link Project Authority (KBLPA) and Steering Committee have been constituted via Gazette notification dated 09.02.2022.
- Total CA release to this project is Rs 5039.16 Cr till 31.08.2022.

A tripartite MoA signed among Govts of MP and UP with Union Government for implementation of the Ken-Betwa link project in Madhya Pradesh and Uttar Pradesh

7. Ujh Multipurpose Project (Jammu & Kashmir):

- Ujh MPP project has been planned to optimally utilize water resource potential of river
- Ujh, a tributary of River Ravi, which is one of the three eastern Rivers of Indus Basin system.
- The Project has been declared as a National Project in Feb, 2008 as it allows India to utilize its share of Indus River system as per provisions of Indus Water Treaty between India and Pakistan. The project entails not only hydro power generation in power-deficit region but also catering to the drinking water requirement as well as meeting the irrigation demand of the area. Provision has also been made for fulfilling the present and upcoming Industrial demand for water.

Location of Proposed Ujh MPP in J&K

Layout of Ujh MPP in J&K

- DPR of Ujh MPP has been prepared by CWC. Project is at River Ujh (a tributary of river Ravi), Village / Tehsil Kathua & Billawar, District Kathua (Jammu region, J & K).
- The project is to provide benefits to Kathua, Hiranagar and Samba districts of J&K.
- In pursuance of MoF letter dated 30.03.2021, a series of 14 meetings under the Chairmanship of Sh. Kushvinder Vohra, Member (WP&P), CWC, were held between May 2021 and November 2021 to relook into the planning and design aspects of Ujh Multipurpose Project and finalization of DPR. Accordingly, proposal of Ujh MPP was modified with revised irrigation planning and irrigation potential was increased to 91073Ha from 76929 Ha. Type of dam to be constructed was changed from CFRD to concrete gravity dam which will have more life as compared to CFRD. Design of power house was also optimized to meet various demands.
- The modified Ujh MPP Proposal was appraised in CWC and was accepted by Advisory Committee of DoWR, RD & GR in the 148th TAC meeting held on 17.01.2022 for an amount of Rs 11907.77 Cr at PL December 2019 PL.
- Ujh MPP will provide irrigation in CCA of more than 91073 ha. Besides, the project envisages Power generation (89.5 MW hydro) and drinking water supply of 18.92 MCM.

8. Teesta Barrage Project in West Bengal

- Teesta Barrage Project in West Bengal was declared as National Project in Feb, 2008.
- Teesta Development Plan consists of three Phases. Benefits envisaged are irrigation benefit to CCA of 9.22 Lakh Ha (Phase-I), 1000 MW Hydro Power (Phase-II) & Navigation Link between Brahmaputra & Ganga (Phase-III).
- Phase-I has three stages and Stage-I has two sub-stages. Teesta Barrage Project (Sub-Stage-I of Stage-I of Phase-I of Teesta Development Plan) was accorded investment clearance by Planning Commission in December 2010 with scheduled completion period byMarch2015.
- The Sub-Stage-I of Stage – I of Phase - I envisages constructions of (i) Barrage across river Teesta, (ii)Two pick up barrages across river Mahananda & Dauk, (iii) Construction of five main canals of total length 210.682 Kms, (iv) Construction of distributaries including minors/sub minors/water courses of about 4200 Kms & (v) hydro Power components with 3 units of 22.5 MW (total 67.5 MW) which were already completed and commissioned at the time of investment clearance.
- The Sub-stage – I, on completion, would create irrigation potential of 527 Th Ha over a CCA of 342 Th Ha. The estimated cost of the Project was Rs. 2988.61 Cr [at 2008 PL].

Spillway of Teesta Barrage in West Bengal

Teesta-Mahananda Link Canal of Teesta Barrage Project in West Bengal

LIST OF NATIONAL PROJECTS

Sl. No	Name of the Project	State	Benefits: 1) Irrigation Potential (ha.) 2) Power (MW) 3) Storage (MCM)	Latest Estimated Cost (Rs in Cr)	Irrigation Potential Envisaged (Lakh Ha)
National Projects under Implementation/execution					
1	Gosikhurd Irrigation Project	Maharashtra	1) 2.50 lakh 2) 26.5 MW 3) 1147.14 MCM (Gross)	18494.57 (PL 2012-13)	2.31 (NP comp)
2	Saryu Nahar Pariyojana	Uttar Pradesh	1) 14.04(NP Component:4.73) 2) – 3) Barrage	9802.67 (PL 2016)	4.73 (NP comp)

Sl. No	Name of the Project	State	Benefits: 1) Irrigation Potential (ha.) 2) Power (MW) 3) Storage (MCM)	Latest Estimated Cost (Rs in Cr)	Irrigation Potential Envisaged (Lakh Ha)
3	Polavaram Irrigation Project	Andhra Pradesh	4.36 lakh 960 MW 5511 MCM (Gross)	55,548.87 (P.L. 2017-18)	4.36 (NP comp)
4	Shahpurkandi Dam Project	Punjab	1) 0.37 lakh 2) 206 MW 3) 120.71 MCM (Gross)	2715.70 (PL Feb. 2018)	0.37 (NP comp)
5	Teesta Barrage Project	West Bengal	9.23 lakh (NP component: 5.27 lakh) 1000 MW Barrage	2988.61	5.27 (NP comp)
6	Lakhwar multipurpose project	Uttarakhand	1) 0.3378 lakh 2) 300 MW 3) 587.84 MCM (Gross) / 39.415 MCM (Drinking)/39.415 MCM (Industrial)	5747.17 (PL July,2018)	0.338
7	Renukaji Dam project	Himachal Pradesh	1) Drinking water 2) 40 MW 3) 498 MCM Drinking (Live)	6946.99 (PL Oct, 2018)	NIL (only drinking water component)
8	Ken-Betwa Link Project	Madhya & Uttar Pradesh	1) 9.08 lakh (CCA) 2) 130 MW 3) 3495 MCM (Live)	44605 (PL 2020-21)	9.04

Sl. No	Name of the Project	State	Benefits: 1) Irrigation Potential (ha.) 2) Power (MW) 3) Storage (MCM)	Latest Estimated Cost (Rs in Cr)	Irrigation Potential Envisaged (Lakh Ha)
Details of National Projects accepted by Advisory Committee of DoWR, RD & GR :					
9	Ujh Multipurpose Project	Jammu & Kashmir	1) 0.91 lakh 2) 89.5MW 3) 925 MCM (Gross) / 20 MCM (Drinking)/20 MCM (Industrial)	11907.77 (PL Dec, 2019)	0.769
Details of Projects under Appraisal :					
10	Kulsi Dam Project /	Assam	1) 0.395 lakh (GIA) 2) 55 MW 3) 525.64 MCM (Gross)	Unit-I = 1073.05 Unit-II = 290.12 E&M Cost = 91.78 (PL June 2017)	0.395 (GIA) 0.260 (GCA) 0.205 (CCA)
11	Noa Dihing Dam Project	Arunachal Pradesh	1) 0.036 Lakh (CCA) 2) 72 MW 3) 322.00 MCM (Gross)	1291.93 (PL May, 2017)	0.0695 (GIA) 0.0515 (GCA) 0.0360 (CCA)
12	Bursar HE Project	Jammu & Kashmir	1) 1.74 lakh (Indirect) 2) 800 MW 3) 616.74 MCM (Gross)	16839.90 (PL Oct 2016)	1.74
Details of Projects under DPR / PFR stage :					
13	Kishau multipurpose project	Himachal Pradesh & Uttarakhand	1) 0.97 lakh ha 2) 660 MW 3) 1824 MCM (Gross)/ 617 MCM (Drinking)	7193.23 (PL 2010)	0.97

Sl. No	Name of the Project	State	Benefits: 1) Irrigation Potential (ha.) 2) Power (MW) 3) Storage (MCM)	Latest Estimated Cost (Rs in Cr)	Irrigation Potential Envisaged (Lakh Ha)
14	Gyspa HE Project	Himachal Pradesh	1) 0.50 lakh ha 2) 300 MW 3) 912.78 MCM (Live)	-	0.50
15	2nd Ravi Beas Link Project	Punjab	Harness water flowing 0.58 MAF across border (about 719.30 MCM in non-monsoon period)	-	NIL (Harness water flowing 0.58 MAF across border (about 719.30 MCM in non-monsoon period). IP is yet to be finalized
16	Upper Siang Project	Arunachal Pradesh	1) Indirect 2) 9750 MW 3) 9.2 BCM (Live) 4) Flood moderation	-	Indirect Irrigation

ROLE OF CW&PC / CWC IN ACHIEVING INTER-STATE COOPERATION IN WATER RESOURCES SECTOR

CWC has always been instrumental in convening joint meetings between party States to discuss the issues further and help them in evolving a mutually acceptable solution. Solutions to many inter-state problems were first evolved at technical level meetings and then ratified by respective governments at political level. A few of them are mentioned below.

Achievements

CWC has always been instrumental in convening joint meetings between party States to discuss the issues further and help them in evolving a mutually acceptable solution. Solutions to many inter-state problems were first evolved at technical level meetings and then ratified by respective governments at political level. A few of them are mentioned below.

- During its formative years, Central Water & Power Commission successfully resolved Tungabhadra water dispute between Madras, Mysore and Hyderabad States.
- Orissa and Madras had negotiated an agreement on sharing of power from Machkund project under the able guidance of CW&PC.
- CW&PC played a major role in deciding the location of projects and sharing of benefits in respect of Krishna and Godavari projects. To this effect, a technical committee appointed by the Planning Commission and headed by Chairman, CW&PC gave its recommendations for optimum utilisation of Krishna river waters and the same were put into action.
- A committee was set up under the chairmanship of the Chairman, CWC in 1978 to make a final assessment of the water resources of the Subarnarekha basin below Kokpara at 75% dependability and to recommend allocations between the co-basin States of Bihar, Wet Bengal and Orissa. The three States took note and accepted the recommendations of the committee.
- Many technical meetings were convened by CWC with the States of Andhra Pradesh and Orissa to discuss the inter-State issues involved in the Vamsadhara project Stage-II.
- CW&PC / CWC has been involved in the various inter-State water sharing agreements / inter-State meetings. CWC played an important role in arriving at these inter-state agreements / decisions in the inter-State meetings in the past. Some of the agreements / meetings / conference where CWC was involved are Inter-State conference on the utilization of Krishna and Godavari waters held on 27th and 28th July, 1951; 2nd meeting of Subarnarekha and Burabalanga projects Committee held on 19.06.1964; Meeting held on 10.01.1984 under the Chairmanship of Member (WR), CWC on Vamsadhara Project Stage-II Flood Hydrology of Neradi Barrage; 3rd inter-State meeting on the Palar Water Dispute between Tamil Nadu & Andhra Pradesh held on 24.12.2010; Agreement dated 05.05.2012 for Inter-State Board for PranhitaChevellaSujalaSravanti Project among the State of Maharashtra and Andhra Pradesh etc.
- CW&PC/CWC provided technical support to Cauvery Fact Finding Committee and reaching an understanding on Cauvery water disputes among basin States.

- In pursuance to the Hon'ble Supreme Court's interim order dated 10th May, 2013, MoWR constituted Supervisory Committee under the Chairmanship of Secretary, MoWR to give effect to the implementation of the CWDT Award dated 05.02.2007. Chairman, CWC was one of the Member and Chief Engineer, CWC was the Member Secretary of the Supervisory Committee. CWC played very important role in the functioning of the Committee
- CW&PC dealt with the question of allocation of cost of common works of Chambal project between the Madhya Pradesh and Rajasthan states.
- CWC was associated with formulating Memorandum of understanding and other agreements between Yamuna basin States for sharing of Yamuna waters.
- There has been role of CW&PC on Setting up The Rajasthan Canal Board Resolution Dated 19th December, 1958.
- There has been a role of CW&PC on Construction of BhakraNangal Project between Punjab and Rajasthan.
- There has been role of CWC on the Thein Dam and Power Plant Scheme between Punjab and Jammu &Kashmir.
- CWC was also associated with agreements between Uttar Pradesh and Madhya Pradesh on irrigation projects like Bhander Canal, Rangwan Dam and Jamni Dam in Bundelkhand region across the tributaries of Yamuna.
- An inter-state meeting convened by Chairman, CWC in June, 1975 decided sub-basin wise share of Sone basin states.
- There has been role of CWC between the Governments of Punjab and Himachal Pradesh Relating to the construction of Shah Nehar Barrage and the MukerianHydel Channel
- CWC was also associated with the agreement of 1981 on allocation of surplus Ravi Beas waters.
- The inter-State meeting between the officials of UP & Bihar on the Western Gandak Canal system was held under the chairmanship of Member (WP&P), CWC on 14/8/2014.The issue was amicably settled
- Inter-State meetings on Sone river dispute were held under chairmanship of the Chairman, CWC with the officials of Govts. of co-basin states. In the second meeting held on **07.04.2015,** it was finally concluded that the two states U.P & Bihar would meet periodically every two months to analyze the release pattern vis-a-vis the JOC recommendations from Rihand dam and try to solve the issues bilaterally. Therefore negotiated settlement of the issue has been worked out and MoWR, RD & GR has informed CWC that there is no imminent need for referring the matter to Tribunal under ISRWD Act, 1956.

CWC has brought out a series of publications titled "**Legal Instrument on Rivers in India**" in following four volumes:

Volume-I	:	Constitutional Provisions, Central Laws and Notifications.
Volume-II	:	Awards of Inter-State Water Disputes Tribunals.
Volume-III (in 2 parts)	:	Agreements on Inter-State Rivers.
Volume-IV	:	International agreements and treaties.

STATUS OF TRIBUNALS

The Central Government has, so far, set up nine Tribunals to settle inter-State water disputes among the States under Inter-State River Water Disputes (ISRWD) Act, 1956

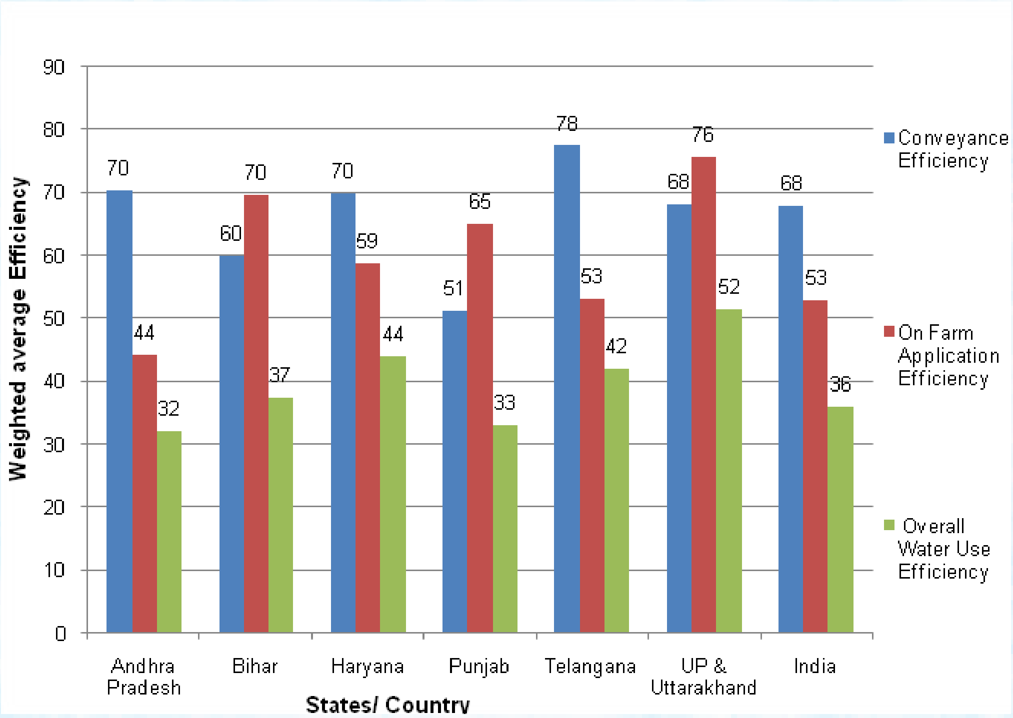
Sl. No.	Name of the Tribunal	States Concerned	Date of Constitution	Present Status
1.	Godavari Water Disputes Tribunal	Maharashtra, erstwhile Andhra Pradesh, Karnataka, Madhya Pradesh, Chhattisgarh, Odisha and UT of Puducherry	10th April, 1969	Decision given in July 1980.
2.	Krishna Water Disputes Tribunal - I	Maharashtra, erstwhile Andhra Pradesh and Karnataka	10th April, 1969	Decision given in May 1976.
3.	Narmada Water Disputes Tribunal	Rajasthan, Madhya Pradesh, Gujarat and Maharashtra	6th October, 1969	Award given in December, 1979. Narmada Control Authority (NCA) was constituted to give effect to the decision.
4.	Ravi & Beas Water Tribunal	Punjab, Haryana and Rajasthan	2nd April, 1986	Report & Decision under Section 5(2) of ISRWD Act, 1956 given in April, 1987. Clarification/explanation sought from the Tribunal under Section 5(3) of the said Act by the party States. The matter is sub-judice.
5.	Cauvery Water Disputes Tribunal	Kerala, Karnataka, Tamil Nadu and Union Territory of Puducherry	2nd June, 1990	Report and decision under Section 5(2) of ISRWD Act given on 05.02.2007. In accordance to Supreme Court Order dated 04.02.2013, the final decision dated 05.02.2007 of the Tribunal was published in the official Gazette on 19.02.2013. Subsequently, Hon'ble Supreme Court vide its judgment dated 16.02.2018, slightly modified the Tribunal Award dated 05.02.2007. The Tribunal has been dissolved on 16.07.2018.

Sl. No.	Name of the Tribunal	States Concerned	Date of Constitution	Present Status
6.	Krishna Water Disputes Tribunal -II	Karnataka, Andhra Pradesh, Telangana and Maharashtra	2nd April, 2004 (effective date of constitution is 01.02.2006)	Report and decision under Section 5(2) of ISRWD Act given on 30.12.2010. Further report under Section 5(3) of the Act given by the Tribunal on 29.11.2013 which could not be published in the Official Gazette on account of stay by Hon'ble Supreme Court vide Order dated 16.09.2011. According to Section 89 of AP Reorganization Act, 2014, term of the KWDT-II has been extended with certain Terms of Reference. The Tribunal is currently hearing the matters and yet to submit its Final Award. The matter is sub-judice.
7.	Vansadhara Water Disputes Tribunal	Andhra Pradesh and Odisha	24th February, 2010 (effective date of constitution is 17.09.2012)	Report and decision under Section 5(2) of ISRWD Act, 1956 given on 13.09.2017. The Tribunal has submitted the Further Report under Section 5(3) of the Act on 21.06.2021. The Award of the Tribunal dated 21.06.2021 is yet to be Notified. Government of Odisha has filed an SLP in Hon'ble Supreme Court seeking not to publish the Award. The Tribunal has been dissolved on 09.03.2022.
8.	Mahadayi Water Disputes Tribunal	Goa, Karnataka and Maharashtra	16th November, 2010 (effective date of constitution is 21.08.2013)	Report & Decision under Section 5(2) of ISRWD Act, 1956 submitted on 14.08.2018. Basin States have filed separate SLPs in Hon'ble Supreme Court. State of Karnataka has filed an Interlocutory Application (I.A.) before Supreme Court for a direction to the Union of India to publish the Award dated 14.08.2018. Supreme Court vide its Order dated 20.02.2020, allowed the said I.A. subject to the result of the pending proceedings. Accordingly, the Tribunal Award dated 14.08.2018 has been published in Official Gazette on 27.02.2020. The Tribunal is yet to submit its Further Report under Section 5(3) of the Act. The matter is sub-judice.
9.	Mahanadi Water Disputes Tribunal	Chhattisgarh, Odisha, Jharkhand, Maharashtra and Madhya Pradesh	12th March, 2018	Matter is sub-judice before the Tribunal under section 5(2) of ISRWD Act.

CWC is carrying out various studies for Performance Assessment of Irrigation Projects.

1. **Water Use Efficiency (WUE) Studies**

- Irrigation Sector is the biggest consumer of fresh water (about 80%) and any improvement in the Irrigation Projects Efficiency will be like creating a new source of water supply which can be gainfully utilized to meet the other competing/conflicting water demand.
- A Technical Advisory Committee (TAC) was constituted on 22.08.2005 under the Chairmanship of Member (WP&P), CWC for carrying out the WUE studies in the country.
- During 10th & 11th Five Year Plans, CWC conducted Water Use Efficiency studies in respect of 35 irrigation projects from 07 States under Scheme 'R&D in Water Sector'. The overall project efficiency of the studied projects ranged from 13 to 62% with the group weighted average of the projects studied at around 36%. The Studies had valuable insight on state of affairs on water management vis-a-vis water resources projects efficiency.
- Action initiated for taking up WUE Studies in respect of another 10 Major & Medium Irrigation (MMI) projects in the Country.
- CWC is also associated with Technical Examination of WUE/ Baseline Study of Irrigation projects being taken up by NWM. These studies have been entrusted to reputed Water Resources Institutes such as NERIWALM Assam, WALMTARI Hyderabad, WALMI Aurangabad & CWRDM Kerala.



- CWC also encourages State Govts. to carry out WUE study for their completed irrigation projects and further action on findings of the studies/ interventions for increasing the WUE and ultimately farmers' income by formulating scheme for ERM of projects.

2. **Performance Evaluation Studies (PES)**

- CWC started conducting Performance Evaluation Studies in the country in Seventies. The objectives of performance evaluation studies of Irrigation Projects are measurement of gaps, impacts on agro-economic, socio-economic, environment, and identification, reasons for shortfalls and its remedial measures in order to improve the efficiency of the projects.

- So far, PES of 137 major and medium irrigation projects from various regions/states of the country have been completed.

Name of State	Pre-project Evaluation Studies	Post Project Evaluation Studies				Total
		State	CWC	CBIP	MoWR	
Andhra Pradesh	1	2	2		1	6
Arunachal Pradesh	1	--	--	--	--	1
Assam	--	--	2	--	1	3
Bihar	1	16	1	1	1	20
Gujarat	25	5	2	-	2	34
Haryana	2	3	--	1	2	8
Himachal Pradesh	--	--	1	--	2	3
Jharkhand	--	--	1	--	--	1
Karnataka	--	1	--	--	1	2
Kerala	--	2	1	--	--	3
Madhya Pradesh	11	--	2	--	--	13
Maharashtra	--	6	4	--	3	13
Manipur	--	--	1	--	--	1
Odisha	--	2	2	--	1	5
Punjab	--	1	1	--	--	2
Rajasthan	--	2	2	--	3	7
Tamilnadu	--	--	2	--	3	5
Uttar Pradesh	--	3	3	--	1	7
West Bengal	--	1	1	--	1	3
	41	**44**	**28**	**2**	**22**	**137**

- Action has been initiated for conducting PES in respect of another 10 Major & Medium Irrigation (MMI) projects in the Country.

3. Benchmarking Studies

- In India, 'Benchmarking in Irrigation Systems' was launched during February, 2002 by organizing a national workshop with World Bank assistance at Hyderabad with the objectives of identifying the best management practices, generating competition among various agencies or the projects, units for distributor networks or Water Users' Associations (WUAs), prioritizing and evaluating rehabilitation and remodeling or modernization projects and assessing and monitoring the irrigation efficiency.
- A Core Group under the Chairmanship of Member (WP&P), CWC has been set up for Benchmarking of Irrigation Systems in India. Core Group is playing an active role as a coordinator as well as a facilitator by way of providing technical support to the State Governments.
- National/ regional/ project level workshops are being organized by CWC through State Government institutions in various states to facilitate concerned State Governments to take up benchmarking of irrigation projects in their respective States.
- 17 nos. of benchmarking workshops have been organized till date. CWC has also been encouraging States to use water management tools such as water auditing and benchmarking of irrigation projects by publishing General Guidelines on these subjects.

NEW INITIATIVE SUPPORT FOR IRRIGATION MODERNIZATION PROGRAMME (SIMP)

- CWC initiated a new activity namely "Support for Irrigation Modernization Program (SIMP)" in Aug-2020 with technical assistance from the Asian Development Bank (ADB) to modernize Major/ Medium Irrigation (MMI) projects in the country.

- SIMP aims to improve water use efficiency, increase crop water productivity and ultimately increase farmer's income in the command area of the project through application of national/ international best practices.

- For overall implementation and management of the programme, a Central Irrigation Modernization office (CIMO) has been setup under Chief Engineer (POMIO), CWC supported by National/ International consultants.

- To introduce SIMP to States, a National Webinar was held in December'2020 under the Chairmanship of Secretary (WR,RD&GR) during which 25 States & 2 UTs participated which were represented by the concerned Addl. Chief Secretary/ Principal Secretary/ Secretary/ EnCs of WRD

- The phase-wise activities along with the financial arrangements are as mentioned below:

Phases of Implementation	Activities Proposed	Financial Arrangement
Phase-1	Identification of 3-4 MMI projects in the Country to be taken up for modernization as 1st Batch of projects	Funded from ADB's Technical Assistance (TA) funds
Phase-2	Preparation of Irrigation Modernization Plans (IMPs) for 1st batch of projects.	State Irrigation Modernization Unit (SIMU) to be setup by concerned States. SIMU to prepare IMP under technical guidance and expert advice from CIMO. To be funded from ADB's TA funds.
Phase-3	Preparation of Detailed Project Reports (DPRs) based on the IMPs, financing documents, detailed engineering designs, initiation of tendering process	To be funded by the state from its own finances or using the ADB's Project Readiness Financing (PRF) loan facility
Phase-4	Implementation of the irrigation modernization project	To be funded by the state from its own finances or financed through an ADB loan and the State's counterpart funds

- 57 project proposals were received for modernization from various States/UTs under SIMP. Based on the selection criteria developed by CIMO and consultations held with the concerned States during April-May'2020, following projects have been shortlisted for inclusion under Batch-1 :

S. No.	State	Project Name	CCA (ha)	Status of Proposal
1	Rajasthan	IGNP St-II	3,20,000	Under Consideration for Batch-1. Either of the project to be taken up as per State's priority
2	Rajasthan	Chambal	2,29,000	
3	Maharashtra	Palkhed	65,045	Under Consideration for Batch-1
4	Haryana	Loharu Canal	19,940	Under Consideration for Batch-1
5	Karnataka	Vani Vilasa Sagara	13,000	Under Consideration for Batch-1
6	Andhra Pradesh	Kurnool Canal	1,46,220	Backup List of Projects
7	Telangana	Kaddam Narayan Reddy	34,000	Backup List of Projects
8	Madhya Pradesh	Thanwar Dam	9,327	Backup List of Projects

- Time to time meetings have been taken by Sh. Kushvinder Vohra, Member (WP&P), CWC to discuss the modalities related to the programme, decide the future course of action and review the progress of works.
- Department of Economic Affairs has approved ADB's Mission regarding SIMP for holding discussions with Secretary (WR,RD&GR), Chairman (CWC), other senior officials from Minsitry of Jal Shakti and also the WRDs and Finance Departments of the shortlisted Batch-1 States.
- A meeting to kick start the Mission was convened under the Chairmanship of Dr. R.K. Gupta, Chairman, CWC on 18.02.2022 through Video Conferencing. During the meeting, Dr. Gupta

expressed the growing need for modernization of MMI schemes in India and appreciated the efforts being made under SIMP in this regard. Thereafter, Mission Meetings have been held with Secretary (WRD), Rajasthan and officials from WRD, Maharashtra on 08.03.2022 and 09.03.2022 respectively.

- Phase-2 of the Programme is expected to be commencing soon which will include preparation of IMPs in respect of the Batch-1 projects along with a module for Training & Capacity Building of officers from CWC and the concerned States on the related aspects of Irrigation Modernization.

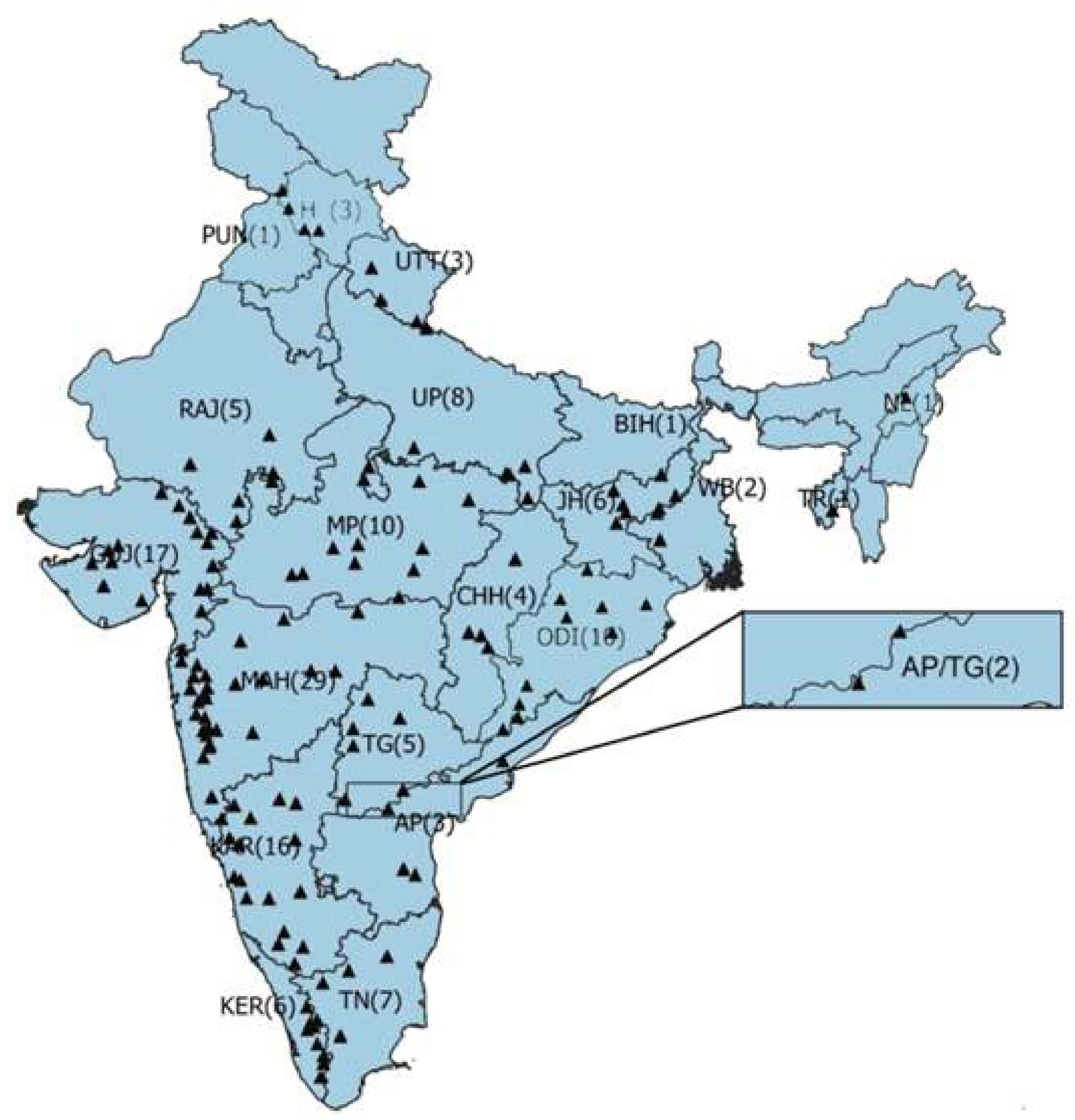
Several Guidelines have been published by POMIO, CWC with regards to the Performance Assessment Studies viz. as below:

1. 'Guidelines for computing the Water Use Efficiency of the Irrigation Projects' published during 2014.

2. 'Guidelines for improving Water Use Efficiency of irrigation, domestic and industrial sectors' published during 2014.
3. 'Guidelines for Performance Evaluation of Irrigation System' published during 2002.

RESERVOIR STORAGE MONITORING IN THE COUNTRY

- During 1979 drought, the Ministry of Agriculture set up an institutional mechanism of Crop Weather Watch Group (CWWG) as a nodal agency of India in all matters related to drought, consisting representatives from Department of Agriculture, IMD, ICAR, Ministry of Information and Broadcasting, Central Water Commission and others. Therefore, Central Water Commission had started monitoring of major reservoirs of the country since 1981.
- Reservoir Monitoring started with 23 important reservoirs. As on date, 140 major reservoirs are being monitored by CWC. The total live storage capacity of these 140 reservoirs is 175.957 BCM which is about 68.25% of the live storage capacity of 257.812 BCM (Estimated).
- Weekly bulletin is uploaded on the CWC website and also shared with PMO, Niti Aayog, MoJS, MOP, MOA&FW, IMD, and a states.
- Advisory is being issued to the State Govt. for judicious use of available water whenever the percentage of departure of current storage of all reservoirs under CWC monitoring in a state falls below 80% of Normal (Average Storage of last Ten years),
- Weekly bulletins have been helping States in planning of water utilisation all through the year. It is also shared with Crop Weather Watch Group (CWWG) of the Ministry of Agriculture and Farmers Welfare (MoA&FW), GoI which acts as an inter-Ministerial mechanism.



Trend in Reservoir Storage in Country (Water Year June 2021 to March 2022)

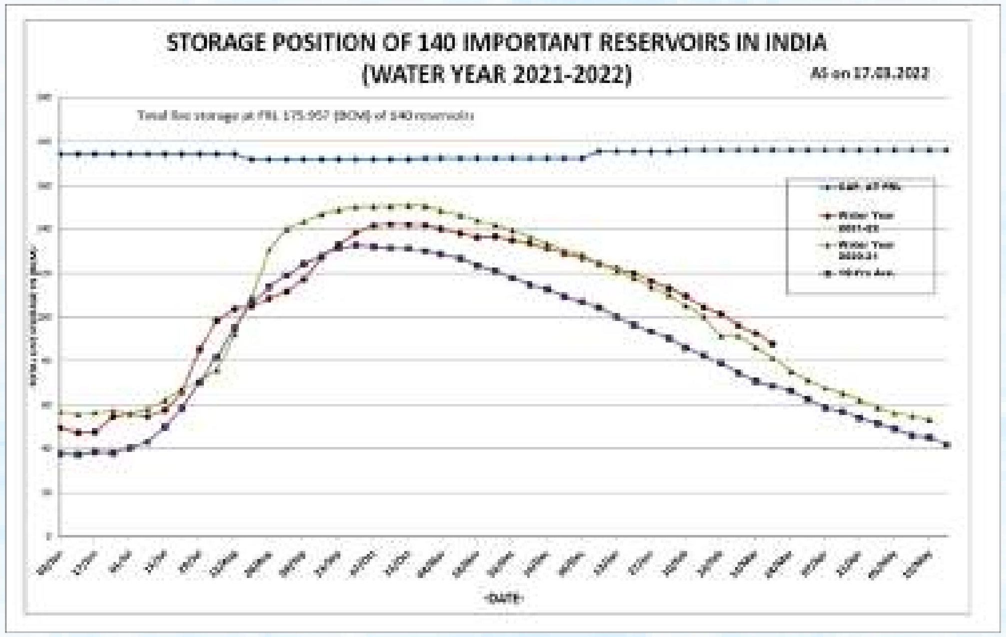


Fig. 22: 140 Reservoirs under CWC Monitoring

- CWC participates in weekly meetings convened by Crop Weather Watch Group for Drought Management (CWWGDM) during June to September every year to monitor drought situation, review agricultural activities, crop planning strategy across the country and to suggest remedial measures to States in case of distress situation.
- CWC also attends the meetings of Crisis Management Group, Ministry of Agriculture and Farmers Welfare (MoA&FW) to manage the various phases of drought in the country.
- A 'Reservoir Dashboard' has been created on CWC portal (http://cwc.gov.in/wm_dashboard) for having a quick glimpse of live storage status of important reservoirs in the country along with useful statistics.
- Existing Telemetry systems are proposed to be used for capturing reservoir data expeditiously. New telemetry systems may also be installed for this purpose.

Fig. 23: Reservoir Dashboard on CWC Portal

9

Basin Planning and Application of Remote Sensing in Water Sector

Basin Planning and Application of Remote Sensing in Water Sector

INDIAN WATER RESOURCES: ISSUES, CHALLENGES AND WAY FORWARD

Water resource is fundamental requirement for human well-being, socio-economic development, poverty alleviation and overall sustainable development. According to various projections, the demands for freshwater will increase significantly in the coming decades under the pressure of population growth and mobility, economic development, international trade, urbanization, climate change etc. There is huge temporal and spatial variation in the availability of water resources in India. Having monsoon-based climate, India received more than 75% of precipitation in the months of July-September and even this is not evenly distributed in space. The average rainfall (1985-2015) in India is about 1104 mm per year (Reassessment Study, CWC 2019). North-eastern region of the country has a very high rainfall (around 11000 mm/year) whereas western region received very scanty precipitation (around 100 mm/year in western Rajasthan). In the course of high agricultural, industrial and economic growth, India faces difficult challenges to meet the growing demand of its burgeoning population for food, water, and energy in the face of climatic and other socioeconomic changes. The projected water demand for all uses in India will be of the order of 1180 billion cubic meters (NCIWRD, Report 1999) which is about 70% more than the current utilization of 700 bcm. The availability of total water (both surface and groundwater) resources in the all 20 river basins of the country has been estimated as 1999.2 billion cubic meter (Reassessment Study, CWC, 2019). There is no pronounced impact of climate change on overall availability of water resources but there is increase in extreme hydrological events such as floods and droughts. The availability of water resources for various uses can be augmented and aforesaid challenges be address by optimum development including inter-basin transfers.

The underlying message of the United Nations Sustainable Development Goals 6 (SDG) is to 'ensure availability and sustainable management of water and sanitation for all'. Achieving clearly defined 8 number of targets of SDG 6 by 2030 will ensure that water available for multiple uses in sustainable manner and better managed. Central Government has rolled down numerous interventions such as Jal Jeevan Mission, Pradhan Mantri Krishi Sinchai Yojna (PMKSY), Swachh Bharat Abhiyan, Jal Shakti Abhiyan, Atal Bhujal Yojna, Namami Gange, National Water Mission, National Hydrology Project (NHP), Dam Rehabilitation and Improvement Project (DRIP), National Aquifer Mapping and Management (NAQUIM) Programme, Interlinking of Rivers, etc. which will ensure achieving targets of SDG 6 in time bound manner. Further, water being primarily a State-list subject as per Indian constitution, various State Governments also execute several programme and schemes for development and management of water resources in their respective territories.

Water is very complex, multi-stakeholder and trans-disciplinary resource, therefore, a comprehensive approach needs to be adopted. Traditionally, various interventions pertaining to water resources have been made without much focus on cross-sectoral coordination. It generally targets the sector-specific objectives and thereby it might be able to achieve stated objective but result into risks and uncertainties to allied sectors. Therefore, developing a suitable environment for appropriate management of water resources in the Indian scenario, following roadmap may be adopted in a systematic manner:

i. Integrated approach across the sector with proper coordination at every stage.

ii. Adequate legal provision by means of Acts, Laws, Guidelines, regulatory setup etc.

iii. Appropriate Institutional arrangements for implementation of programmes/Schemes.

iv. Optimum development of multipurpose water resource project (including interlinking of rivers) potentials with creation of adequate storage.

v. Financing provisions by means of public, private, PPP etc. backed by solid financial model.

vi. Adoption of state-of-the-art technology facilitating accelerated development and management of water resources.

vii. Dedicated research and development in water sector centered towards problem solving.

viii. An elaborate capacity building for range of stakeholders.

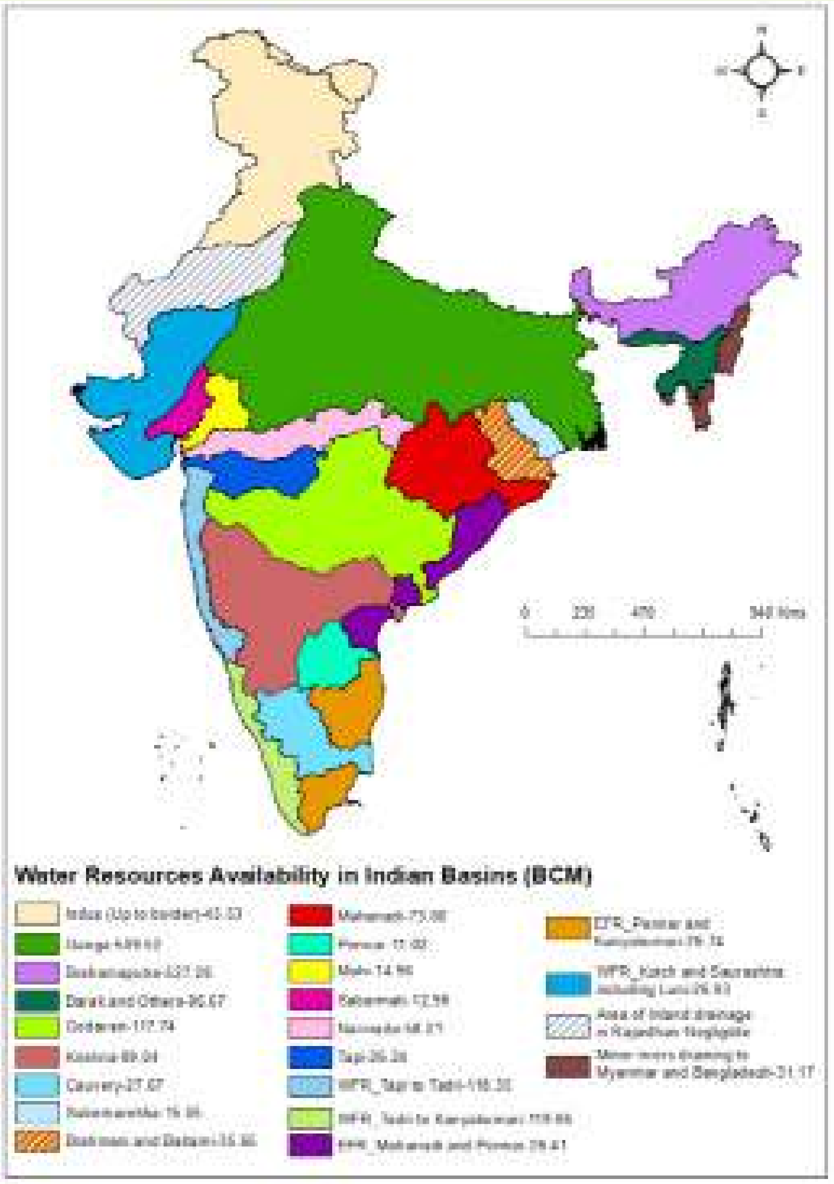
ix. Enhanced participation of stakeholders at every level.

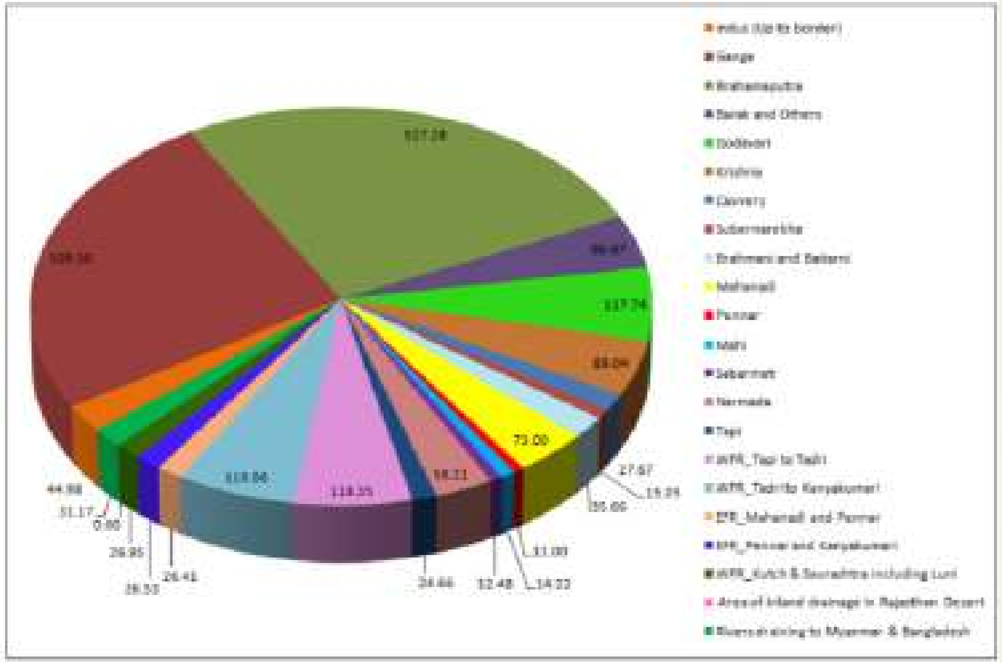
Fig. 1: Roadmap for Water Resources Management in India

REASSESSMENT OF WATER AVAILABILITY IN INDIA USING SPACE INPUTS

The study of "Reassessment of Water Availability in India using Space Inputs" conducted by Central Water Commission with technical support from National Remote Sensing Centre (NRSC), Hyderabad, was inaugurated by Hon'ble Minister, Ministry of Jal Shakti on 26.06.2019 and the average annual water resources availability of 20 river basins in the country is assessed as 1999.20 Billion Cubic Meters (BCM).

Fully science based state-of-the art modelling tools and satellite data have been used in the study. The methodology for reassessment was finalised by a Committee consisting of experts from CWC, NRSC, Indian Meteorological Department (IMD) and Academia. Data for a period of 30 years (1985-2015) was used. The most distinguishing features of the study are incorporation of rainfall, land use, land cover, proper estimation of demand, evapotranspiration, soil moisture and development of basin and sub-basin wise models with the help of the software namely 'Water Resources Assessment Tool' developed by NRSC. Estimation of Drinking, Industrial and Livestock water demands were based on population





whereas Irrigation water demand was based on Thomthwaite-Mather method. The results of the report as given below:

The outcome of this study will be very useful for proper planning and development of country's water resources.The study is the culmination of the tireless efforts put in by the study team of field organisations of Central Water Commission (CWC) under coordinated effort of Basin Planning & Management Organisation (BPMO), CWC. To fulfil this task, the team has solicited partnerships with the field organisations of CWC to maximize outreach.

S. No.	Earlier studies	Year	Water Availability (BCM)	Remarks
1	First Irrigation Commission	1901-03	1443	Runoff coefficient method (Excluding Burma, Assam, and East Bengal)
2	Khosla's formula	1949	1673	**Empirical formula**
3	CW & PC	1954-66	1881	Statistical Analysis of flow data + RR relationship
4	CWC Publication	1988	1880	With GW corrections
5	CWC	1993	1869	Flow data & RR relationship
6	NCIWRD	1999	1953	Based on 1993 study (Brahmaputra & Krishna revised)

RESERVOIRS SEDIMENTATION STUDIES

- The sedimentation is natural phenomenon in the reservoirs which is of vital concern to all water resources development projects as it not only occurs in the dead storage but also encroaches into the live storage capacity which impairs the intended benefits for the reservoirs. Water storage capacity of reservoirs is reduced by the accumulating sediments and long term efficiency of reservoirs also gets reduced considerably.
- In order to make in depth studies and to recommend to the Government the future policies to ensure adequate silt storage and retardation of sedimentation in the reservoirs, the then Ministry of Agriculture and Irrigation (Department of Irrigation), Government of India had set up a Reservoir Sedimentation Committee in February 1978 under the Chairmanship of Member (WR), Central Water Commission. The Committee submitted its report in July 1980 and embarked on a programme of conducting Capacity Survey of some important reservoirs of the country as per its recommendations.
- The capacity surveys were entrusted to Central Water Commission along with task of Collection and compilation of sedimentation data of various reservoirs in the Country and updating compendium prepared earlier and conducting Sedimentation Studies using Hydrographic Surveys for Important reservoirs in India.
- CWC carried out capacity survey of important reservoir using both hydro-graphic survey and satellite remote sensing techniques. Till 2020, CWC has completed capacity survey works of 36 reservoirs using hydro-graphic survey and 159 reservoirs have been surveyed using satellite remote sensing.
- The Surveys helps in updating the area elevation capacity curves of reservoirs, sedimentation distribution and bed- profiling, predict their future useful life, formulation of Sedimentation managements strategies and policies.
- Four (4) editions of compendium has been published by CWC :

Edition	Title of Publication	Year of Publication	No. of reservoirs included
1st	Compendium on silting of reservoirs in India	1991	46
2nd	Compendium on silting of reservoirs in India	2001	144
3rd	Compendium on silting of reservoirs in India	2015	243
4th	Compendium on Sedimentation of reservoirs in India	2020	369

The 4th edition of the compendium published in 2020 contains Reservoir Capacity data for 369 reservoirs. Out of these 369 reservoirs, 272 reservoirs have been hydrographically surveyed and remaining 97 have been surveyed through remote sensing. Of the 272 reservoirs being surveyed hydrographically, 36 reservoirs have been surveyed by CWC and the data of remaining 236 have been provided by the respective State Govts. Similarly out of the 97 reservoirs being surveyed through remote sensing surveyed data of 59 reservoirs have been used from CWC surveys and data of rest 38 reservoirs have been provided by the respective State Govts.

The reservoirs were divided into 7 regions (mentioned below)

Sedimentation Region	
1	Himalayan Region (Indus, Ganga and Brahmaputra basins)
2	Indo Gangetic Plains
3	East flowing rivers upto Godavari (Excluding Ganga)
4	Deccan Peninsular east flowing rivers including Godavari and south Indian rivers a)Excluding reservoirs in the Western Ghat
5	West flowing rivers upto Narmada
6	Narmada and Tapi Basins
7	West flowing rivers beyond Tapi and south Indian rivers

The rate of sedimentation with previus compendium has been analyzed the results were more or less comparable except for few deviations which were due to different sample sizes. The results are as under:

Comparison with Results of Previous Compendium

Region No.	Description	Compendium Edition 2020 Hydrographic Survey			Compendium Edition 2015 Hydrograpbic Survey		
		Reservoirs Number	Rate of Sedimentation (mm yr)		Reservoirs Number	Rate of sedimentation (mm/yr.)	
			Avg Value	Median Value		Avg Value	Median Value
1	Himalayan Region (Indus, Ganga and Brahmaputra basins)	31	1.22	0.42	14	2.58	1.58
2	Indo Gangetic Plains	15	0.95	0.72	15	0.98	0.75
3	East flowing rivers upto Godavari (Excluding Gann)	0.76	0.63	5	0.76	0.68	
4	Deccan Peninsular east flowing rivers including Godavari and south Indian rivers	114	227	0.44	115	1.74	0.38
5	West flowing rivers upto Narmada	53	1.12	0.86	53	1.117	0.86
6	Narmada and Tapi Basins	10	2.84	0.65	10	1.742	0.65
7	West flowing rivers beyond Tapi and south Indian rivers	35	3.07	2.07	31	3.32	2.13
	Total	263	1.96	0.716	243	0.716	

*The overall avg value of rate of sedimentation was not mentioned in compendium 2015 edition however its value comes out to be 1.5047 mm/yr

- CWC has taken up sedimentation survey of 32 reservoirs under National Hydrology Project (NHP) Phase I and works has already been started on these. For Phase-II, 87 reservoirs will be taken up, for which tendering is under process.
- In addition, 50 in-house and 80 outsourced sedimentation assessment studies using Satellite Remote Sensing. Out of these 50 in house studies, 16 in-house sedimentation assessment studies using remote sensing technique have already been performed and approved in FY 2021-22.

A CASE STUDY OF RESERVOIR SEDIMENTATION SURVEY USING REMOTE SENSING TECHNIQUES

Remote Sensing Technique

Reservoirs, created by dams on rivers, lose their storage capacity due to sedimentation. Satellite remote sensing technology have demonstrated proven capabilities in estimation of Sedimentation in Live Storage Zone of Reservoirs. Multi temporal satellite data have been used as an aid to capacity survey of many reservoirs in a cost and time effective manner. While this technique helps in revising capacity table between full reservoir level and minimum draw down level, loss of dead storage capacity can be obtained only through conventional hydrographic survey.

CWC has carried out 179 Sedimentation Assessment studies both in-house and by outsourcing using Remote Sensing. Since 2020, the in-house studies are conducted using Microwave data (instead of optical data). The advantage of using microwave data is that the microwaves can penetrate clouds and thus cloud unaffected images can be obtained easily with better resolution and frequency, even for Full Reservoir level (FRL) which is usually during monsoon season.

As per approved EFC targets for 5-year period 2021-2026, 50 in-house and 80 (in 2 batches of 40 reservoirs each) outsourced sedimentation assessment studies using SRS are to be done. During the current financial year 2021-22, 16 in-house sedimentation assessment studies using remote sensing technique have been carried out.

Sediment deposition, by itself, is inevitable.

Fig. 2: State-wise Reservoir Sedimentation Studies in Live storage zoneusing RS technique

Case Study of Jakham Reservoir

Jakham Dam was constructed in 1986 over river Jakham, which is tributary of river Mahi in Chittorgarh district of Rajasthan. Project has a designed live storage capacity of 132.28 MCM.

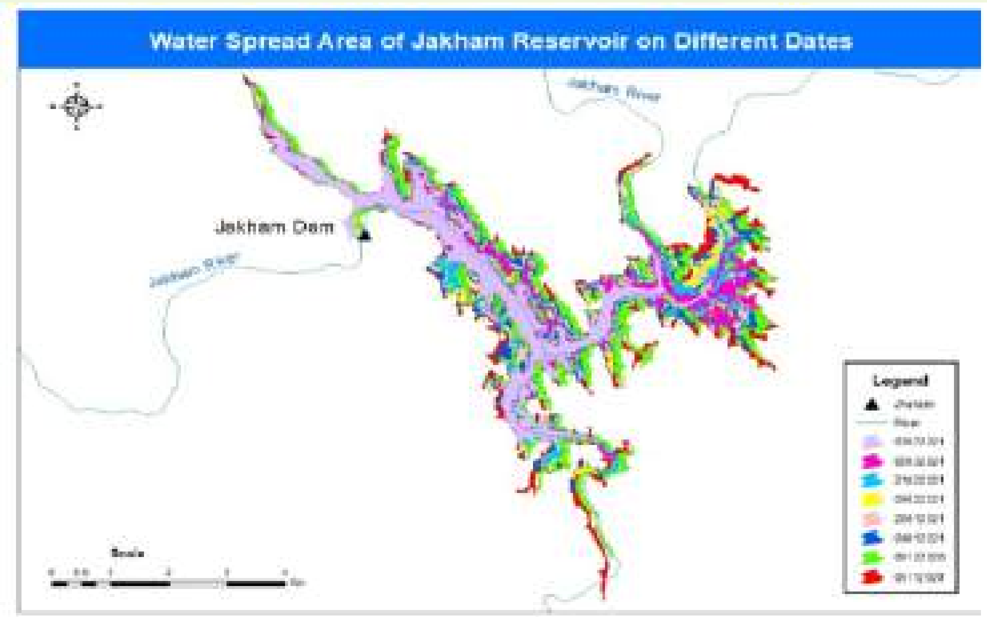


Fig. 3: Superimposed Multi-date Water- spread Areas of Jhakham Reservoir

- EstimateSegmental Live Capacity using trapezoidal formula. Summation of segmental capacities will give cumulative present live capacity.
- EstimateLive Capacity loss by comparison with original and previous hydrographic or Remote Sensing surveys.

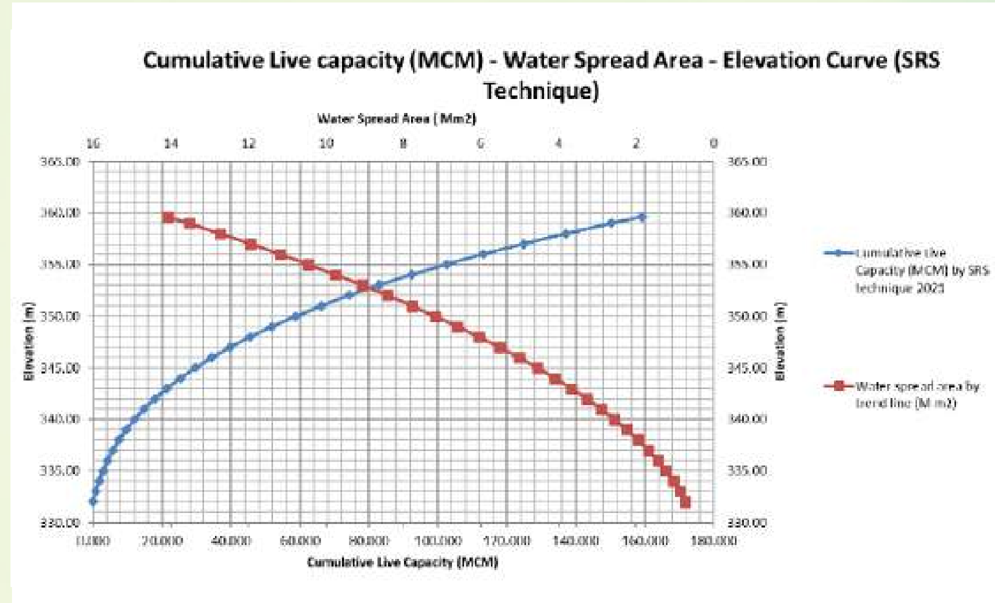


Fig. 4: Elevation – Area- Capacity Curve- Jakham reservoir, Rajasthan (2021)

Approach and Methodology

- Download multidate satellite data between max and min operating levels.
- Delineate Water Spread Area using ARC-GIS.
- Plot Water spread Area vs Elevation and define water spread area at every 1 m interval using best fit line equation.

Study Outcome

- After analysis of the satellite data in the present study, it is found that live capacity of Jakham reservoir in 2021 is 159.312 MCM witnessing a live storage loss of 16.139 MCM (i.e. 9.199%) in a period of 18 years during 2003 to 2021. This accounts for live capacity loss of 0.511% per annum since 2003.

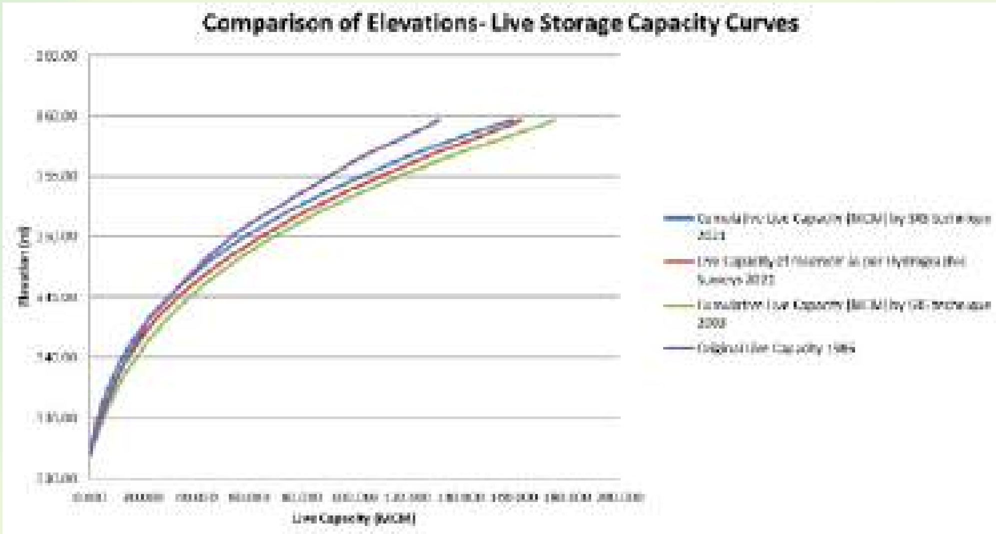


Fig. 5: Comparison of Elevation-Live Storage Capacity Curves (MCM)-Jakham reservoir, Rajasthan

- It may be noted that hydrographic survey of Jakham reservoir was also conducted in the year 2021 that reported live capacity as 162.68 MCM having a deviation of only 2% from the SRS study (159.312 MCM), thus establishing the accuracy of both the methodologies.

Advantages of Remote Sensing Approach

- Remote Sensing technique makes use of water spread of reservoir between max and min operating levels
- Water spread observations below MDDL are not possible as reservoir levels do not generally go below MDDL
- Use of remote sensing is thus restricted to Live Storage zone only
- It is quick, cost-effective, convenient, and effective for inaccessible remote areas.
- Capacity of reservoir can be established for earlier years also.

Hydrographic Survey

The sedimentation is natural phenomenon in the reservoirs which is of vital concern to all water resources development projects as it not only occurs in the dead storage but also encroaches into the live storage capacity which impairs the intended benefits for the reservoirs. Hydrographic surveys helps in estimating gross capacity loss in reservoirs, area elevation capacity curves of reservoirs, sedimentation distribution and bed- profiling, predict their future useful life, formulation of Sedimentation managements strategies and policies.

CWC carried out the task of collection and compilation of sedimentation data of various reservoirs in the Country andcarried out capacity survey of 36 important reservoir using hydro-graphic survey till FY 2020-21.

Four (4) editions of compendium titled "Compendium on silting of reservoirs in India" has been published by CWC:

Year	Edition	No. of reservoirs included
1991	1st	46
2001	2nd	144
2015	3rd	243
2020	4th	369

- CWC has taken up sedimentation survey of 32 reservoirs under National Hydrology Project (NHP) Phase I and works has already been started on these. For Phase-II, 87 reservoirs will be taken up, for which tendering is under process.
- The reservoirs were divided into 7 regions (mentioned below)

1	Himalayan Region (Indus, Ganga and Brahmaputra basins)
2	Indo Gangetic Plains
3	East flowing rivers upto Godavari (Excluding Ganga)
4	Deccan Peninsular east flowing rivers including Godavari and south Indian rivers a)Excluding reservoirs in the Western Ghat
5	West flowing rivers upto Narmada
6	Narmada and Tapi Basins
7	West flowing rivers beyond Tapi and south Indian rivers

Case Study of Jakham Reservoir

Approach and Methodology

- Conduct Hydrographical and topographic survey of the reservoir area up to the Full Reservoir Level and MWL of the reservoir.
- The survey system basically comprise of three components:

Positioning System	Global positioning system in Differential Mode.
Depth Measurement Unit	Digital Echo-Sounder / Bathymetry /Transducer for depth measurement.
Computer interface	Hypack software for data logging and processing of positioning data with contour plots.

Study Outcome

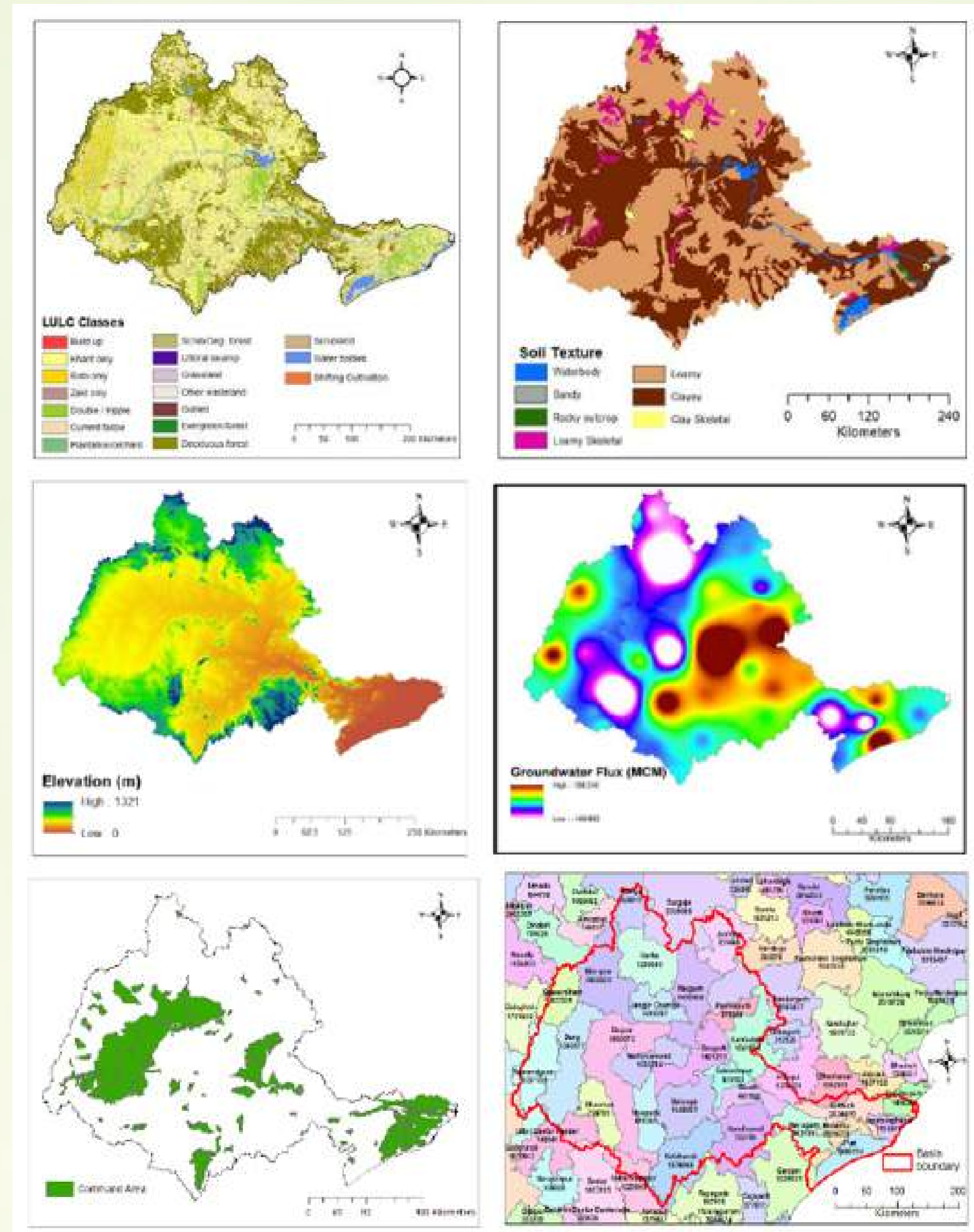
1. Re-surveyed Gross Capacity in 2021 works out to 168.35 MCM against the earlier surveyed capacity of 182.73 MCM in 2002.
2. The incremental loss in capacity of the reservoir between 2002 and 2021 works out to 14.38 MCM.
3. It is seen that the volume of sediment trapped during the past 19 years for the incremental period between 2002 and 2021 works out to 0.757 MCM/year or 7.493 Ha-m/100 Sq.km/year.
4. The reservoir is losing Gross capacity at the rate of 0.414% per annum and the annual loss in Dead Storage Capacity and Live Storage Capacity works out to 1.164% and 0.383% respectively.

Reassessment of Water Availability in India Using Space Input

The study of "Reassessment of Water Availability in India using Space Inputs" was conducted by CWC with Image Processing software support from National Remote Sensing Centre (NRSC) in the year 2019.

The average annual water resources availability of 20 river basins in the country was assessed as 1999.20 Billion Cubic Meters (BCM).

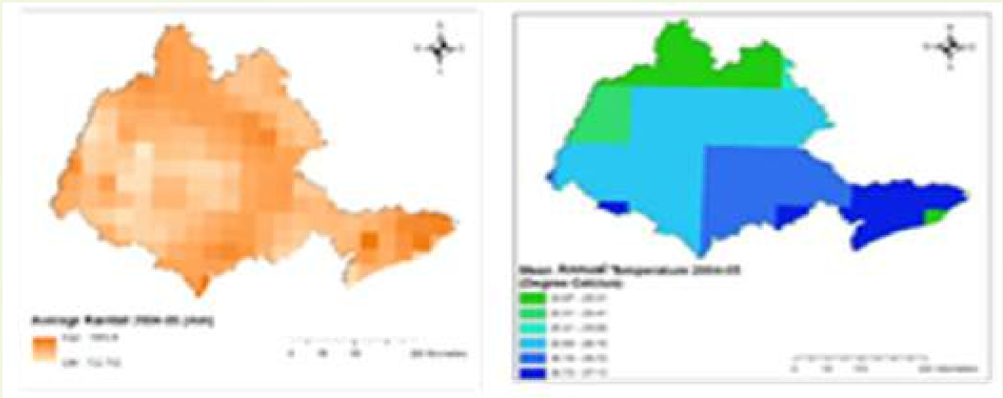
Earlier, Reassessment of Water Resources studies used to be through conventional methods that posed a problem of huge data collection about upstream water utilisation from all projects. Most of the time, such data was either not available or available for only major projects. The use of Space Inputs indirectly assesses the consumptive use through ET estimations through LULC. The most distinguishing features of the study was incorporation of rainfall, LULC, proper estimation of consumptive use, evapotranspiration, soil moisture, and development of basin and sub-basin wise models.



Case Study of Mahanadi Basin

Approach and Methodology

- Delineate the basin
- Data used are IMD temperature (1°X1°) and precipitation (0.25°X0.25°) gridded data, LULC map, Soil Classification data, types of crops, type of Ranifed areas (forests, orchards, rainfed agriculture etc), GW data, Population, and population projection, reservoir data etc.



- Using Thornthwaite Mather equation estimate the potential ET from Precipitation and temperature
- Correct the ET for irrigation supplies made through irrigation through SW and GW.
- Estimate the domestic, livestock, and industrial water consumption.
- Estimate the evaporation loss through reservoirs.
- Calculate the water availability through water balance equation.

Satellite derived inputs used in the study such as LULC, soil moisture, DEM, groundwater flux, command areas, administrative boundaries, gridded rainfall and temperature etc. for Mahanadi basin (arranged Left to Right)

Outcome of Study

- Mean available water resource of Mahanadi basin is 73.00 BCM.
- Maximum annual water availability is 142.61 BCM during 1994-95. Minimum annual water availability is 31.77 BCM during 2000-01.
- Annual rainfall in the basin varies from 923 mm to 1,905 mm during 1985-86 to2014-15 and mean rainfall of these 30 years is 1,317 mm.

Crop Area Estimation and Assessment Of Irrigation Potential Studies

Crop area estimation using satellite remote sensing technique of 52 AIBP projects was undertaken by CWC to assess gap in irrigation potential created & actual irrigation potential utilization.

The work of "Assessment of irrigation potential created through mapping of irrigation infrastructure using high resolution satellite data in selected AIBP projects" was carried out using high resolution Indian satellite data Cartosat-1(2.5 m resolution) satellite data & Google Earth.

Case Study: Mahi Irrigation Project

Approach and Methodology

Satellite based crop area assessment was done using Landsat 8 Imageries downloaded from USGS website and analyzed using Arc-GIS software. In this approach, satellite images of the project area before it was included in AIBP scheme and a recent image in rabi/kharif season were taken (Figure shows an example of Mahi irrigation project). The area under crop for the command was obtained following the steps shown

- Download Landsat Imagery through USGS website
- Add images in different bands in Arc-Map
- Stack Bands using Composite bands tool
- Convert Composite Image into FCC image
- Clip Satellite image as per command area
- Generate NDVI image from FCC image
- Mark/Reclassify all pixels representing vegetation
- Convert Raster image to vector polygon

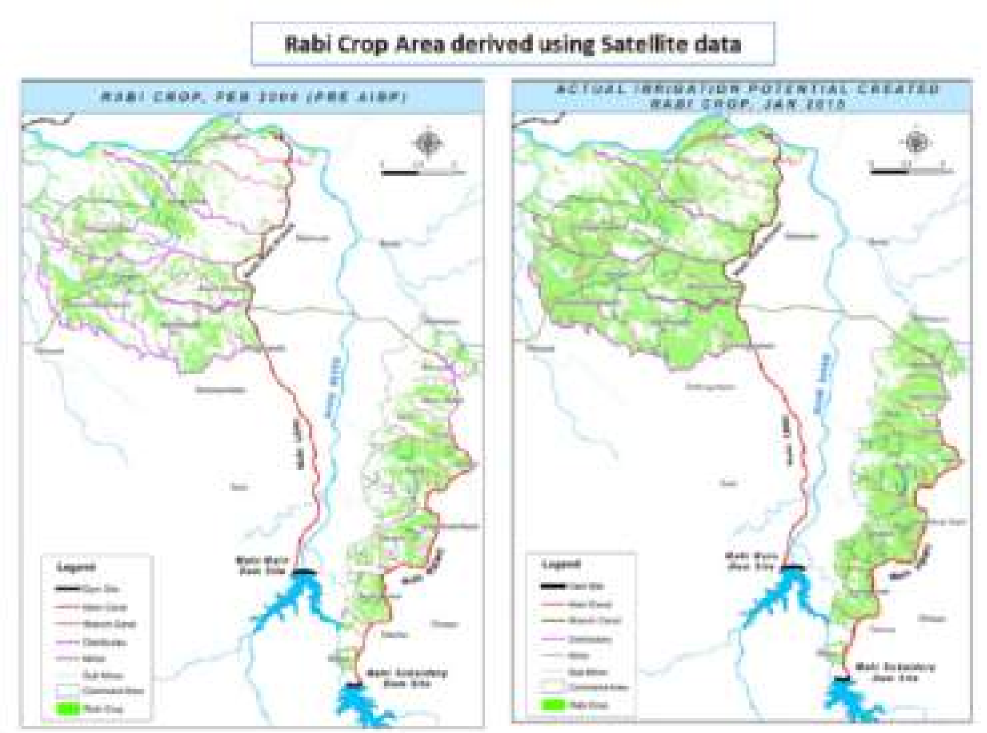


Fig. 6: Rabi Crop Derived using satellite data of Mahi Irrigation Project (MP) reporting a gap in crop area of -1831.09 ha

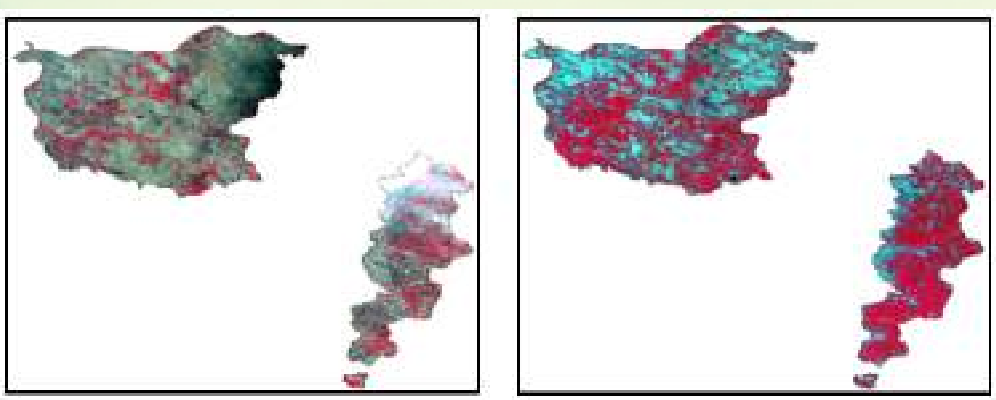


Fig. 7: Satellite Image – Landsat 7 & 8 (30 mresolution) for the years 2000 (left) and 2015 (right) of Mahi Irrigation Project (MP)

- Delete class other than vegetation such as forest, wasteland and built up area.
- Crop Area calculation using Calculate geometry tool in Arc-GIS

Outcome of Study

The study shows that the projects included under AIBP scheme have largely benefited from the scheme creating additional irrigation potential and quite a few of these projects have also been able to achieve their desired potential.

Advantages of Remote Sensing Techniques

- Satellite derived Normalized Difference Vegetation Index (NDVI) is used for estimation of crop yield.
- Satellite data-based monitoring and evaluation of irrigated command areas is useful to derive baseline inventory of irrigation infrastructure and helps in performance evaluation and problem pockets identification.
- Another advantage of satellite data is creation of time series as much as 15-20 years for monitoring the changes in time.

Waterlogging and Salt Affected Area

During 10th plan period the work of "Assessment of waterlogging and salt affected area in the major and medium irrigation projects in the country" was taken up by CWC. The work was awarded to RRSSC, Jodhpur in 2003 with the following objectives:

- Assessment of waterlogged areas due to surface inundation and saline and /sodic lands using multi-temporal satellite data.
- Spatial correlation between critical ground water depth (from well observation data) and surface waterlogging manifested on satellite data.

- Development of information system by integrating all (collected/ processed/developed) during the study for all the States and Union Territories.
- Preparation of state wise consolidated report for the country as a whole.

Approach and Methodology

1. Appropriate satellite data selection for two seasons & procurement
2. Collection of various data such as command boundaries, well data, topo maps, NBSS and LUP mapsetc
3. Scanning of base maps, command boundary maps, mosaics of scanned maps on spatial framework
4. Identification & demarcation of commands on topo maps and digitization
5. Pre-field analysis of waterlogged areas and data for soil salinity, locating the points for sample collection.
6. Integrated waterlogged areas map
7. Groundwater data tabulation, spatial database generation & depth to water level maps.
8. Correlation of depth of groundwater with observed waterlogging
9. Consultation with NBSS & LUP maps for probable salt affected areas
10. Analysis of soil samples
11. Classification of salt affected soils into alkaline, saline, saline-alkaline and their severity levels

Outcome of Study

The study on mapping and assessment of waterlogged and salt affected areas in 1701 irrigation commands (429 major and 1272 medium) covering 88895.620 Th ha (27.04% of the geographical area of the country) using remote sensing and GIS techniques for the year 2003-'05 revealed following facts:

- Extent of total waterlogged areas was 1719.279 Th ha which is 1.93% of the command area.
- About 0.14% of the command area was under most critical category (GW table depth <1m) in pre monsoon season which increased to 1.95% in post monsoon season. However, there was no significant correlation between surface waterlogged areas and GW table rise.
- Total salt affected areas occupied 1034.541 Th ha which is 1.16% of the command area.

Glacial Lake Outburst Flood (GLOF) Study

Glacial Lake Outburst Flood (GLOF) is the flood generated due to outburst of glacial lake which may cause disaster in the downstream. Monitoring their formation, status, and changes is crucial for safeguarding downstream utilities

The Himalayan regions including the Bhutan Himalayas have suffered many Glacial Lake Outburst Floods (GLOF) events. GLOFs from the Bhutan Himalayas were recorded at least in the early 1940s, 1957, 1960, 1969 and 1994.

In India, the outburst of Chorabari glacial lake in Kedarnath, Uttarkhand in June 2013 caused severe casualty of human life and devastation of properties in downstream.

The GLOF study is an important component of disaster Management Planning. Apart from that GLOF study is also essential for finalising the discharging capacity of spillway for the River Valley Project being

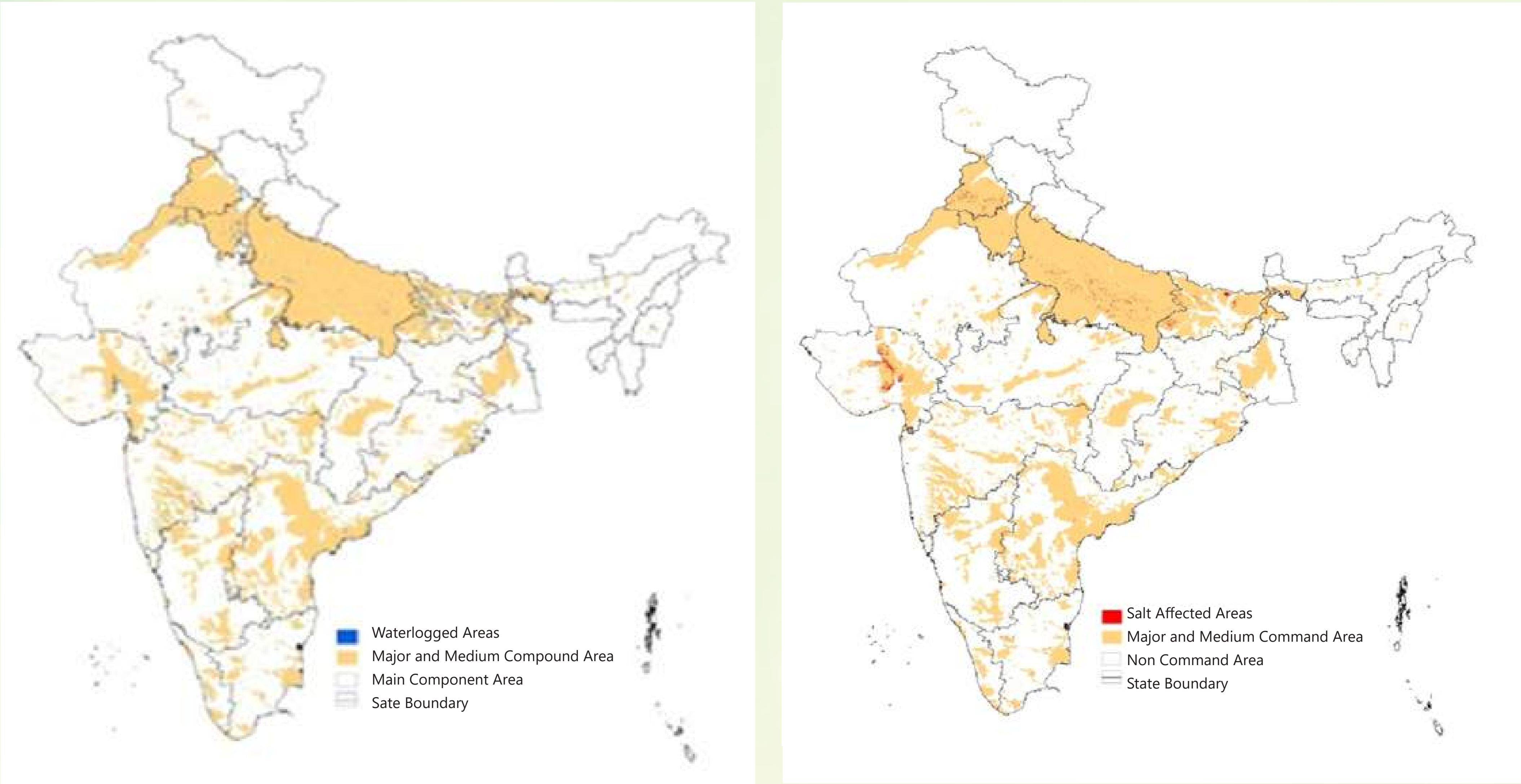


Fig. 8: Waterlogged (top) and salt affected areas (bottom)within Major and medium command areas in India.

planned in Himalayan regions, if potentially dangerous glacial lakes are present in their catchment area.

CWC has carried out a number of GLOF studies. Some of the important ones are GLOF Studies for Punatsangchhu Hydroelectric Project (Bhutan), Arun-III Hydroelectric Project (Nepal), Kalai-I, Kalai-II, Hutong-II and Oju Hydroelectric Projects (Arunachal Pradesh), Lhonak GLOF Estimate (Sikkim), Chorabari GLOF (Uttarkahand), etc.

Methodology for GLOF Estimation

- Identify the potentially dangerous glacial lakes in the project catchment based on the location of lakes, associated mother glaciers, and topographic features around the lakes and glaciers.

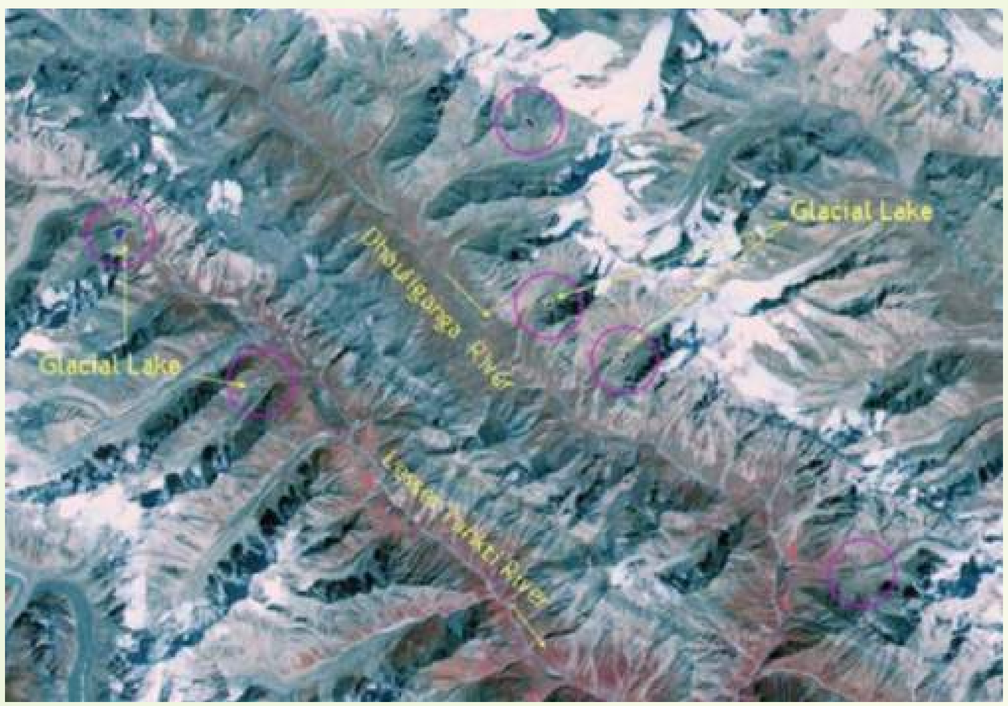


Fig. 9: Glacial Lake identification on satellite data

- Identify the possible combination of potentially dangerous glacial lakes
- Estimate the lakes water spread area and their volume and finalize of Glacial lakes for GLOF simulation after a detailed criticality analysis based on lake volume, its distance from the project site and average slope of the river from the glacial lake till the project site.
- Estimate the breach parameter for moraine dam and simulate dam breach flood using any mathematical model like MIKE11/HEC-RAS.
- Channel route the lake outburst flood through the entire reach of river from the GLOF site to project site to get the magnitude of flood peak at project site.

Advantages of Remote Sensing Approach

- Satellite Data form the only source to map and inventorise these natural entities, as they lie in most inaccessible areas.
- Satellite Imageries provide important information on the status of the glaciers, dynamic changes over time, aerial extent, and breach location in the case of disaster.
- The glacial lakes are easily identifiable on multi-spectral satellite data and their spatial extent can also be measured with reasonable accuracy.
- Satellite data of medium resolution (24-30 m) and fine resolution (6m) is found suitable to map these frozen entities.

INTEGRATED RESERVOIR OPERATIONS AND RULE LEVELS FORMULATIONS

Rule Curve/Level is the target level planned to be achieved in a reservoir, under different conditions of probabilities of inflow and / or demands, during various time periods in a year.Normally, there are two rule levels in a reservoir: 1) **Upper Rule Level** and 2) Conservation Rule Level(s). The Upper Rule Level is meant to provide dynamic flood cushion in the filling phase of the reservoir and allows gradual filling of the reservoir and also derived to fill up the reservoir by the end of monsoon season at a certain reliability. The **Conservation Rule Level** is provided in order to meet the conservation demands at a given reliability of meeting the demand (100% for drinking water, 90% for hydropower, 75% for irrigation etc). One can have different zones for Conservation Rule Levels for different types of water usage at different reliability.

The water level in the reservoir should not be above **Upper Rule Level** at the time of impingement of flood wave in any timestep in the filling phase. However, during routing of the flood wave, the space above Upper Rule Level may be utilised preferably up to FRL/MWL for temporarily storing the flood waters above Upper Rule Level and once the flood wave recedes, the reservoir level should again be brought back to Upper Rule Level or below it by releasing the water through penstocks, other outlets and finally through spills in case the penstock discharging capacity is exceeded.

In the depletion phase, the water situation in the reservoir needs to be assessed in every ten-daily timestep in view of approaching inflows, demands to be met, and prevailing water level in the reservoir. In case in any year, during the depletion season, the water level falls below the **Conservation Rule Level**, this is kind of an alert situation in view of meeting forthcoming demands. Unless the inflow situation improves in subsequent timesteps, a suitable curtailment in supplies may be made keeping in view the reservoir level, conservation rule level, expected inflows, and demands to be met. In extremely bad years (annual inflow less than average demands), the reservoir may fail in meeting various demands.

Zoning for Multi-Purpose Reservoir

In multi-purpose reservoirs where joint use of some of the storage space has been envisaged, operation becomes complicated due to competing and conflicting demands e.g. irrigation and hydropwer, flood and conservation, etc. So, a compromise will have to be effected in flood

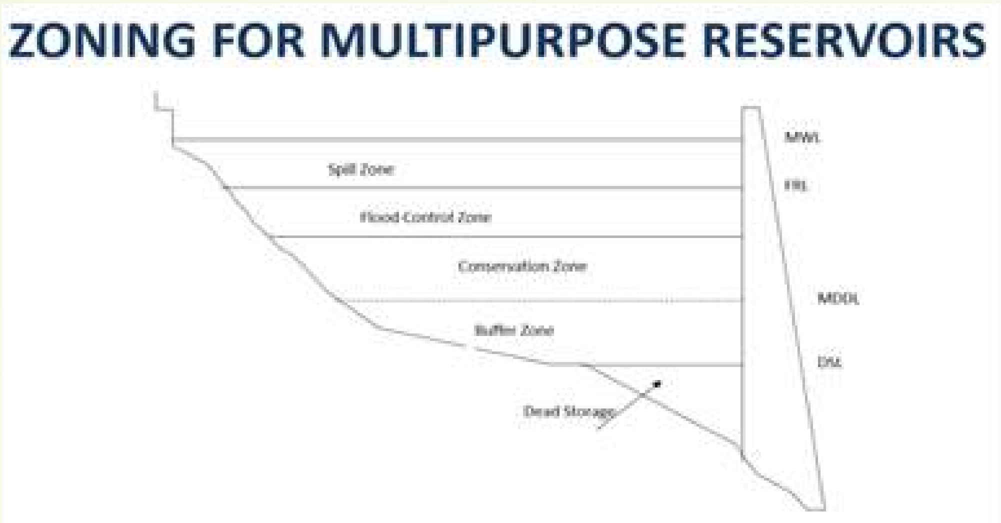


Fig. 10: Zoning in Reservoirs

control operations or meeting of conservation demands. The concept of joint use of storage space, with operational criteria to maximise the the complimentary effects and to minimise the competetive effects requires careful design.

Case Study of Idukki Reservoir

Kerala is a high rainfall State with a very limited storage space available in reservoirs. Idukki reservoir is situated on river Periyar in Kerala having a total live storage of about 1460 MCM. During August 2018 Kerala witnessed extreme flooding situation due to heavy rainfall all over Kerala causing landslides, deaths and misery to people. On the request of Govt of Kerala, guidance was provided by CWC to formulate the Rule Levels for a few major reservoirs in Kerala including Idukki reservoir.

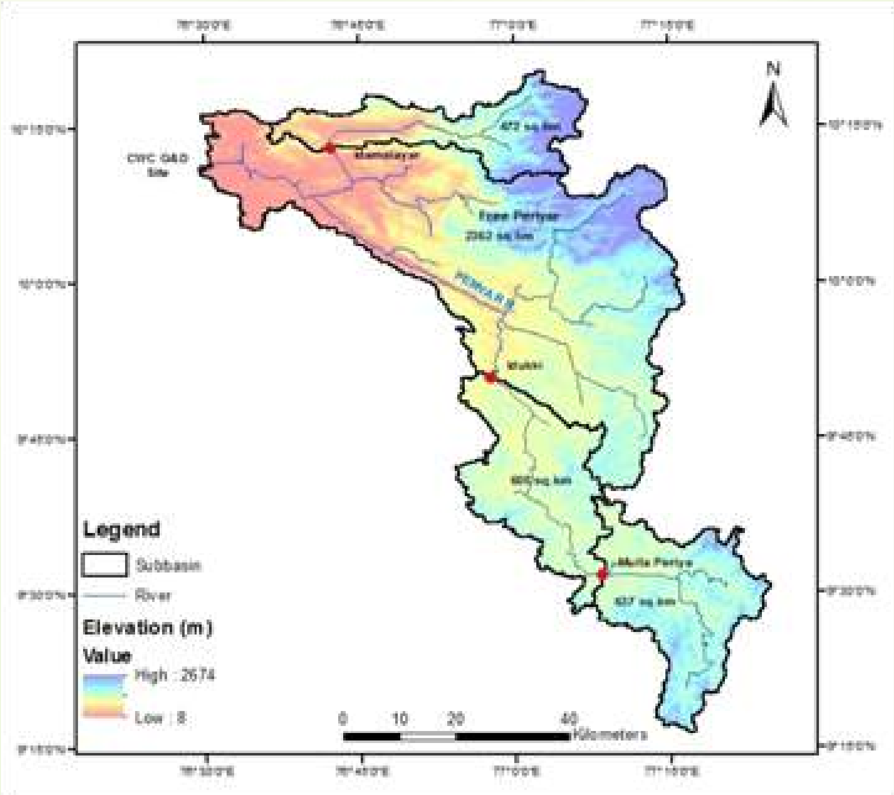


Fig. 11: Drainage area map of Periyar basin

Approach and Methodology

- Probability based approach was adopted for formulating the Rule Levels
- Inflow series for 38 years on 10-daily time-step (1981-82 to 2018-19) was used.
- Demand on 10-daily time-step was used. The reservoir is operated for hydropower generation.
- Last updated Elevation Capacity tables were used.
- Conservation Rule Levels were drawn for hydropower demands and 90th percentile time-step inflows. Three conservation Rule Levels were provided.
- Upper Rule Levels were drawn with the probability of filling the reservoir at least at 50% reliability.
- The Rule Levels were then tested against different years having probability of occurrence of 10%, 25%, 50%, 75% and 90%.

Study Outcome

- The results of simulation showed reservoir filled in 23 years out of 38 years of simulation (60% probability of filling).

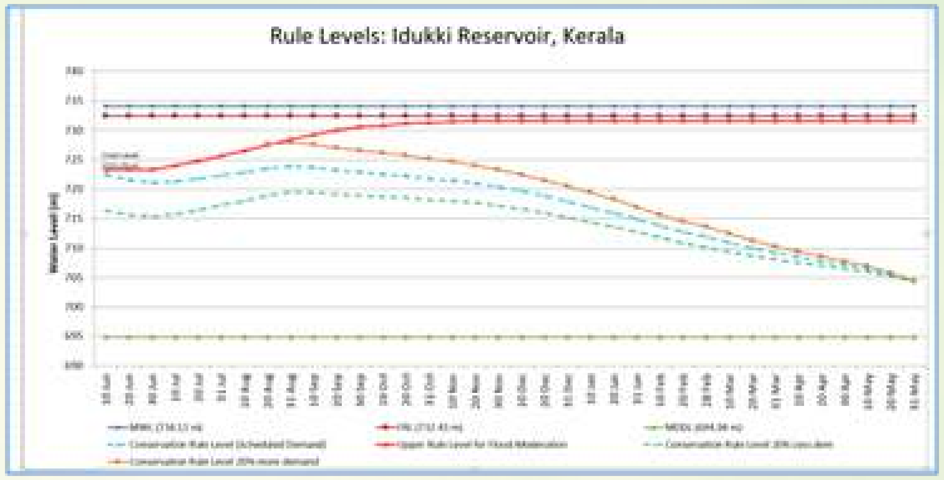


Fig. 12: Rule Levels of Idukki Reservoir

- The testing of Rule Levels showed that the demands are comfortably met at 90% reliability.
- Provision of carry-over storage at the end of hydrological year helps the reservoir.
- Flood cushion was created more than what was available in 2018 floods.

Advantages of Probability Based Approach

- Taking a sufficiently long inflow series (about 35 years) sufficiently covers most of hydrological scenarios (extremely wet, extremely dry, normal, and combination thereof).
- Simulating all years (as they came), increases the confidence level in formulation of reservoir operation policy.
- The operation policy, thus formulated, gives the operator a clear guidance as to what has to be done when the reservoir levels falls below or exceeds the Rule Levels.

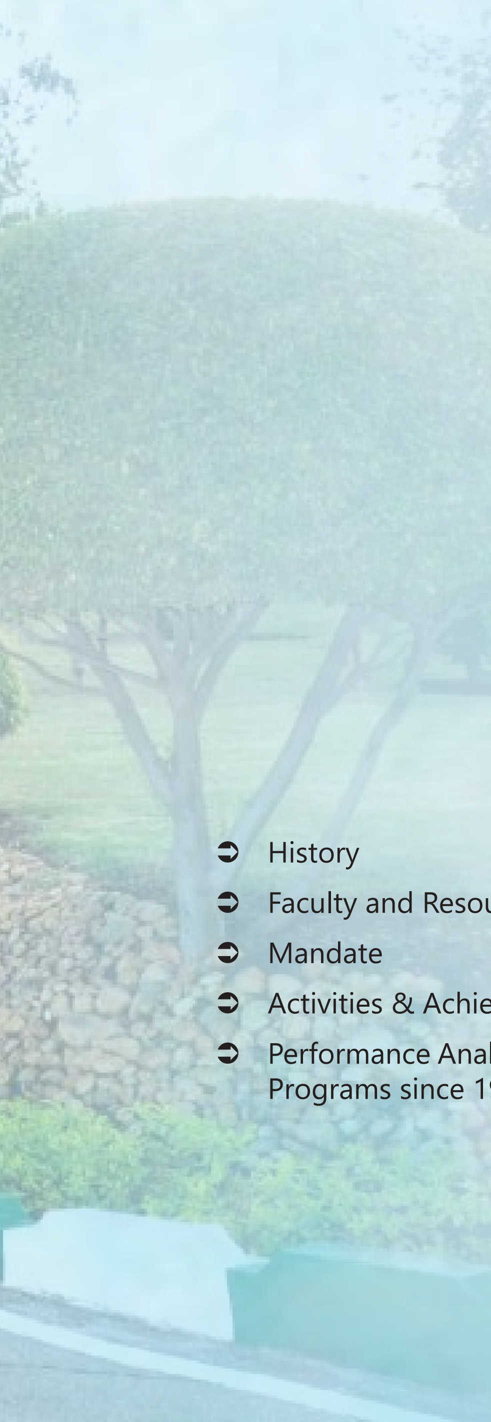
Rule Levels by CWC

CWC has drawn or provided guidance in formulating Rule Levels for following reservoir:

1. Tehri
2. Bansagar
3. Ukai
4. Damodar Valley reservoirs (Tenughat, Panchet, Konar, Tilaiya, and Maithon
5. Idukki, Kakki, Mulla-Periyar and Idamalayar reservoirs of Kerala
6. Srisailam, Nagarjuna Sagar (KRMB)
7. Tungabhadra reservoir

Idukki Dam, Kerala (1976)


राष्ट्रीय जल अकादमी



10

National Water Academy - At a Glance

- History
- Faculty and Resource Pool
- Mandate
- Activities & Achievements
- Performance Analysis Physical Achievement of Training Activities Summary of Training Programs since 1988 to till date (31.03.2022)

National Water Academy - At a Glance

National Water Academy (NWA), Pune under Central Water Commission (CWC)is functioning as "*Centre of Excellence*" in the field of training and capacity building of professionals and other stakeholders of water resources sector.

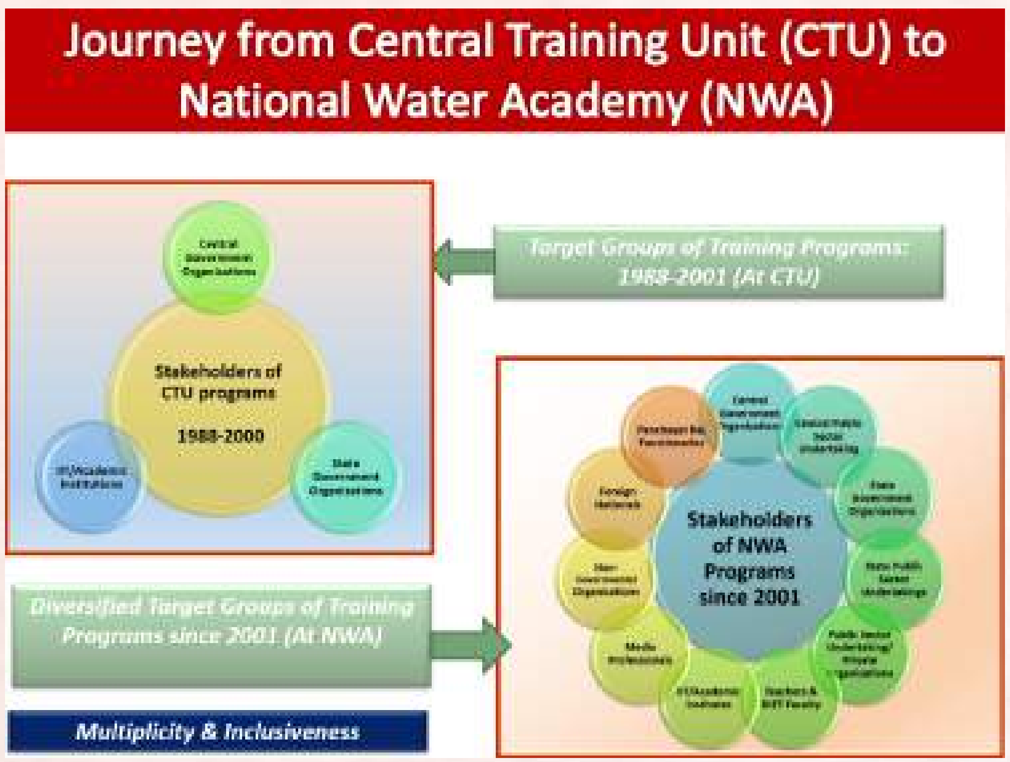
History

National Water Academy, earlier named as Central Training Unit (CTU) was set up by the Ministry of Water Resources, Govt. of India under CWC, inthe year 1988 to impart training to the in-service engineers of variousCentral/ State agencies involved in the water resources development andmanagement.

CTU was established under USAID assistance andstrengthened with the subsequent assistance received from the World Bankunder Hydrology Project.

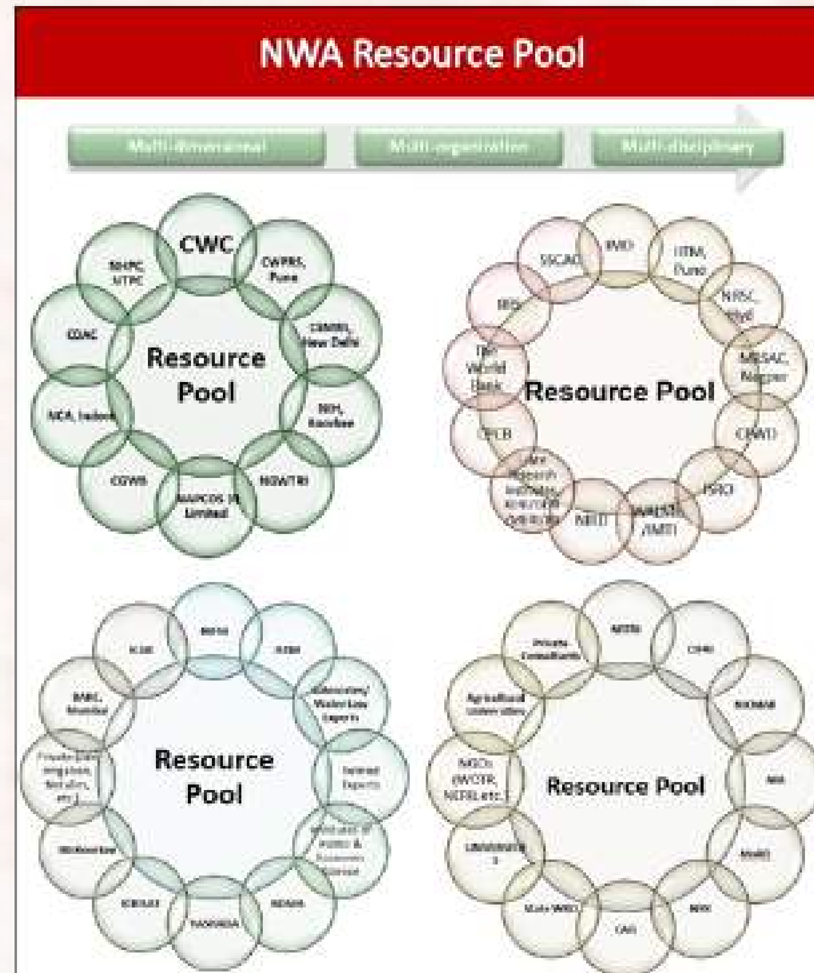
To facilitate increased training activities, CTU was upgraded to National Water Academy (NWA), and it started functioning in its new campus from May 2001.Mandate of NWA was widened to address the training and capacity building needs of water sector professionals and the courses

conducted by NWA were opened to all the States. Training programs of NWA were opened to all stakeholders in the year 2010.



Faculty and Resource Pool

NWA is headed by Chief Engineer and supported by five Director and three Deputy Director level officers, all of them function as Core Faculty of the Academy. NWA has an enriched pool of multi-disciplinary and multi-dimensional serving / retired professionals drawn from the related organizations to serve as guest faculty. Central Water Engineering Services officers are major resource pool for imparting training with focus on applied learning concepts.



Mandate

NWA, Pune is a Central Training Institute mandated to conduct Induction Training Program of Central Water Engineering Services Group A &B Officers and Mandatory Cadre Training Programs for Central Water Engineering Services Group A &B Officers. NWA also conducts training and capacity building programs for various stakeholders in the field of water resources development and management.

Objectives of NWA include conducting

- **Specialized/Core Area Courses** for officers of Central and State agencies;
- Awareness programs on **Flagship Schemes** of the Ministry;
- Mass Awareness Programs for School Teachers; NGOs, Media Professionals, PRIfunctionaries;
- **Purpose Oriented Distance Learning Programs**;
- Training modules **in new emerging technologies for** eg. Applications of RS & GIS, Google Earth Engine and Python Programmingetc., in water resources sector
- **Trainers Development Programs**;
- **National / International Seminars and Workshops** on issues of water resources development/ related subject areas for the benefit of Central / State agencies;
- Develop and maintain linkages with **leading institutions in India and abroad** dealing with training related activities in water resources sector for **sharing the expertise and imparting Trainings**;
- **Customised Trainings** to professionals of other countries as per demand

In addition, objectives of the Academy include assistance to State Government institutes for their specific training needs and collaboration with international agencies like WMO, COMET, ICID etc. for training and capacity building purposes.

International Trainings

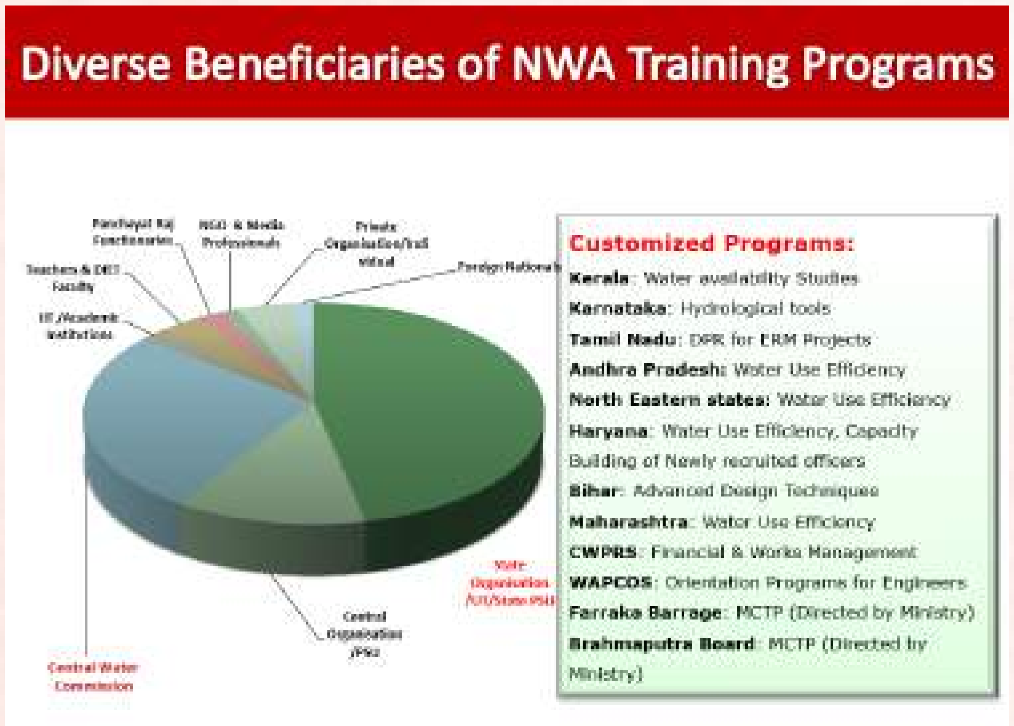
- **World Meteorological Organization**: NWA is a component of the WMO Regional Training Centre of India since 2012 with further Collaboration with COMET, USA
- Distance Learning courses on Moodle platform on:

Basic Hydrological Sciences	10 courses	• 547 Indian participants from State, Central, PSU, Academic, NGOs etc. • 204 Foreign participants from countries of Regional Association – II, WMO (Asian Countries) Total participants = [illegible]
Advanced topics in Hydraulics and Hydrological Sciences	4 courses	

- International Trainings through ITEC Scheme of MEA including for African countries (4 no.)
- **Royal Government of Bhutan:** Demand based trainings to Officials (4 no.)
- **International Commission on Irrigation and Drainage**: collaboration initiated one International Certificate Course on Micro Irrigation System was conducted with participation of 180 Participants (96 Indian + 84 international)
- Two programs viz (a) Flood Forecasting and (b) Irrigation Planning are in progress with ICID.

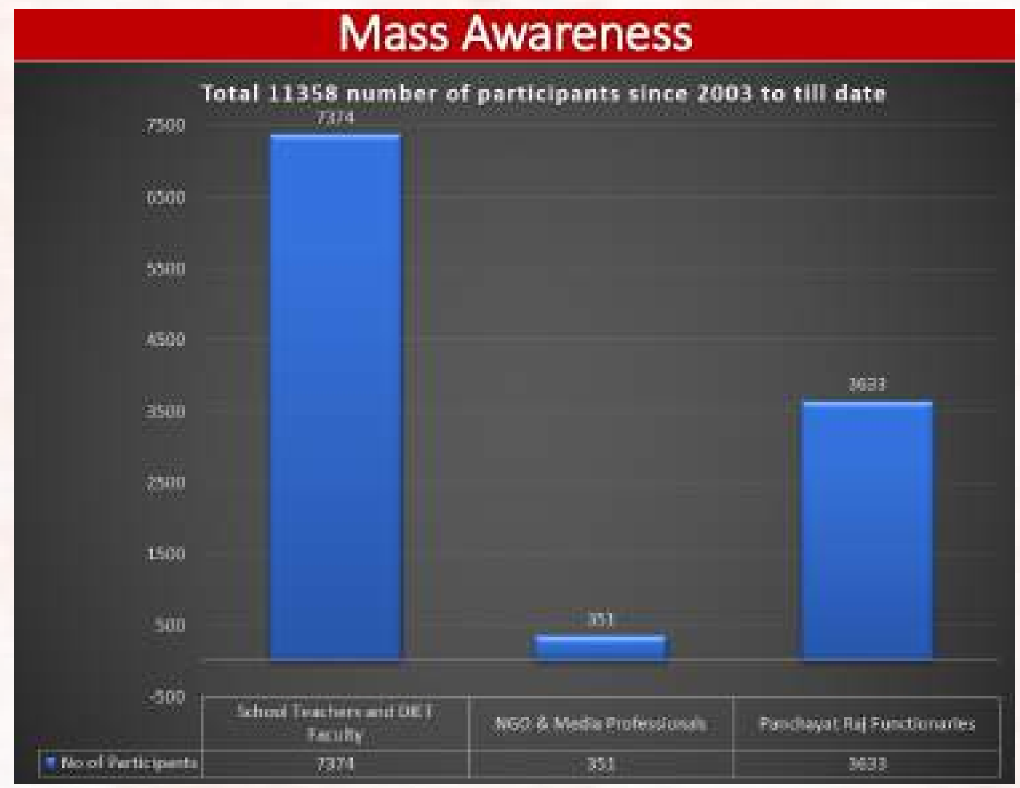
Activities & Achievements

The Academy, in its journey of more than three decades, has systematically and consistentlykept modifying, upgrading, and expanding its activities towards its mission of training andcapacity building of all the stakeholders of water sector so that they are able to manage waterresources issues and overcome problems of the sector in an integrated and sustainablemanner.



NWA, for last 33 years, has been addressing wider training needs of water resources professionals in both technical and non-technical areas. In its national role, the NWA is concentrating on conducting training courses for all water sector professionals in the specialized and emerging areas. Major beneficiaries of these programs are officers from Central and State Governmentdepartments, Central/ State PSUs, Academia etc. National Water Academy has also forayed into custom-designed programs meeting specific requirement of client organizations, both at its campus and off-campus at the client locations. NWA has also been recognized as Regional Training Centre (RTC) of the World Meteorological Organization (WMO) andhas been conducting Distance Learning Programs on the topics of Hydraulics, Hydrological Sciences and Hydrometeorology in association with WMO for Asian countries.Collaboration has been developed recently with International Commission on Irrigation &Drainage (ICID) and an International Certificate course on “Micro Irrigation Systems” was launched in October 2020.

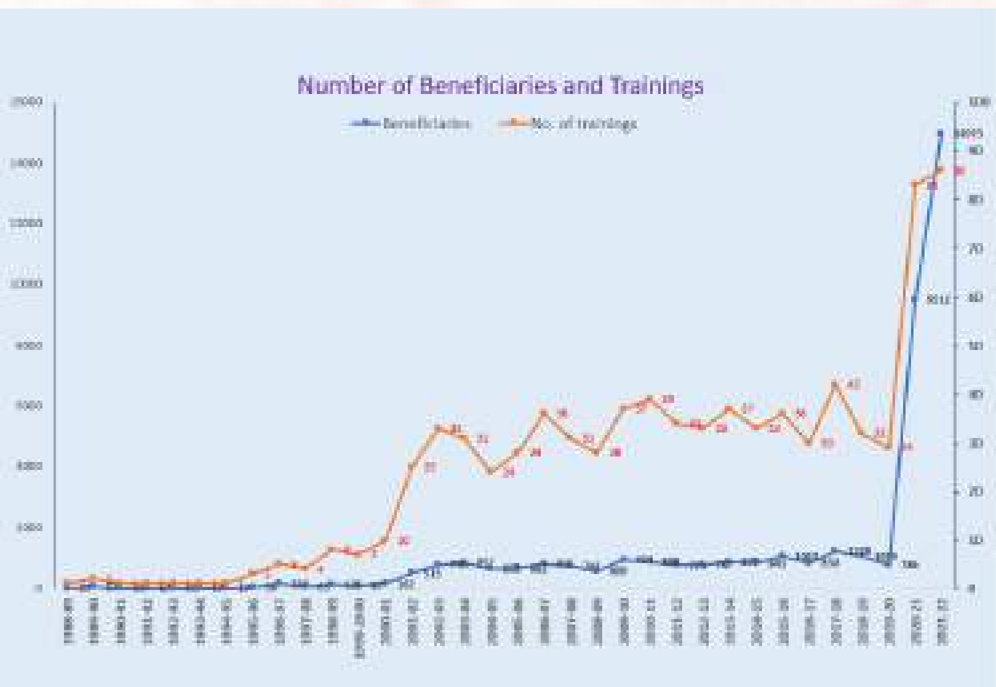
Recognizing the need for water education and to spread water literacy amongst the masses, the Academy has also been conducting mass awareness programs for promoting Water Conservation and



Management targeting School Teachers, NGOS, Media Professionals and Panchayat Raj Functionaries.

Due to COVID-19 pandemic situation after March 2020, NWA quickly shifted its activities to on-line mode by using popular and easily available IT tools. Platforms like Google Classroom, CISCO Webex, Youtube channel and Moodle open-source Learning Management System (LMS) were chosen for organizing the training programs and webinars.NWA has achieved remarkablesuccess during this period by extending its reach pan-India. Mass awareness programs for schoolteachers and programs on emerging technologies, Remote Sensing &GIS using open access software are worthy for special mention.

NWA since its inception to till date (upto 31.03.2022) has conducted 832 programs benefiting 41144 participants.During the year 2021-22, a total of 86 programs were conducted wherein 14973officials were trained through various categories of training programs.



Performance Analysis Physical Achievement of Training Activities Summary of Training Programs since 1988 to till date (31.03.2022)

Year	No. of trainings	Training Weeks	Officers Trained	Man-weeks of Training	Training Days	Man-days of training
1988-89	1	13	29	377	65	1885
1989-90	2	35	67	1170	175	5850
1990-91	I	42	25	1050	210	5250
1991-92	1	42	17	714	210	3570
1992-93	1	42	21	882	210	4410
1993-94	1	42	17	714	210	3570
1994-95	I	42	17	714	210	3570
1995-96	3	55	58	884	272	4420
1996-97	5	44	167	973	217	4865
1997-98	4	34	65	551	170	2755
1998-99	8	14	135	227	68	1135
1999-2000	7	46	97	562	230	2810
2000-01	10	24	162	425	120	2125
2001-02	25	53	515	1109	267	5545
2002-03	33	53	796	1045	262	5225
2003-04	31	76	852	1797	379	8985
2004-05	24	71	668	1846	354	9230
2005-06	28	66	682	1662	329	8310
2006-07	36	56	816	1183	280	5915
2007-08	31	53	742	1021	263	5105
2008-09	28	52	600	1001	251	5005
2009-10	37	48	954	1085	238	5425
2010-11	39	54	880	1029	270	5145
2011-12	34	39	774	860	193	4300
2012-13	33	55	787	1322	275	6610
2013-14	37	73	877	1782	365	8910
2014-15	33	83	843	2847	413	14235
2015-16	36	77	1063	2649	382	13245
2016-17	30	79	850	2067	394	10335
2017-18	42	52	1238	1791	259	8955
2018-19	32	78	1059	2616	388	13080
2019-20	29	60	786	2112	298	10559
2020-21	83	143	9512	18379	716	91896
2021-22	86	78	14973	11605	388	58026
Total	**832**	**1874**	**41144**	**70051**	**9331**	**350256**

Sardar Sarovar Dam, Gujarat (2017)

11

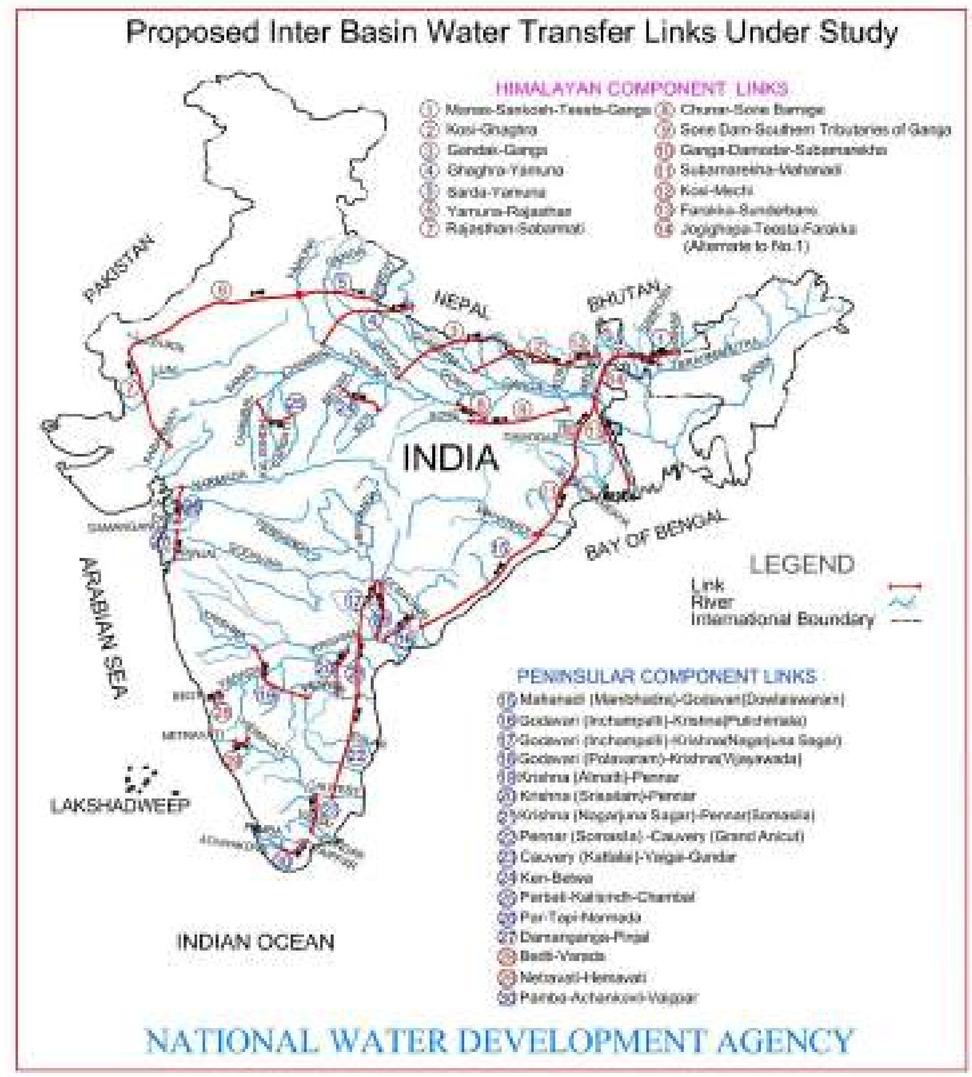
Interlinking of Rivers

- National Perspective Plan (NPP)
- Present Status of Studies and Implementation
- Key Issues in the Implementation of ILR Projects
- Efforts of Government of India For Progress of ILR Programme
- Conclusion

Interlinking of Rivers

National Perspective Plan (NPP)

The water resources are not distributed either in a temporal or spatial sense, equitably in the country. Water is one of the key drivers of socio-economic prosperity of a region. Interlinking of rivers is an idea generated after centuries of such practices at a smaller scale but with demonstrable success to enable an equitable distribution of water in the country and thereby bring prosperity to all. Earlier ideas in this direction were formulated by Dr KL Rao in year 1972 and later on in a different context by CaptDastur in year 1977. The concept was formalized with framing of National Perspective Plan (NPP) of 1980 for transferring water from water surplus basins to water-deficit basins/regions in which 30 links were identified as given under figure.



The distinctive feature of the NPP is that the transfer of water is essentially by gravity and only in small reaches by lifts (not exceeding 120 m). This plan comprises of two components: i) Himalayan Rivers Development; and ii) Peninsular Rivers Development. While the second component will be an inter-state venture, the first will involve neighbouring countries too and thus will be an international venture. The link system was conceived on the basis of "substitution and exchange" to avoid unnecessary lifts. Prima-face the scheme was found to be technically feasible and economically viable (IWRS 1996). The interlinking proposal under NPP comprises of three major links:

(i) Interlinking Mahanadi, Godavari, Krishna, Pennar, Cauvery and Vaigai in the Peninsular India to transfer waters of Mahanadi and Godavari to deficit areas to benefit the States of Odisha, Andhra Pradesh, Telangana, Karnataka and Tamil Nadu and Union Territory of Puducherry.

(ii) Interlinking Brahmaputra with Ganga, Subernarekha and Mahanadi to transfer waters of Brahmaputra to benefit areas in Assam, West Bengal, Bihar, Jharkhand and Odisha.

(iii) Interlinking Gandak, Ghagra, Sarda and Yamuna, all tributaries of Ganga, on to Rajasthan and Sabarmati to transfer the waters of Gandak and Ghagra rivers to benefit areas in Uttar Pradesh, Uttarakhand, Haryana, Rajasthan, Gujarat, Bihar and Jharkhand.

The implementation of interlinking of rivers as per National Perspective Plan shall help in harnessing and transfer of approximately 166 BCM of water. It would provide benefits of 25 million ha of irrigation from surface waters, 10 million ha by increased use of ground waters, raising the ultimate irrigation potential from 140 million ha to 175 million ha. The country would also get large benefits for domestic and industrial water supply, additional generation of hydropower to the tune of 34,000 MW, flood control, drought mitigation, navigation, fisheries, development of infrastructure, control of pollution and improvement of environment etc.

Present Status of Studies and Implementation

The National water Development Agency (NWDA) was established in July, 1982 to study the feasibility of links under Peninsular Component of NPP. Later on the functions of NWDA were modified from time to time to prepare Water Balance of basins/sub- basins/diversions points, Pre-feasibility Reports/Feasibility Reports/Detailed Project Reports of links under NPP as well as intra-state links.

Over the year NWDA has carried out all related studies covering water balance studies of basins/sub-basins and catchments up to diversion points, toposheet studies of reservoirs and link alignments, storage capacity studies of reservoirs, pre-feasibility studies, feasibility studies and Detailed Project Report (DPR) of all links identified under NPP. The prefeasibility studies of intra-state links, as requested by various states, have also been carried out by NWDA. The work of DPRs of some of the intra-state links have been taken up. Till date, NWDA has completed studies as follows:

Sl. No	Particulars	Peninsular Component	Himalayan Component	Total
A	**Proposals under National Perspective Plan**			
1.	Water balance studies of basins/sub-basins	137	--	137
2.	Water balance studies of diversion points	52	19	71
3.	Toposheet and storage capacity studies of reservoir	58	16	74
4.	Toposheet studies of link alignment	18	19	37
5.	Pre-feasibility reports (PFR)	18	14	32
6.	Surveys and Investigations and Preparation of Feasibility Reports (FR) of specific links	14	10 (3 Indian Portion)	24
7	Detailed Project Report of link Projects	8	-	-
B	**Intra-State link proposals of State Governments**			
1	Pre-Feasibility Report	39		
2	Detailed Project Report of link	6		

Central Government is pursuing the ILR programme in the country in a consultative manner building consensus amongst the concerned states for the implementation of the specific link projects. Six link projects have been identified as priority projects for implementation as given below:

(i) Ken-Betwa Link Project

(ii) Damanganga-Pinjal Link Project

(iii) Par-Tapi-Narmada Link Project

(iv) Godavari-Cauvery Link Project (alt. study) viz.,

- Godavari – Krishna (Nagarjunasagar) link
- Krishna –Pennar (Somasila) link
- Pennar-Cauvery (Grand Anicut) link

Concerted efforts led to signing of a tripartite agreement amongst states of Madhya Pradesh, Uttar Pradesh and Central Govt. in March, 2021 for the implementation of Ken-Betwa link project jointly through an special purpose vehicle. Efforts are being made for reaching consensus amongst concerned states for implementation of other matured projects.

Ken –Betwa link project is the first link project under NPP whose implementation has been initiated.Memorandum of Agreement (MoA) between UP and MP for Ken-Betwa link project has been signed among Govts of MP, UP and Centre in the august presence of Hon'ble Prime Minister of India on 22.03.2021.The Govt. of India has approved the implementation of KBLP with an estimated cost of Rs 44605 cr (year 2020-21 price level) with central support of Rs 39317 cr through a Special Purpose Vehicle viz; Ken Betwa Link Project Authority (KBLPA) on 8.12.21. The Gazette Notification has been issued on 11th February 2022 constituting a Steering Committee and Special Purpose Vehicle viz. Ken-Betwa Link Project Authority (KBLPA) for the implementation of KBLP jointly by Government of India and State Governments of MP and UP.

Key Issues in the Implementation of ILR Projects

The interstate issues are the key challenges in the implementation of any ILR project. The States surplus in water resources generally do not agree to such surpluses. It is difficult to have agreement between donor and donee states as the latter in general demand more water. The States are apprehensive about disturbing the existing allocation of water as per awards/interstate agreement. Some States have apprehension that link proposals may have an adverse effect on their existing irrigation and power requirements. In view of growing requirements, some States are challenging the very definition of 'Surplus Basin' agreed earlier.

There are six ILR links whose some of the components lie either in Nepal or in Bhutan. Also there are another seven links of Himalayan component of NPP which are dependent on water brought through these six links. Looking at the reducing water balance in Mahanadi and Godavari basins over the years, even the success of some of the peninsular links shall depend upon the water brought from Brahmaputra basin. Moreover, the efficacy of inter-basin water transfer would depend to large extent upon the water conserved/stored during the monsoon period. Many of the storage sites identified for inter-basin water transfer lie in Nepal and Bhutan. Thus success of ILR projects will depend upon co-operation with the neighbouring countries especially with Nepal and Bhutan, where most of the storages and Head works are proposed.

- Central Water Commission formulated a National Perspective Plan (NPP) for Water Resources Development in August 1980 envisaging inter basin water transfer in the country.
- Under the NPP, 30 links have been identified (16 under Peninsular Component and 14 under Himalayan Component) for preparation of Feasibility Reports (FRs).
- Pre-feasibility Reports of all the links have been completed while Feasibility Reports of 24 links have completed
- CWC provides consultancy services to all ILR projects in respect of project hydrology, design, project preparation and planning as and when referred.
- CWC conducts appraisal of ILR projects when it is declared as national project (Ken-Betwa Link is such project).

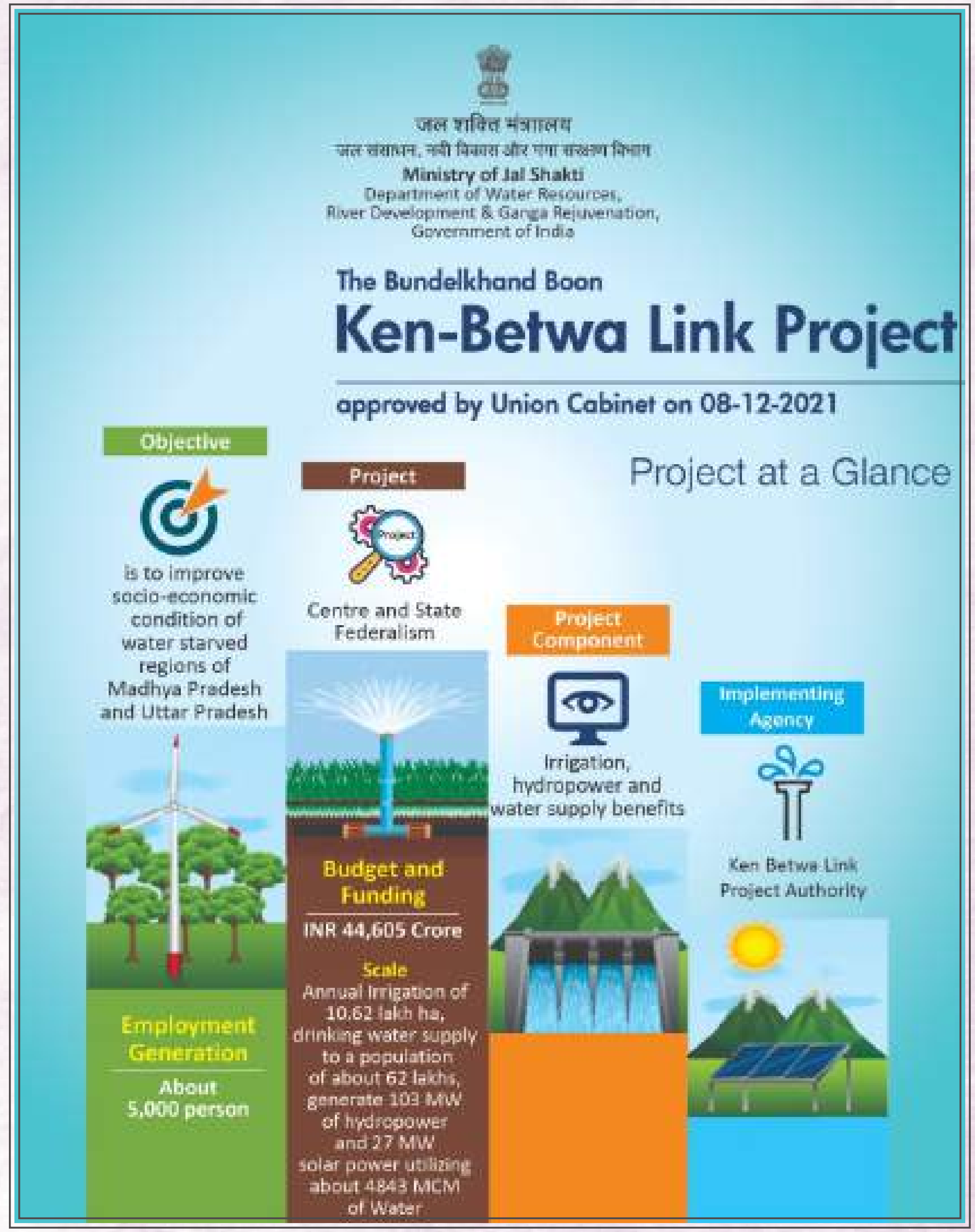
Efforts of Government of India For Progress of ILR Programme

The Hon'ble Supreme Court vide its judgment dated 27.02.2012 in the Writ Petition (Civil) No. 512 of 2002 on 'Networking of Rivers' along with Writ Petition No. 668 of 2002 has directed the Union of India and particularly the Ministry of Water Resources to constitute a Committee under the chairmanship of Hon'ble Minister of Water Resources for the implementation of Interlinking of Rivers Programme. In compliance, MoWR, RD and GR has constituted a committee called Special Committee on Interlinking of Rivers(SC-ILR) and the meetings of the Committee are being held on regular basis. A Task Force for Interlinking of Rivers (TF-ILR) has also been constituted to assist SC-ILR.

The ILR programme has been accorded top priority by the Government of India. Further, as directed by the Supreme Court of India, it is to be promoted as a national programme for the benefit of the nation. Therefore, a constitution of new institution called National Interlinking of Rivers Authority (NIRA) is under consideration in the Ministry of Jal Shakti as an independent autonomous body for planning and investigation of ILR projects and to effectively function for financing and implementation of ILR projects under NPP or any other project of national importance as assigned by the Govt. of India. The Cabinet note for the constitution of NIRA was prepared and submitted to Ministry of Jal Shakti, which was then circulated to various Ministries / Departments in February, 2022.

Conclusion

The interlinking of rivers as proposed under NPP would be immensely helpful in addressing the acute distribution of water resources in the country and providing substantial benefitsof enhanced irrigation potential and water supply for domestic and industrial needs. Govt. of India is making concerted efforts for the implementation of ILR projects. In the existing state of constitutional and legal provisions, the interlinking of rivers programme is being pursued on the principle of consensus and agreement amongst the concerned States. Successful implementation of the ILR projects will depend upon the cooperation and consensus amongst States of India. The co-operation with the neighbouring countries especially with Nepal and Bhutan, where most of the storages and Head works are proposed, would also be critical for ILR programme. There is huge potential for constructive cooperation amongst India, Nepal, Bhutan and Bangladesh.



12

India Water Resources Information System (India – WRIS)

- India-WRIS
- WIMS
- Integrated Water & Crop Information and Management System (IWCIMS)
- State Water Informatics Centre (SWIC)

India Water Resources Information System (India – WRIS)

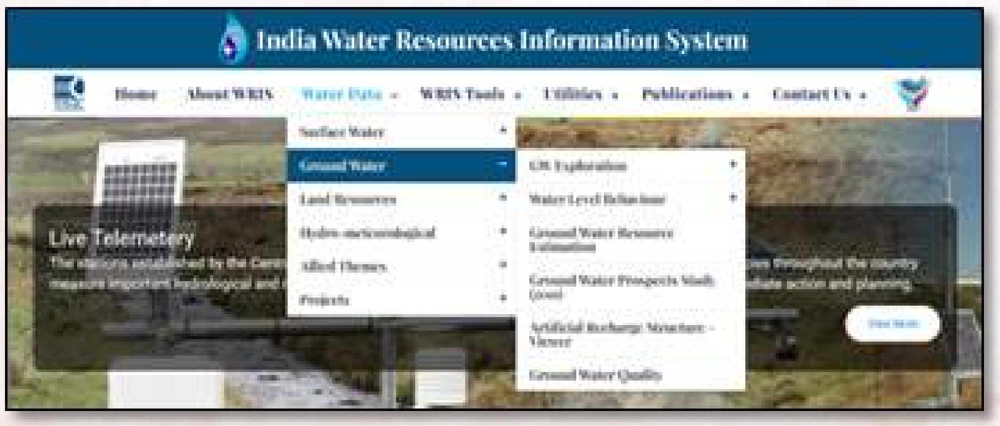
The generation of a database and the implementation of a web-enabled Water Resources Information System popularly known as India-WRIS was initiated through a Memorandum of Understanding signed on December 3rd, 2008 between the Central Water Commission (CWC), Ministry of Water Resources, River Development and Ganga Rejuvenation (now Ministry of Jal Shakti) and the Indian Space Research Organization (ISRO), Department of Space. The project comprises of 30 major GIS layers (viz., River network, basins, canal network, water bodies, hydro meteorological network, administratrive layers etc.) of the country at a scale of 1:50,000. The first full version of website of INDIA WRIS was launched on 07 Dec, 2010 in New Delhi by Hon'ble Minister Water Resources. The version 4.1 was launched in July 2015 and is available in public domain at 1:250000 scale.

Thereafter under the National Hydrology Project & with funding from CWC, a central sector scheme was approved by the Cabinet on April 6th, 2016 with the objective to improve the state of information on water resources for timely and reliable water resources data acquisition, storage, collation & management and to provide tools for informed decision making for management of water resources of the country. This led to the establishment of National Water Informatics Centre (NWIC) by the Government of India on 28th March, 2018 as a subordinate office of Ministry of Jal Shakti, Department of Water Resources, RD & GR. NWIC's goal isto serve as a central repository of updated water data and allied themes.

NWIC is currently handling the operations & maintenance of India-WRIS and WIMS, which is an integrated web-based data collection platform. Further, NWIC has recently initiated two other projects i.e. State Water Informatics Centre (SWIC) & Integrated Water & Crop Management & Information System (IWCIMS).

India-WRIS

The India Water Resources Information System is a "single-window" solution for data on water resources and allied themes. It enables users to Search, Access, Visualize, Understand, and Analyze comprehensive water data for the assessment, monitoring, planning, and management of water resources, to improve Integrated Water Resources Management (IWRM) in the country. All the information in the platform ismade available under simplified themes like Surface Water, Groundwater, Land Resources, Hydro-Meteorological, Allied Themes &Projects,allowing the user to visualize, analyseand download data on a topic of interest. Modules in the portal have been segmented and grouped in a way that they fall into one of the above themes, making it simpler to navigate through the portal's homepage.

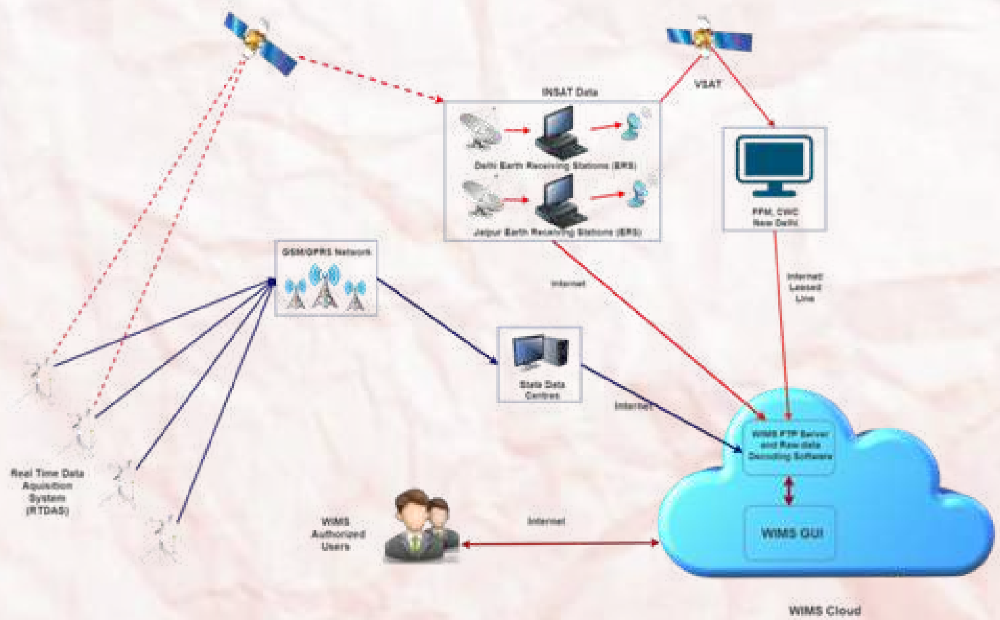


To further enhance the users interest & engagement, the information in the platform is displayed interactively in the form of Maps, Tables, and Pie Charts, etc. Additionally, India-WRIS platform provides a set of tools like Online Web Editor & ARS- Data Entry module for entering the data related to irrigation projects and existing Artificial Recharge Structures in respective modulesUnder the 'Utilities' section, utilities like Data Availability, Geo-Viewer, Meta Data, etc. are also available for users to explore the data availability, visualize multiple GIS layers in a single panel, and metadata of the available layers, etc.

WIMS

Water Information Management System (WIMS) is an integrated web-based data collection platform through which different agencies and stakeholders update the data on Surface & Ground water. The system has functionalities for data entry, management, analysis and reporting. The platform further offers various module-wise applications for State and Central agencies for effective database addition and updation.

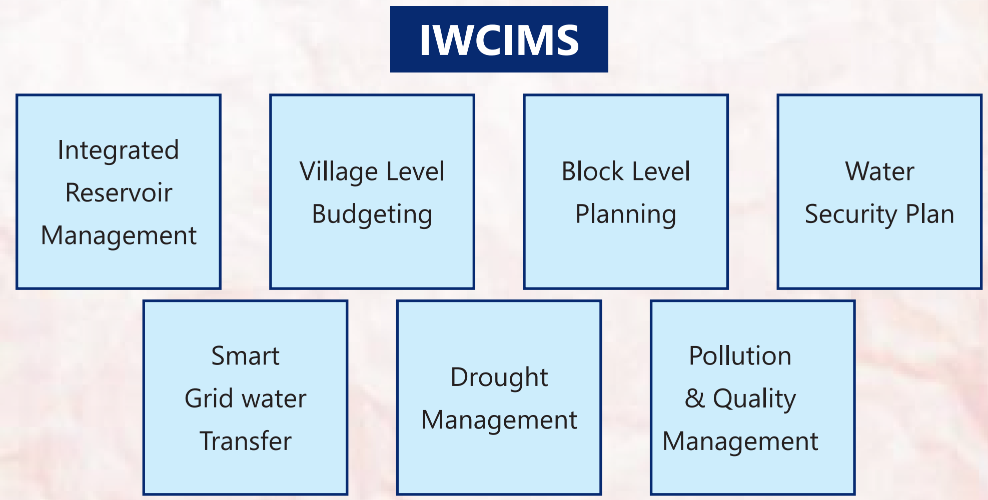
Apart from web-based manual data entry, it allows data entry in an automated method through telemetric sensors. WIMS currently receives data from 79,559 manual & 10,830 telemetric stations in the country. In the case of INSAT network, data from remote stations are acquired by the Central Water Commission's earth receiving stations in Jaipur and Delhi, and then transferred to the WIMS FTP web server via a leased line, where the raw data is captured and decoded. Data acquired using GPRS technology requires each station to send a distinct file every hour, implying that more than 5000 stations send approximately 1,20,000 files every day.



Integrated Water & Crop Information and Management System (IWCIMS)

IWCIMS is planned to act as a single & integrated decision support system for the management of water resources & crop planning. The project has been awarded to WAPCOS Ltd. (a PSE under Jal Shakti Ministry) on a turnkey basis and an MOU was signed between WAPCOS Ltd. & NWIC on March 25, 2021.The project will be undertaken in three phases: pre-implementation phase, implementation phase and post-implementation phase.

This project consists of the development of 7 modules anda Ground Water Information System. This integrated platform will analyse a huge amount of water resource and crop data to provide analysed results so that information-based decisions can be taken by planners, administrators and scientists through seven modules. These 7 modules are interrelated in a way that the output of one module may impact the output of another. The 7 modules of the DSS are:



Developments Under IWCIMS

On March 25, 2021, NWIC and WAPCOS (a PSE under Jal Shakti Ministry) signed a Memorandum of Understanding, and work on the IWCIMS project began. A central-level PMU comprising experts from the CWC, NRSC, NIH, and the Ministry of Agriculture and Farmer Welfare, was constituted as the project's core decision-making authority to monitor and give directions to WAPCOS.

A Memorandum of Agreement (MoA) prepared by NWIC regarding uninterrupted data sharing by the "Associated States and UTs" with the identified vendor for the successful development of IWCIMS project. Rajasthan, Gujarat, Nagaland, Meghalaya and Tripura have already signed the Memorandum of Agreement and are on board for the project. Further, 25 states and 7 Union Territories have nominated nodal officers and their teams to collaborate with NWIC, WAPCOS / vendor, and various state agencies.

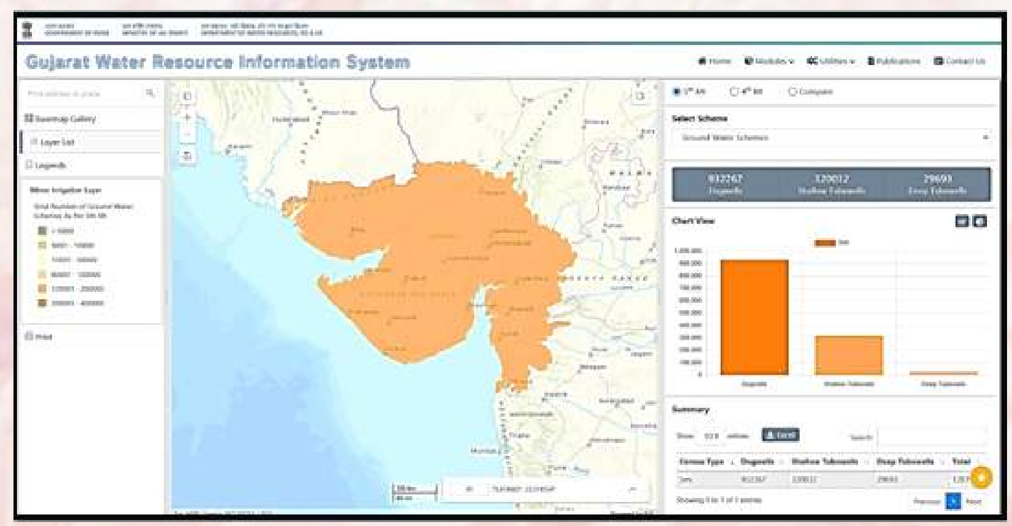
State Water Informatics Centre (SWIC)

NWIC has been encouraging all states to set up a State Water Informatics Centre (SWIC), to facilitate better management of water resources data at the state level. SWIC, in collaboration with the NWIC, is planned to serve as a single point of contact for regional and micro-level data amalgamation and dissemination. It shall act as a nodal agency for data integration and validation following the central standards of water resources data at state level.

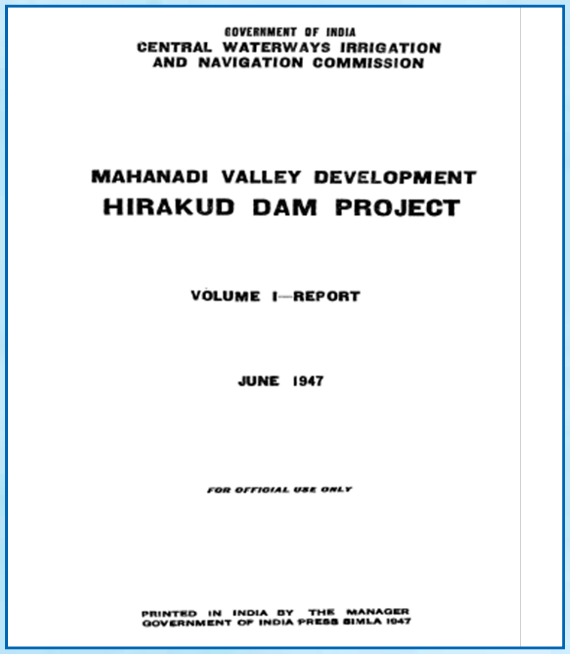
NWIC will handhold the states during all the stages ofimplementation of SWIC and thedevelopment of State-Water Resources Information System (State-WRIS) by providing technical guidance as well as support for all the phases of developments related to SWIC. This way, the establishment of SWIC in states will have benefits in terms of standardized data schema, ease of data sharing, improvement in data quality and validation with proper metadata.

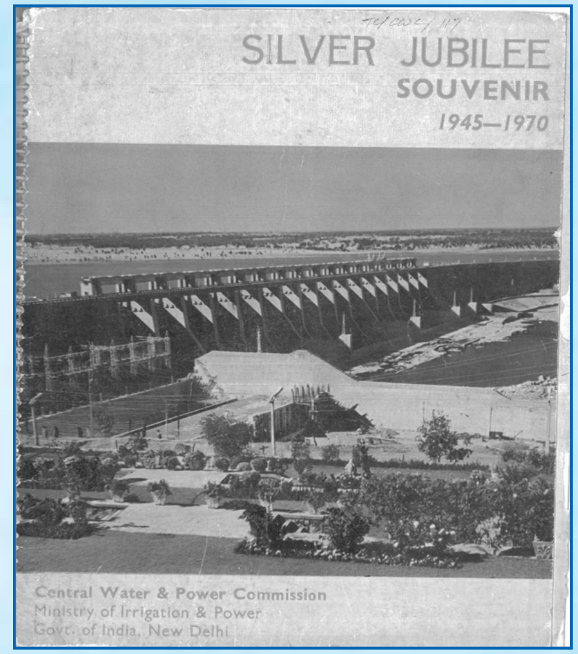
Developments Under SWIC

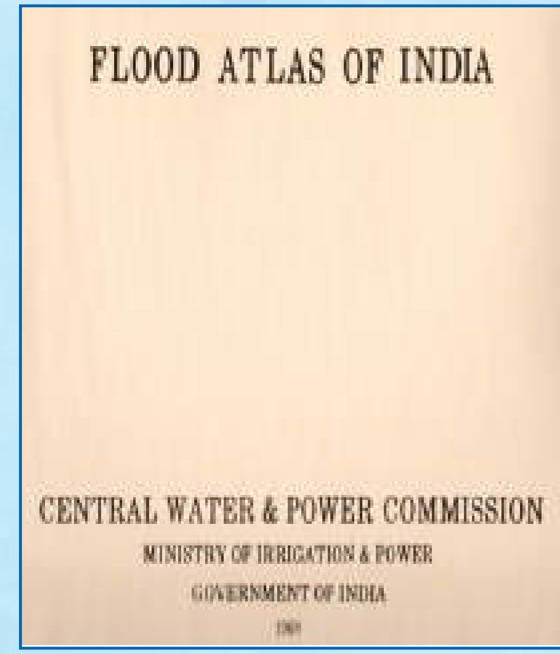
NWIC has already organized several meetings and training sessions with states in preparation for the establishment of SWIC and the development of the State-WRIS platforms. Gujarat & Rajasthan are already on board and would act as pilot states for implementing the SWIC project. NWIC has provided Virtual Machines to Rajasthan and Gujarat for the development of their State-WRIS platforms. A sample of the testing module on Minor Irrigation developed by NWIC for Gujarat State-WRIS is shown below.

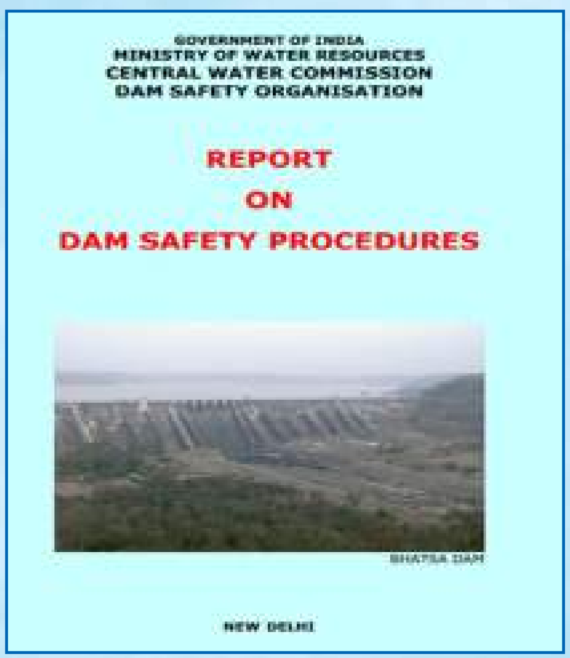


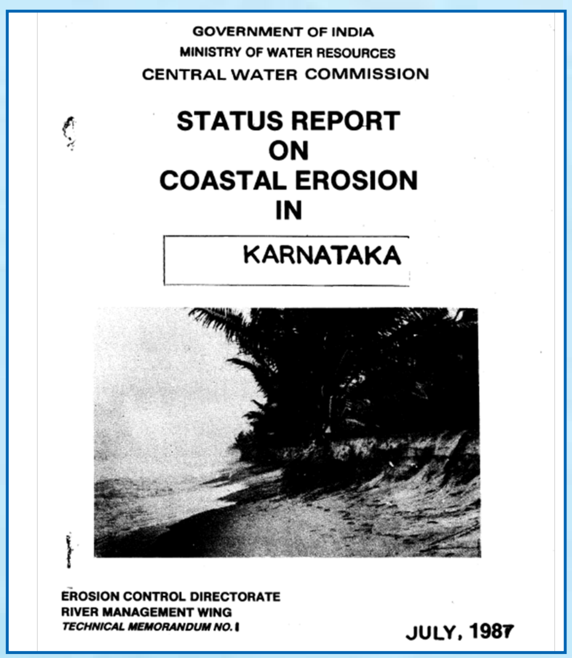
LIST OF IMPORTANT PUBLICATIONS OF CWC

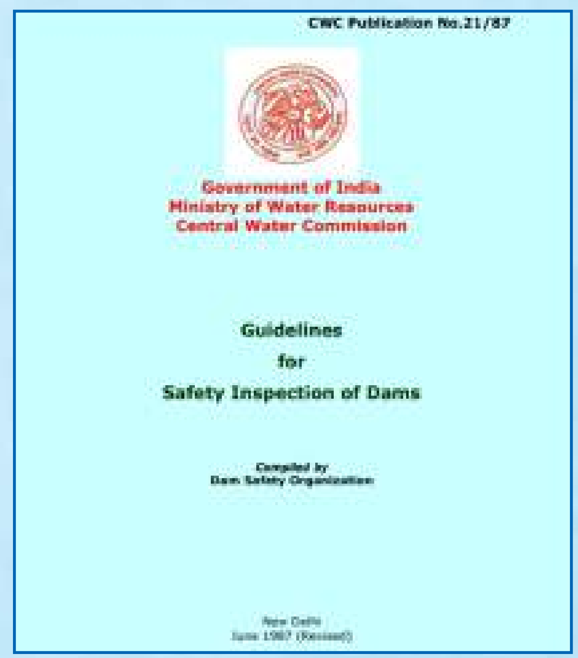


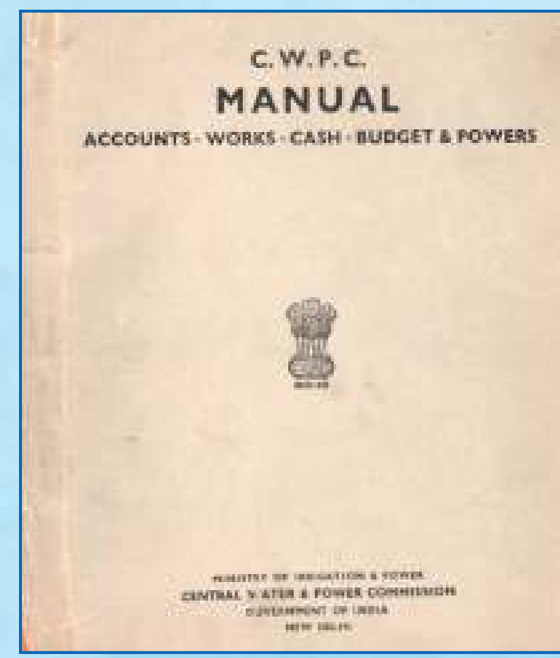


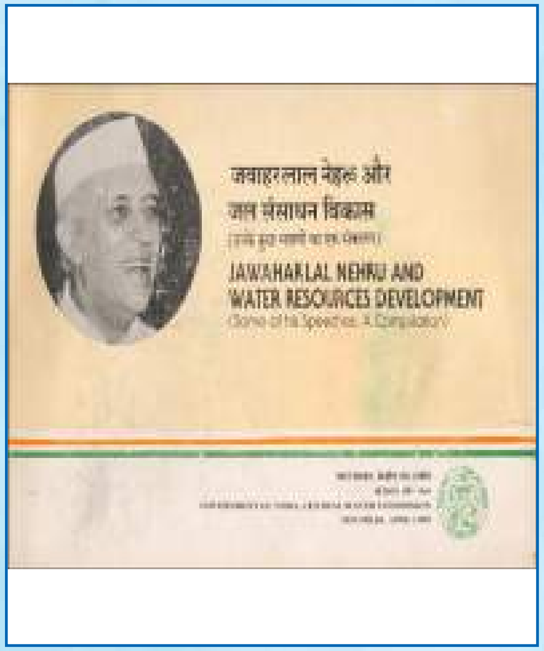


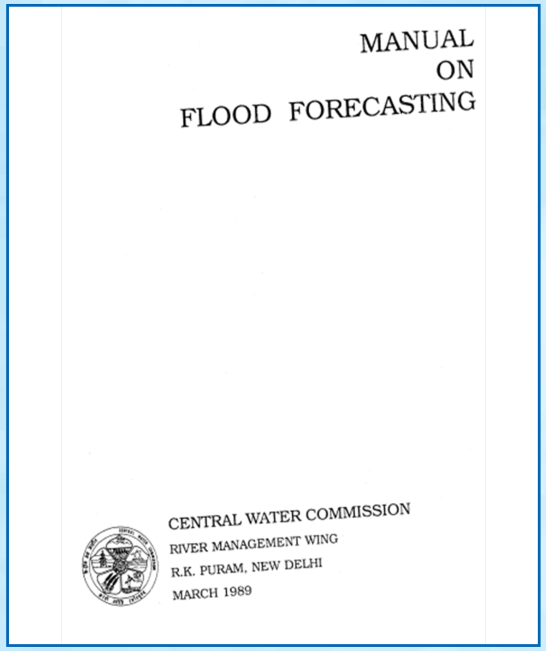


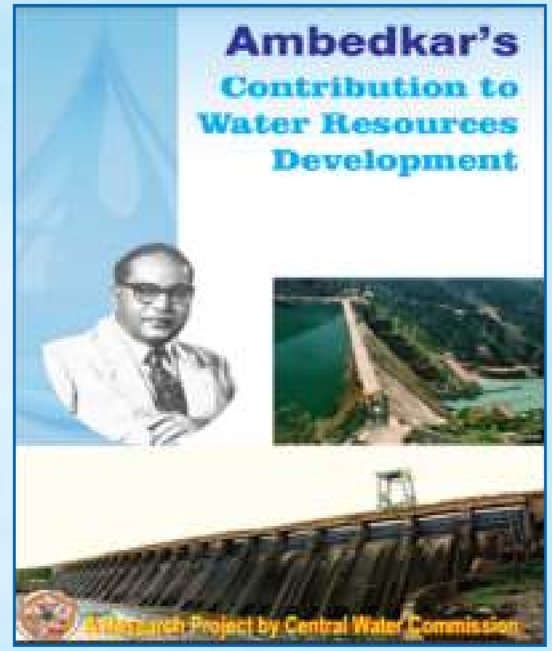


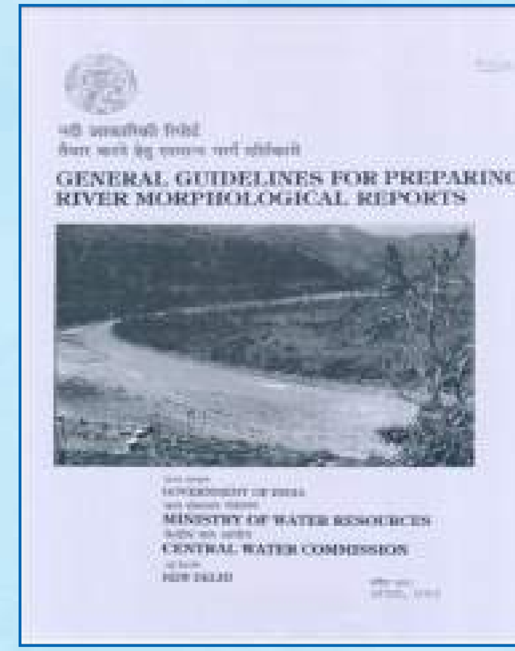




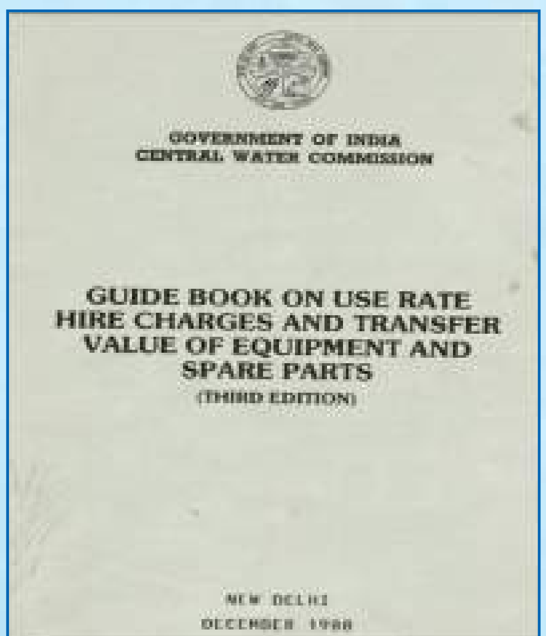

JAWAHARLAL NEHRU AND
WATER RESOURCES DEVELOPMENT

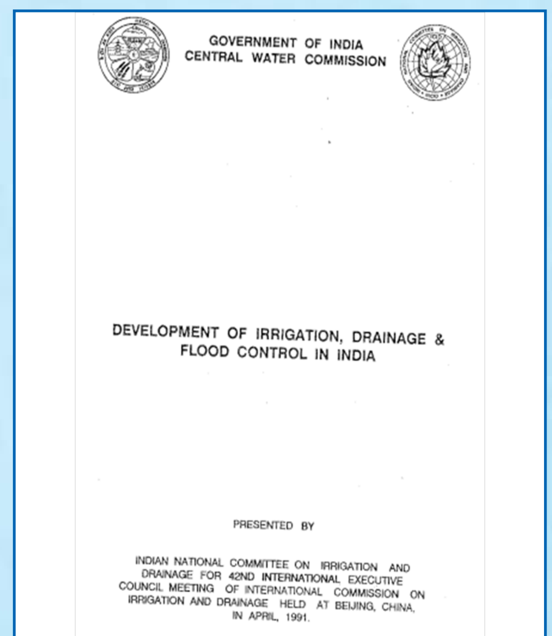

MANUAL
ON
FLOOD FORECASTING
CENTRAL WATER COMMISSION
RIVER MANAGEMENT WING
R.K. PURAM, NEW DELHI
MARCH 1989

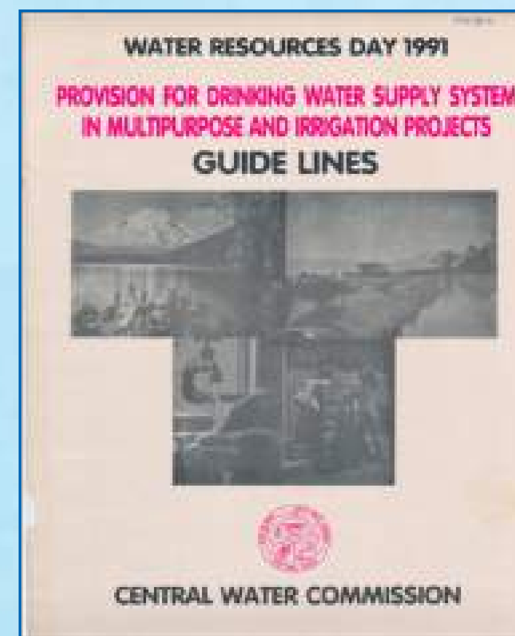

Ambedkar's
Contribution to
Water Resources
Development
A Research Project by Central Water Commission

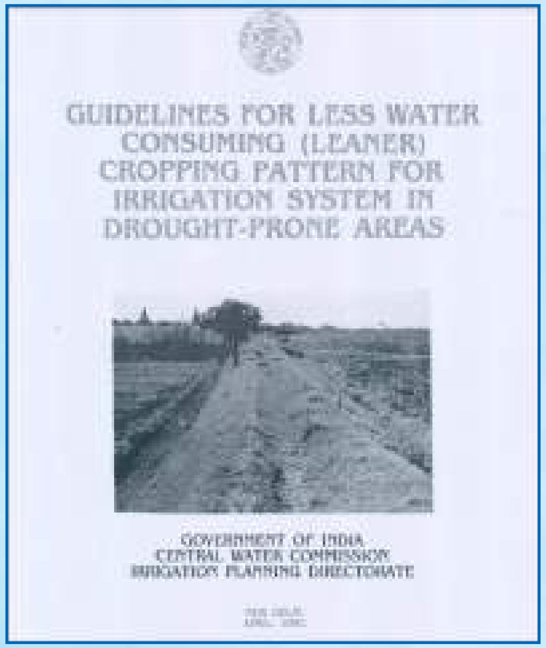

GENERAL GUIDELINES FOR PREPARING
RIVER MORPHOLOGICAL REPORTS
MINISTRY OF WATER RESOURCES
CENTRAL WATER COMMISSION
NEW DELHI


GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
DAM SAFETY ORGANISATION
Standardized Data Book Format,
Sample Checklist and Proforma for
Periodical Inspection of Dams
October 1988
New Delhi

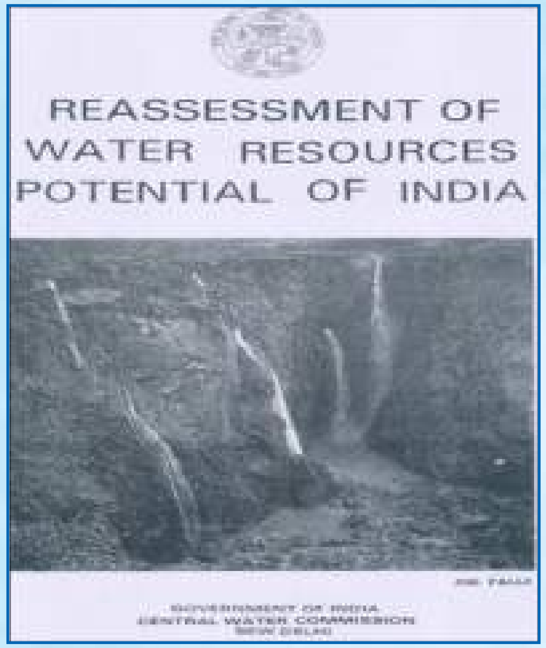

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
GUIDE BOOK ON USE RATE
HIRE CHARGES AND TRANSFER
VALUE OF EQUIPMENT AND
SPARE PARTS
(THIRD EDITION)
NEW DELHI
DECEMBER 1988


GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
DEVELOPMENT OF IRRIGATION, DRAINAGE &
FLOOD CONTROL IN INDIA
PRESENTED BY
INDIAN NATIONAL COMMITTEE ON IRRIGATION AND
DRAINAGE FOR 42ND INTERNATIONAL EXECUTIVE
COUNCIL MEETING OF INTERNATIONAL COMMISSION ON
IRRIGATION AND DRAINAGE HELD AT BEIJING, CHINA,
IN APRIL, 1991.


WATER RESOURCES DAY 1991
PROVISION FOR DRINKING WATER SUPPLY SYSTEM
IN MULTIPURPOSE AND IRRIGATION PROJECTS
GUIDE LINES
CENTRAL WATER COMMISSION


GUIDELINES FOR LESS WATER CONSUMING (LEANER) CROPPING PATTERN FOR IRRIGATION SYSTEM IN DROUGHT-PRONE AREAS

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
IRRIGATION PLANNING DIRECTORATE


REASSESSMENT OF WATER RESOURCES POTENTIAL OF INDIA

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
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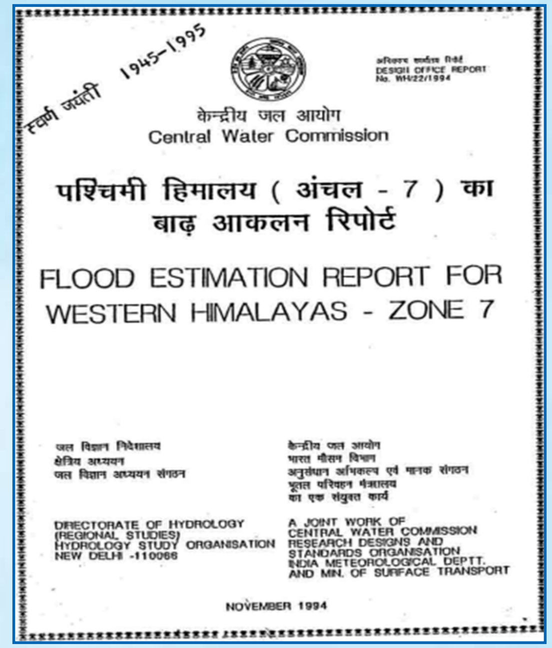

स्वर्ण जयंती 1945–1995

केन्द्रीय जल आयोग
Central Water Commission

DESIGN OFFICE REPORT
No. WH/22/1994

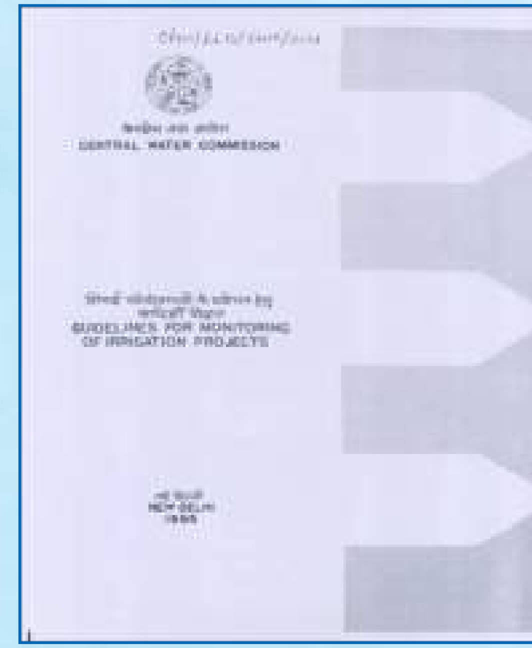
पश्चिमी हिमालय (अंचल - 7) का बाढ़ आकलन रिपोर्ट

FLOOD ESTIMATION REPORT FOR WESTERN HIMALAYAS - ZONE 7

DIRECTORATE OF HYDROLOGY
(REGIONAL STUDIES)
HYDROLOGY STUDY ORGANISATION
NEW DELHI -110066

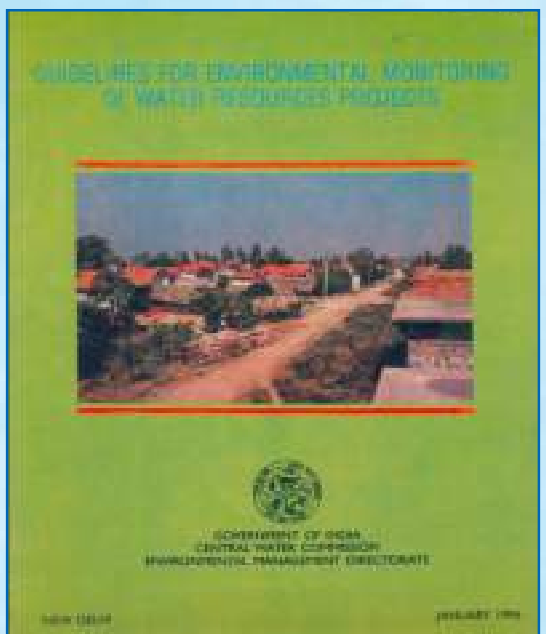
A JOINT WORK OF
CENTRAL WATER COMMISSION
RESEARCH DESIGNS AND STANDARDS ORGANISATION
INDIA METEOROLOGICAL DEPTT.
AND MIN. OF SURFACE TRANSPORT

NOVEMBER 1994


CENTRAL WATER COMMISSION

GUIDELINES FOR MONITORING OF IRRIGATION PROJECTS

NEW DELHI


GUIDELINES FOR ENVIRONMENTAL MONITORING OF WATER RESOURCES PROJECTS

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ENVIRONMENTAL MANAGEMENT DIRECTORATE

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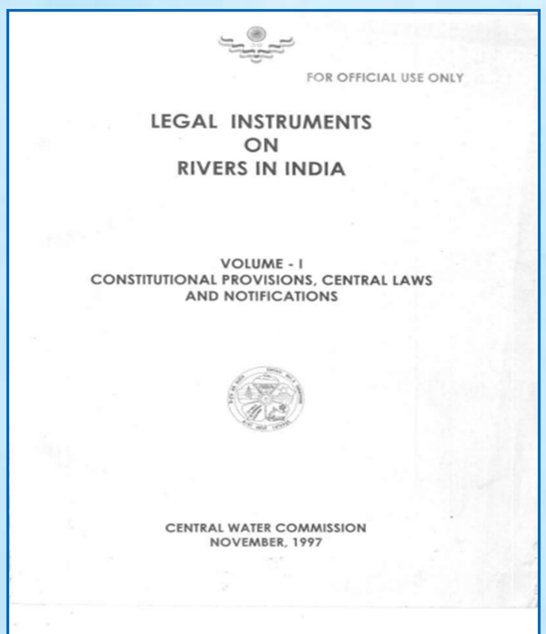
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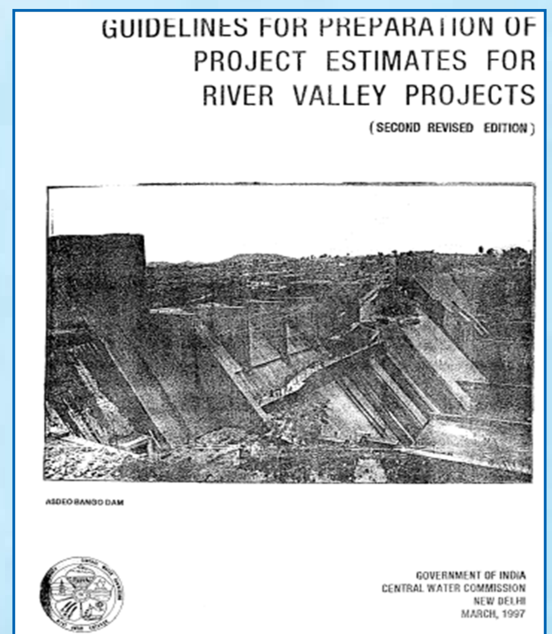
LEGAL INSTRUMENTS ON RIVERS IN INDIA

VOLUME - I
CONSTITUTIONAL PROVISIONS, CENTRAL LAWS AND NOTIFICATIONS

CENTRAL WATER COMMISSION
NOVEMBER, 1997


GUIDELINES FOR PREPARATION OF PROJECT ESTIMATES FOR RIVER VALLEY PROJECTS

(SECOND REVISED EDITION)

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
NEW DELHI
MARCH, 1997


Central Water Commission
Ministry of Water Resources
Government of India

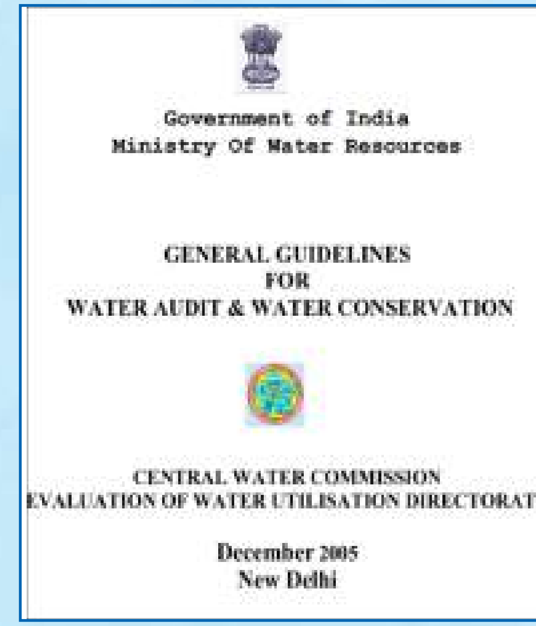
GUIDELINES FOR PLANNING OF PARALLEL CANALS

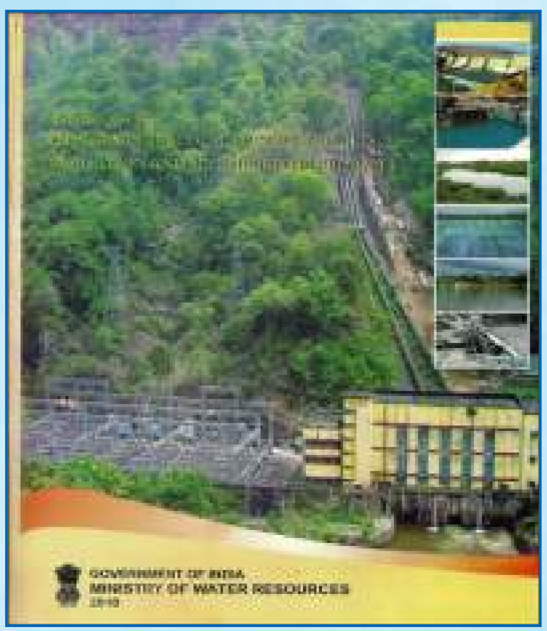
NEW DELHI


सिंचाई प्रणाली के निष्पादन मूल्यांकन
हेतु मार्गदर्शी सिद्धांत
GUIDELINES FOR PERFORMANCE
EVALUATION OF IRRIGATION SYSTEM
केन्द्रीय जल आयोग
Central Water Commission


भारत सरकार
केन्द्रीय जल आयोग
गेज एवं निस्सारण मापन के लिए क्षेत्र निर्देशिका
(जल विज्ञान परियोजना के अंतर्गत तैयार)


Departmental Terminology
Central Water Commission
Ministry of Water Resources
English-Hindi


Government of India
Ministry Of Water Resources
GENERAL GUIDELINES
FOR
WATER AUDIT & WATER CONSERVATION
CENTRAL WATER COMMISSION
EVALUATION OF WATER UTILISATION DIRECTORATE
December 2005
New Delhi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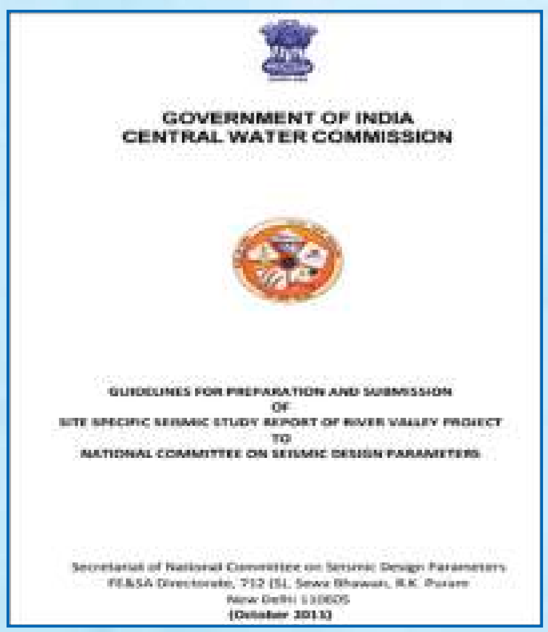
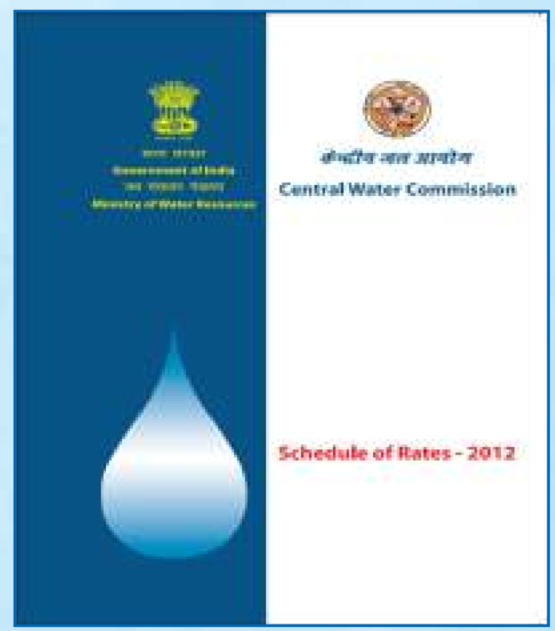
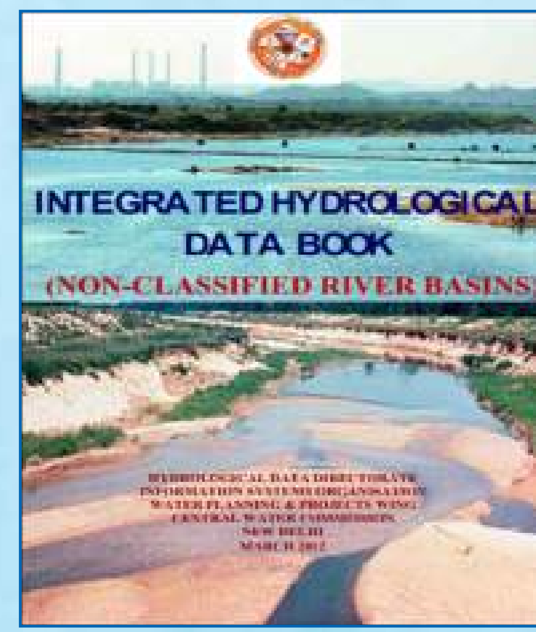
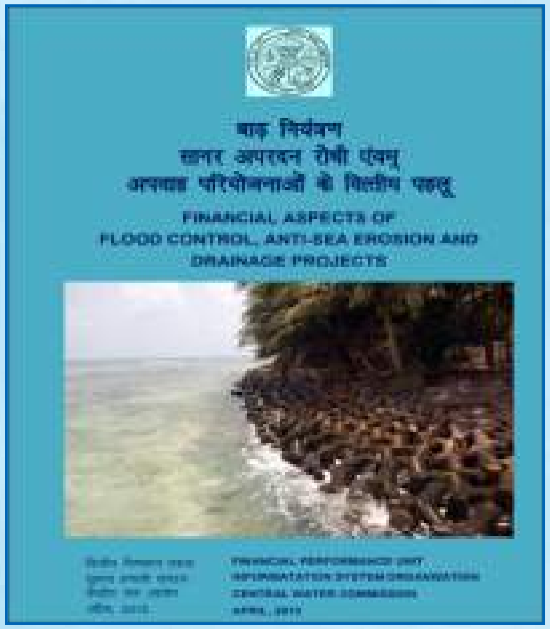
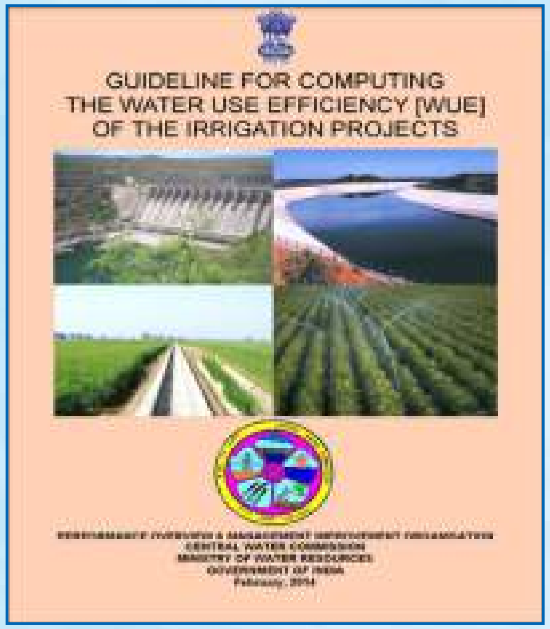
MINISTRY OF WATER RESOURCES


GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
GUIDELINES FOR PREPARATION AND SUBMISSION
OF
SITE SPECIFIC SEISMIC STUDY REPORT OF RIVER VALLEY PROJECT
TO
NATIONAL COMMITTEE ON SEISMIC DESIGN PARAMETERS
Secretariat of National Committee on Seismic Design Parameters


केन्द्रीय जल आयोग
Central Water Commission
Schedule of Rates - 2012


INTEGRATED HYDROLOGICAL
DATA BOOK
(NON-CLASSIFIED RIVER BASINS)


बाढ़ नियंत्रण
सागर अपरदन रोधी एवम्
अपवाह परियोजनाओं के वित्तीय पहलू
FINANCIAL ASPECTS OF
FLOOD CONTROL, ANTI-SEA EROSION AND
DRAINAGE PROJECTS


GUIDELINE FOR COMPUTING
THE WATER USE EFFICIENCY [WUE]
OF THE IRRIGATION PROJECTS
CENTRAL WATER COMMISSION
MINISTRY OF WATER RESOURCES
GOVERNMENT OF INDIA
February, 2014


Government of India
Ministry of Water Resources
Central Water Commission
Status of Trace and Toxic Metals in Indian Rivers
River Data Directorate
Planning & Development Organisation
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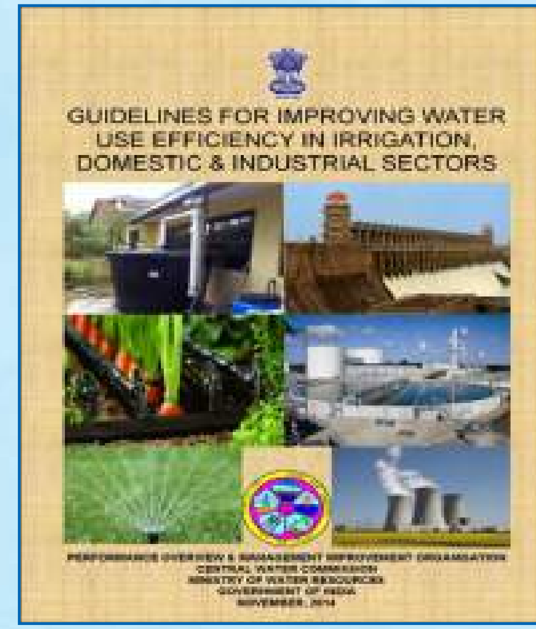
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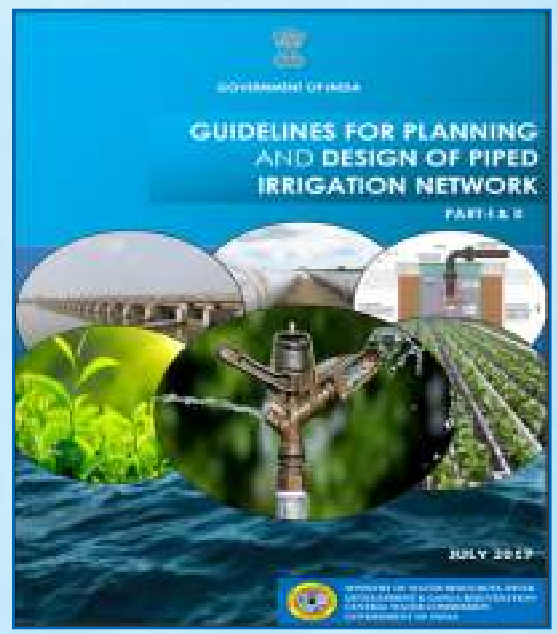
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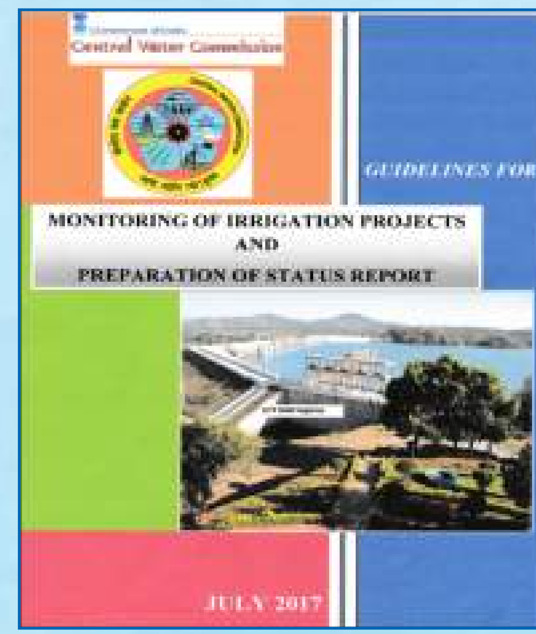
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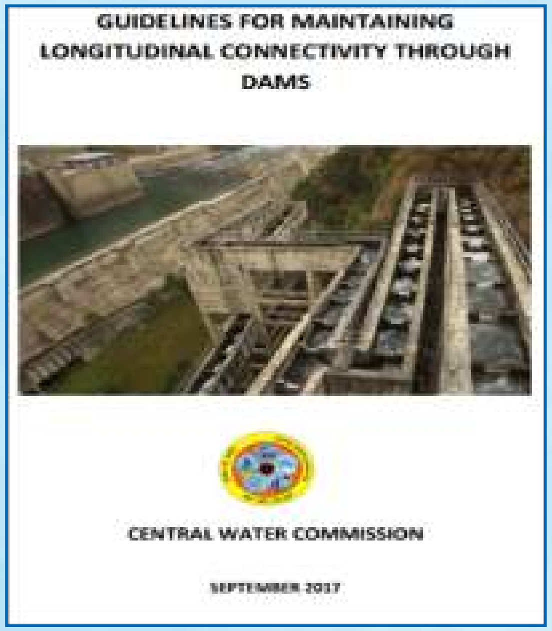
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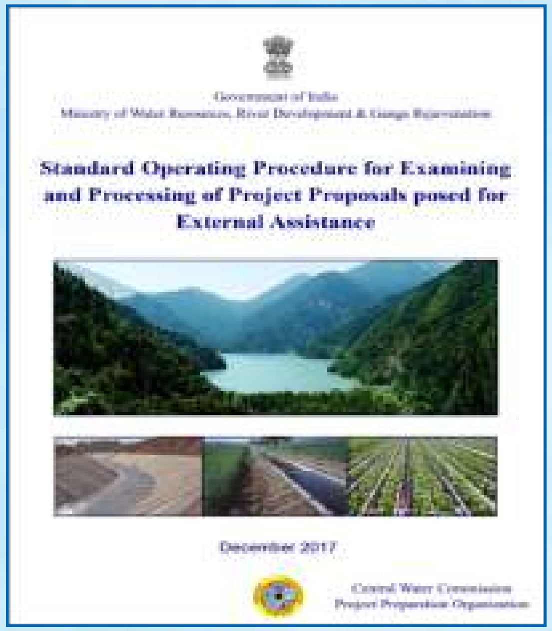
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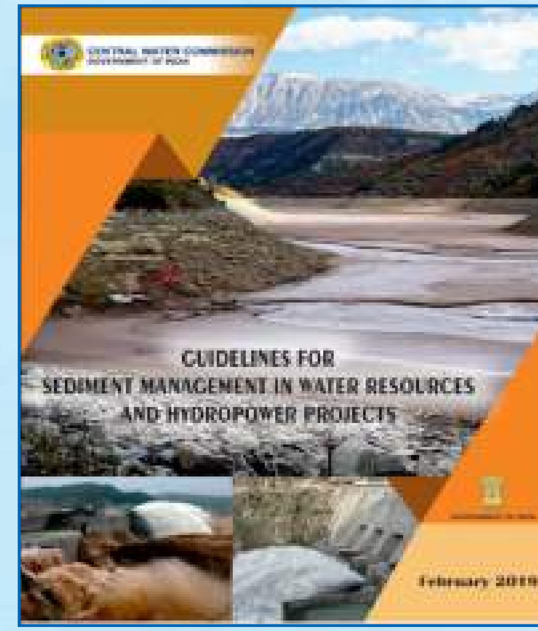
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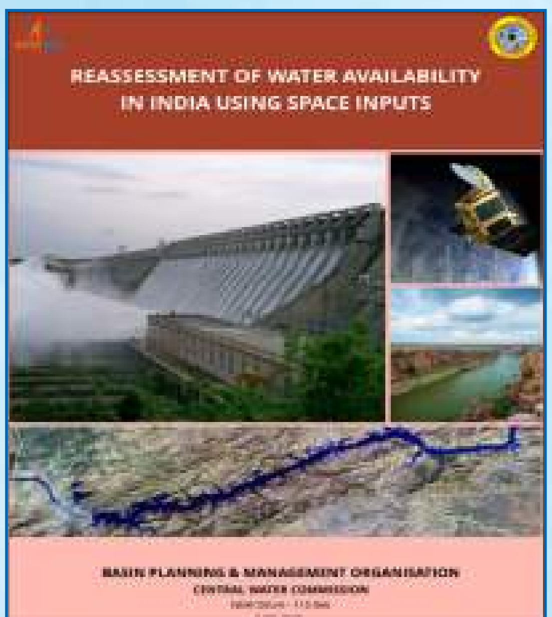
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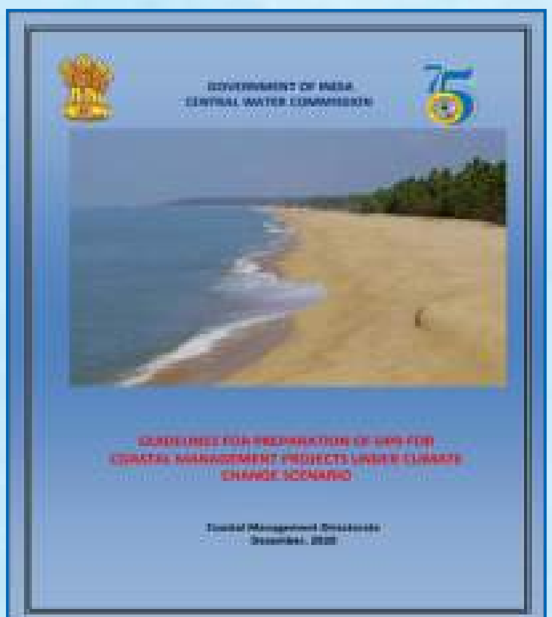

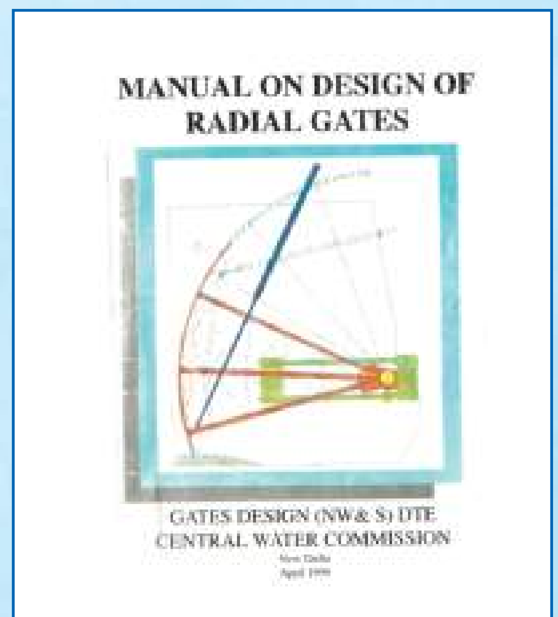
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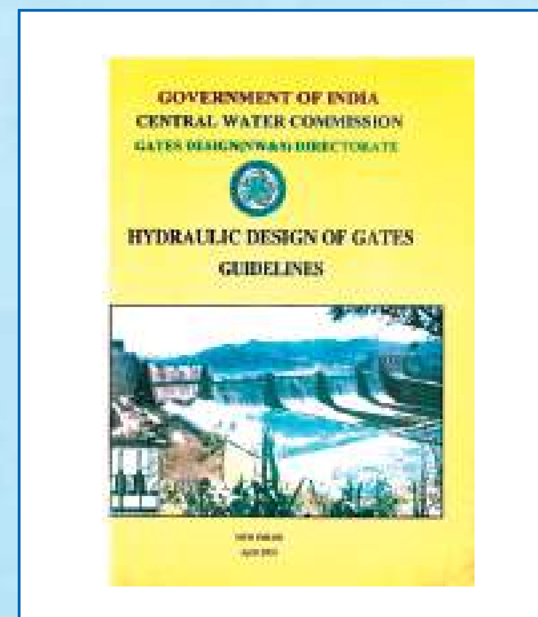
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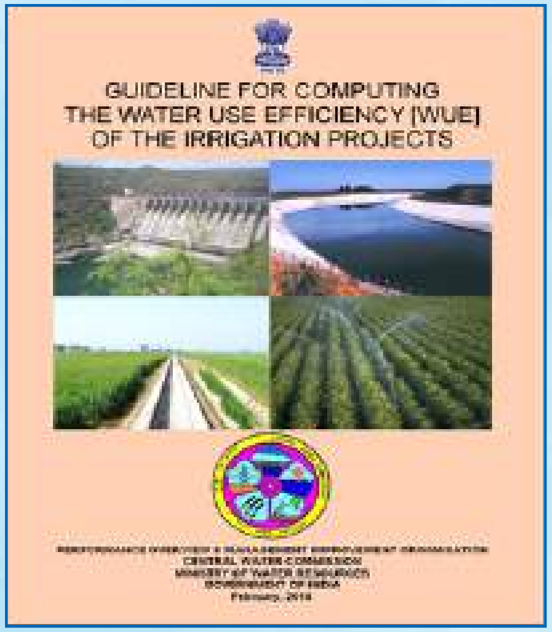
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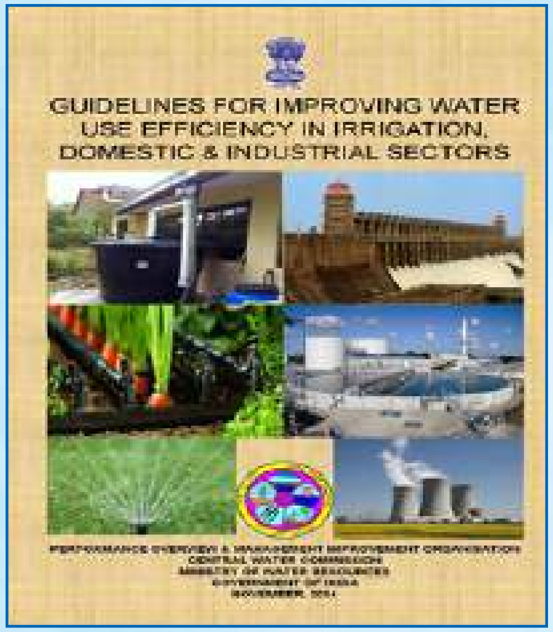
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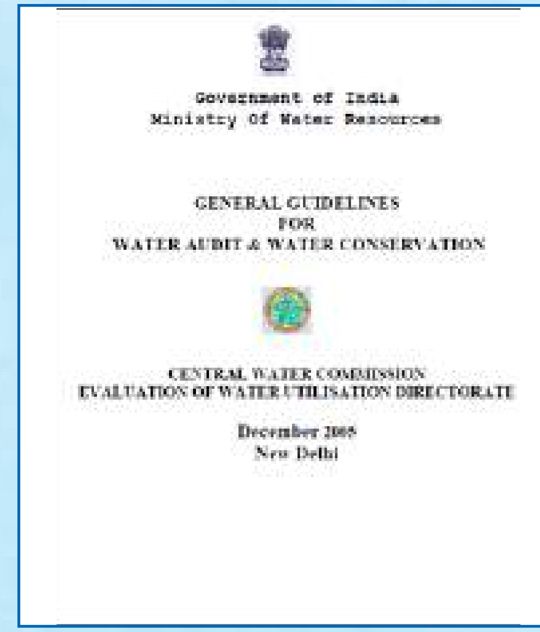
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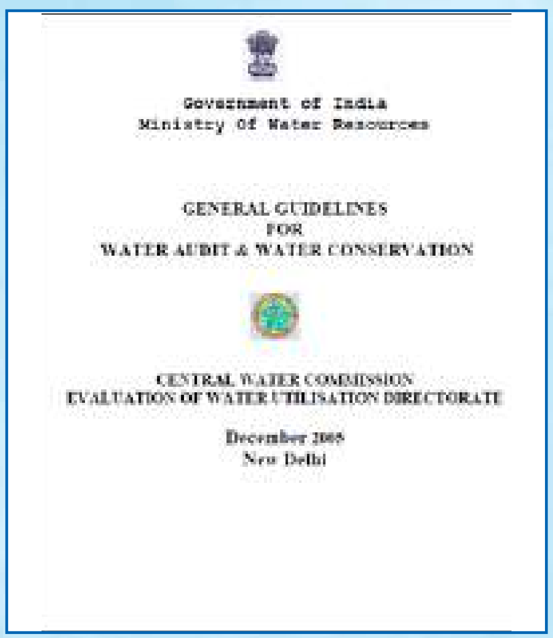
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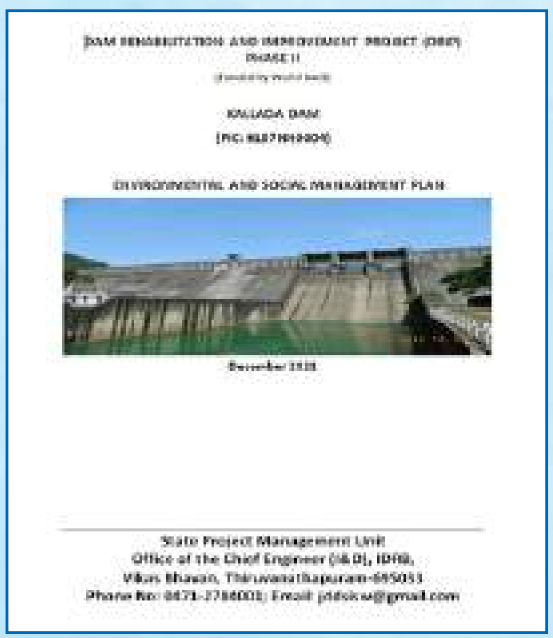
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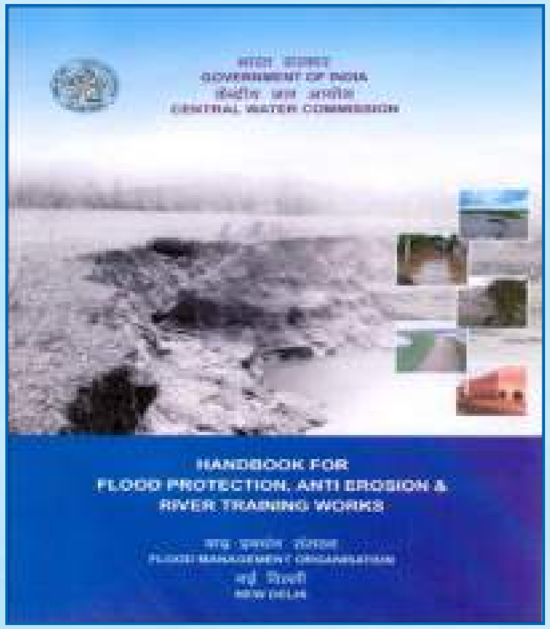
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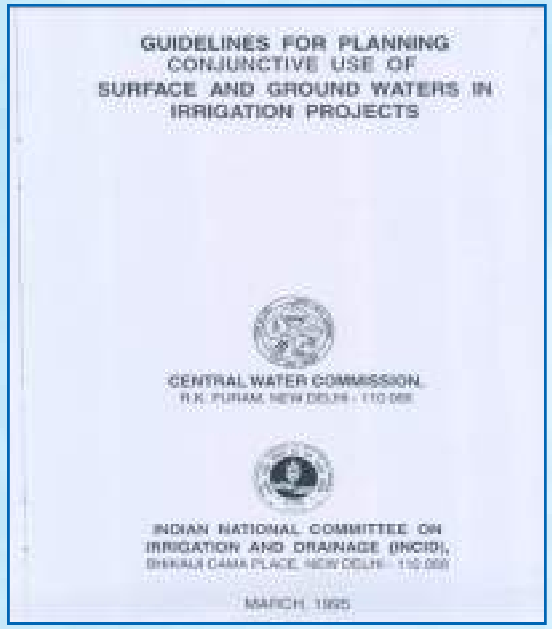
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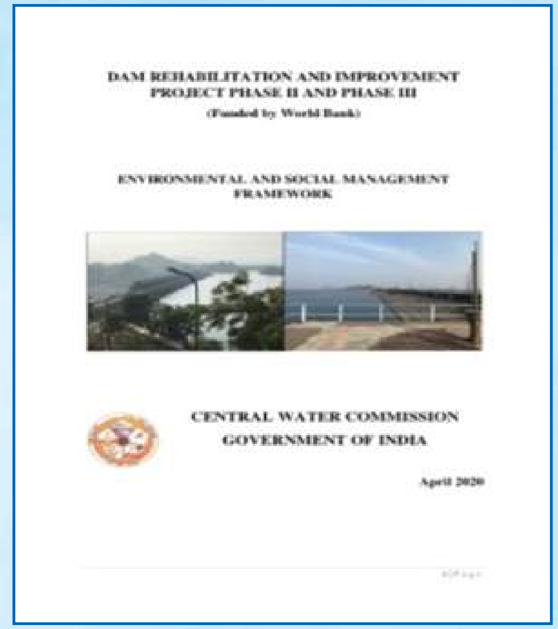
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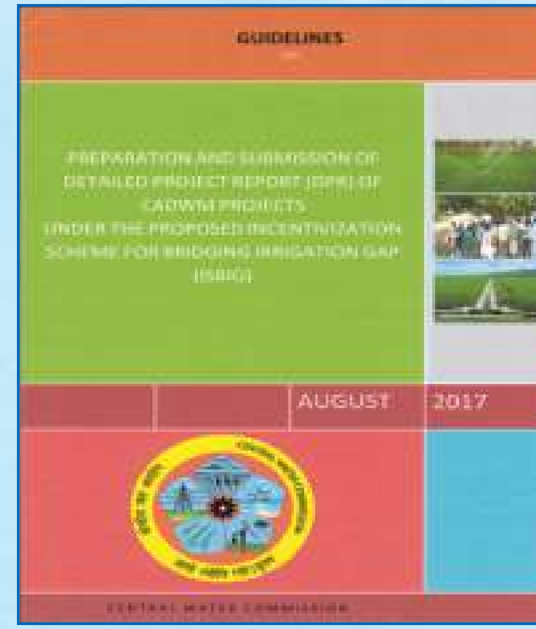
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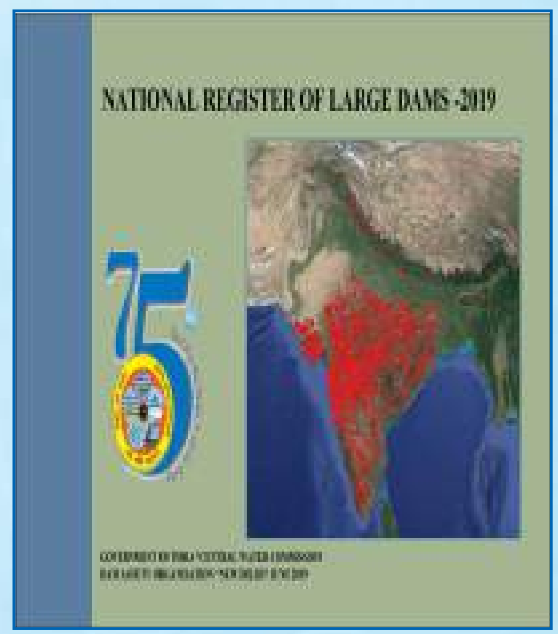
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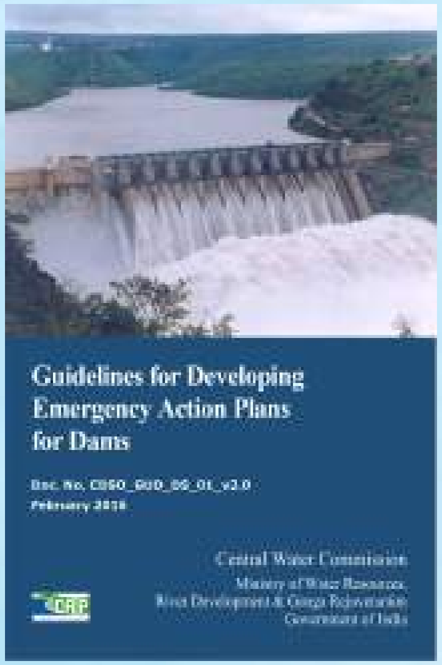
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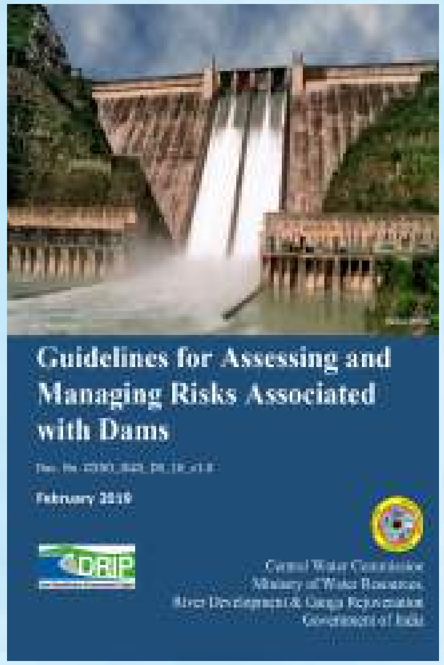
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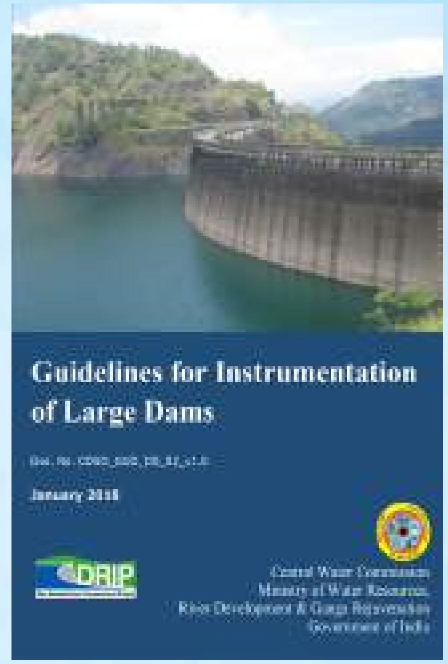
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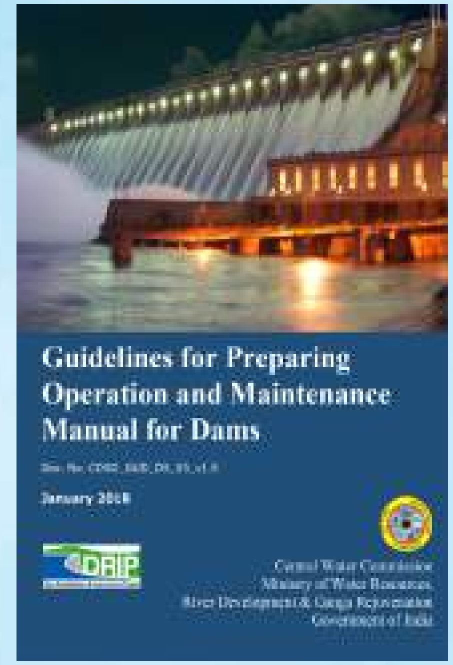
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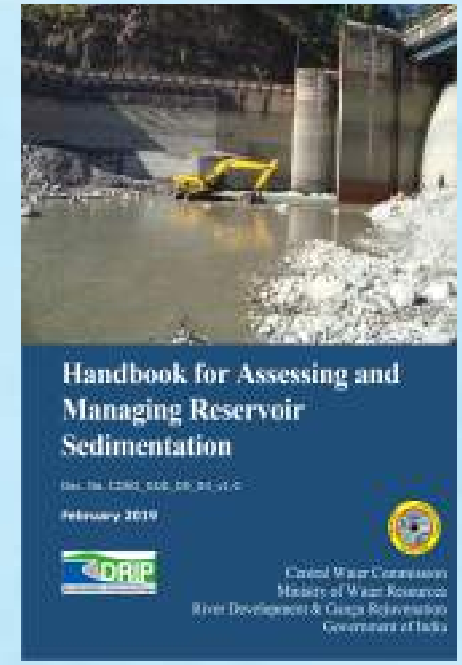
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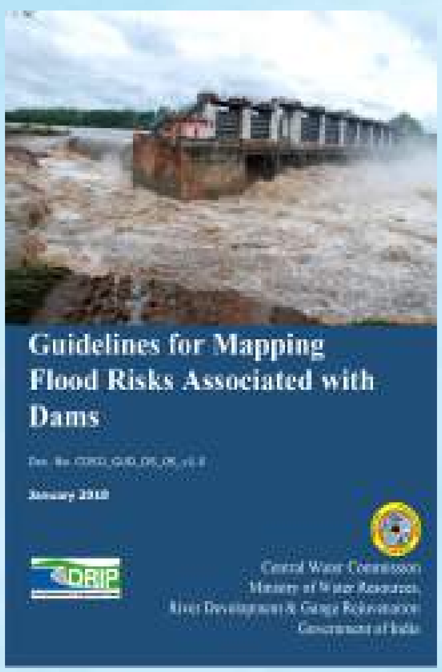
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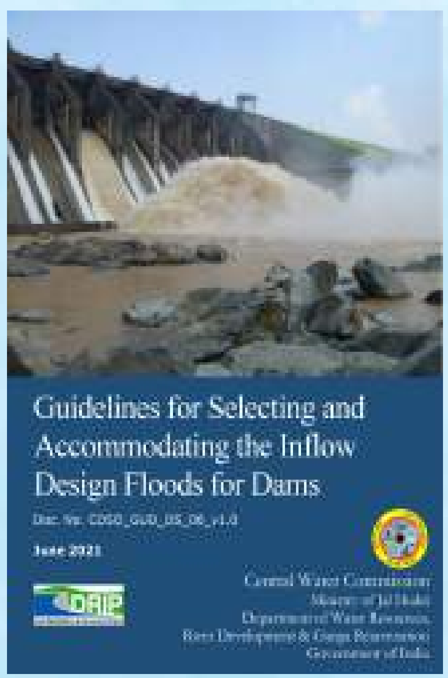
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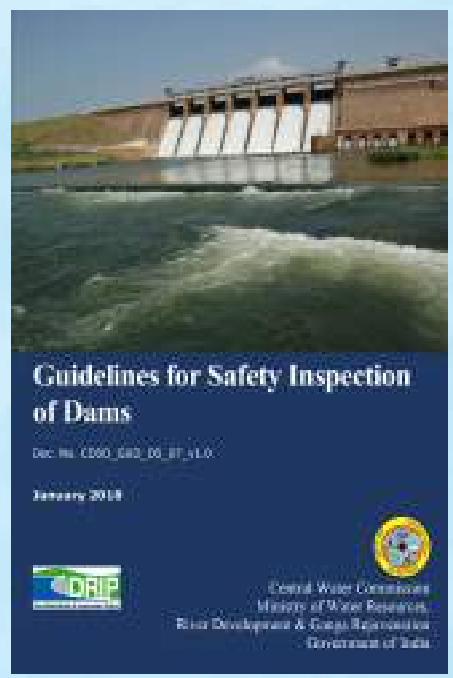
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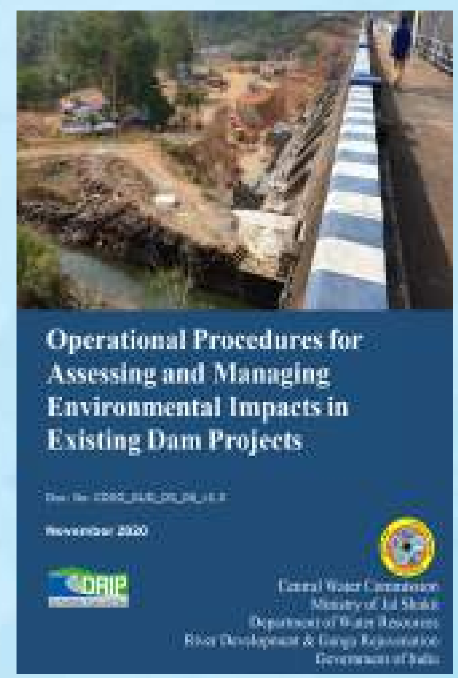
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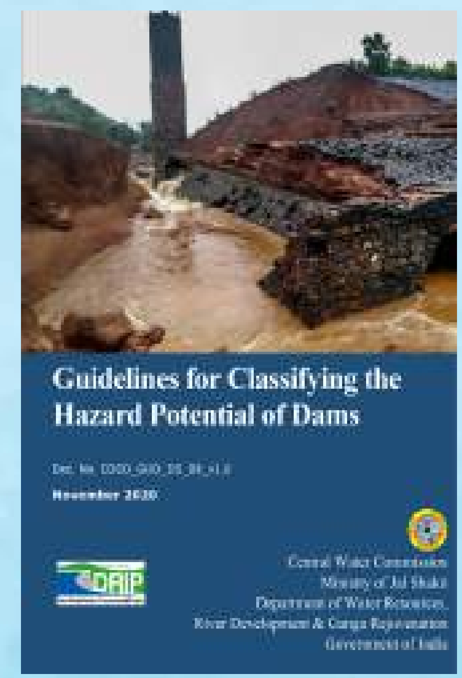
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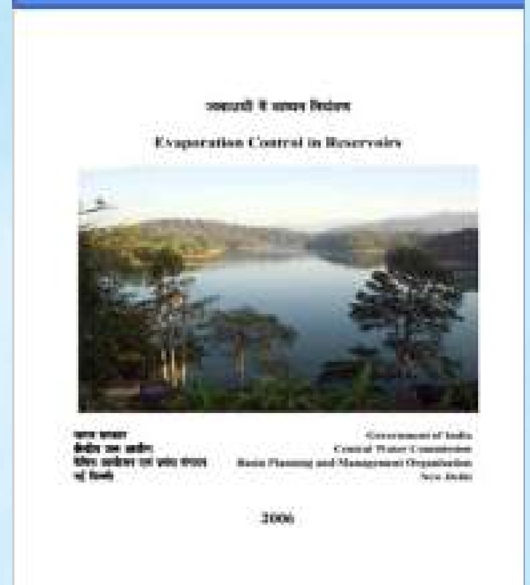

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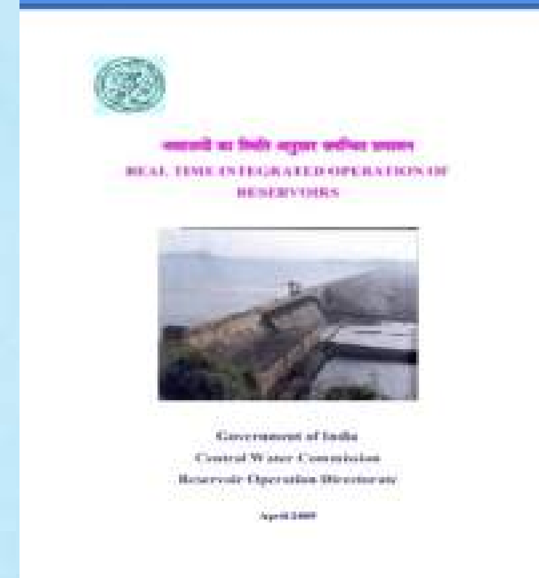

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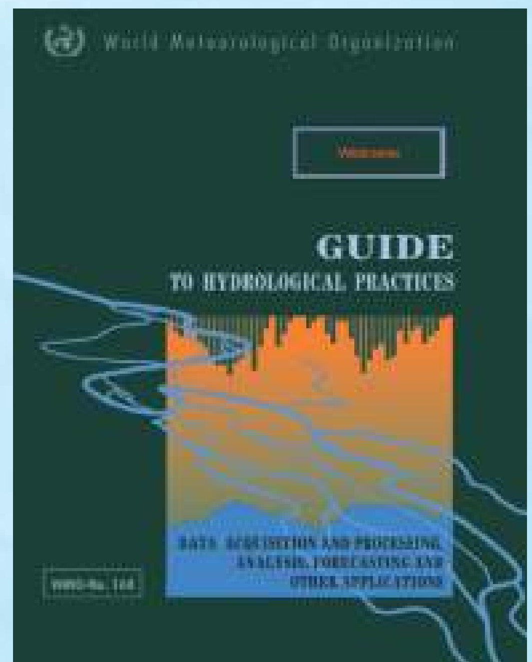

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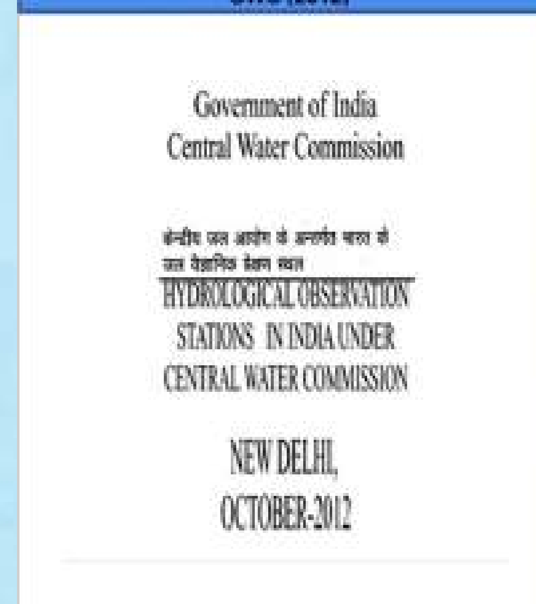

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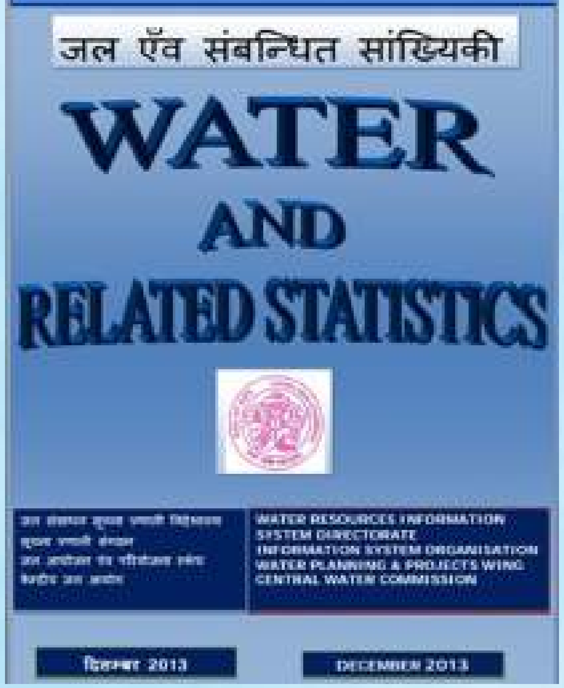

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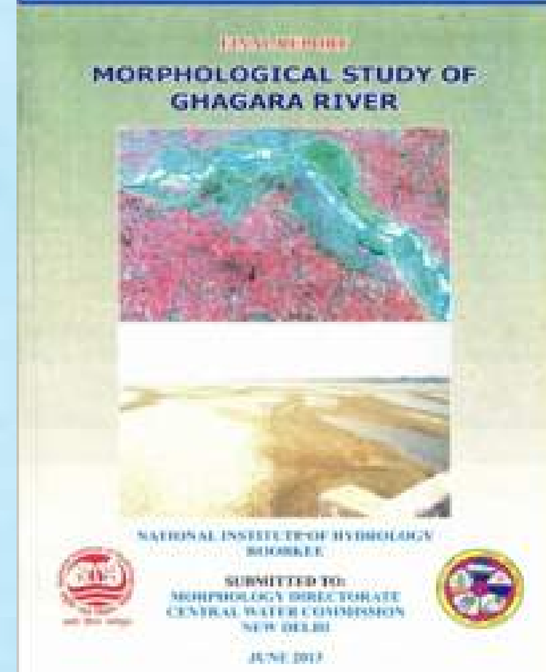

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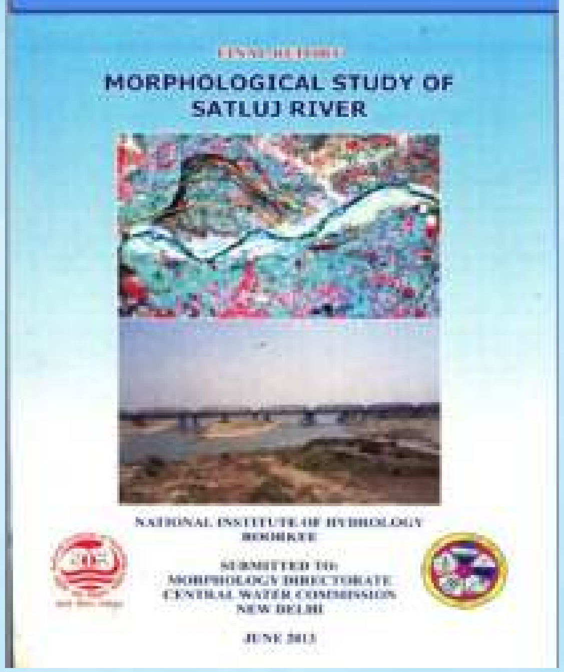

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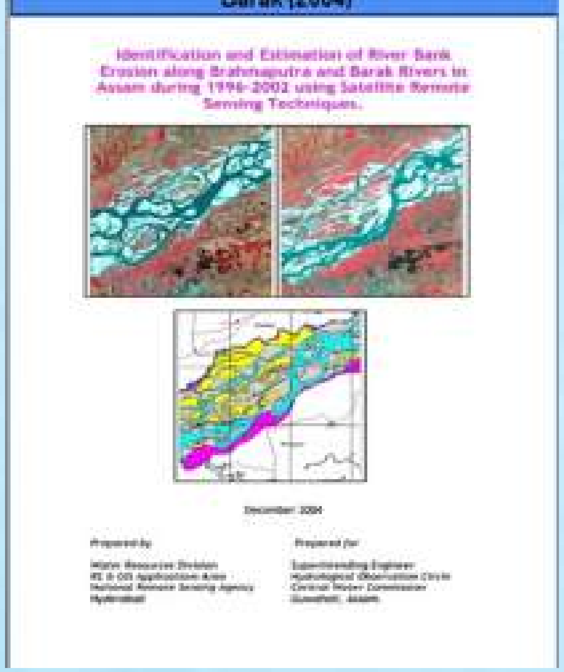

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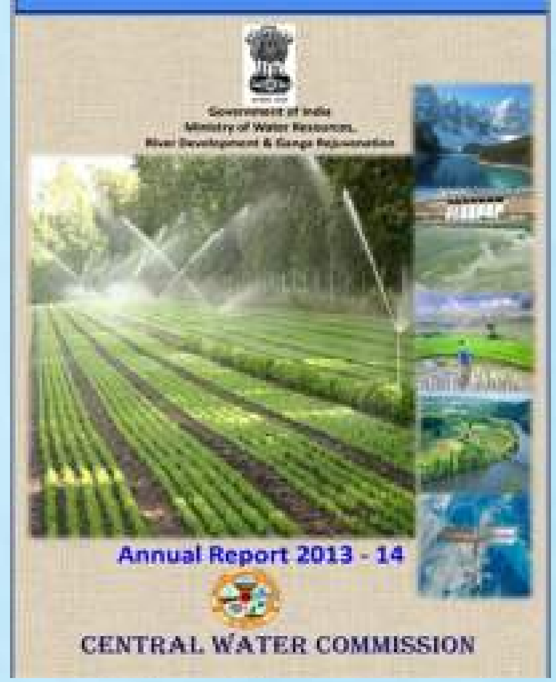

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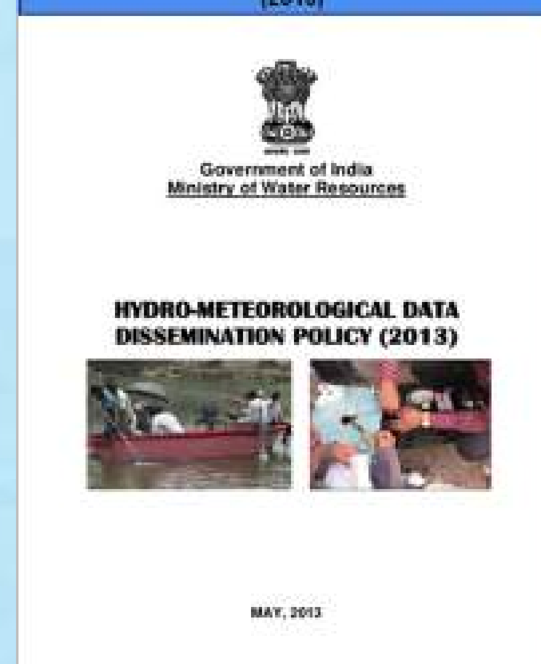

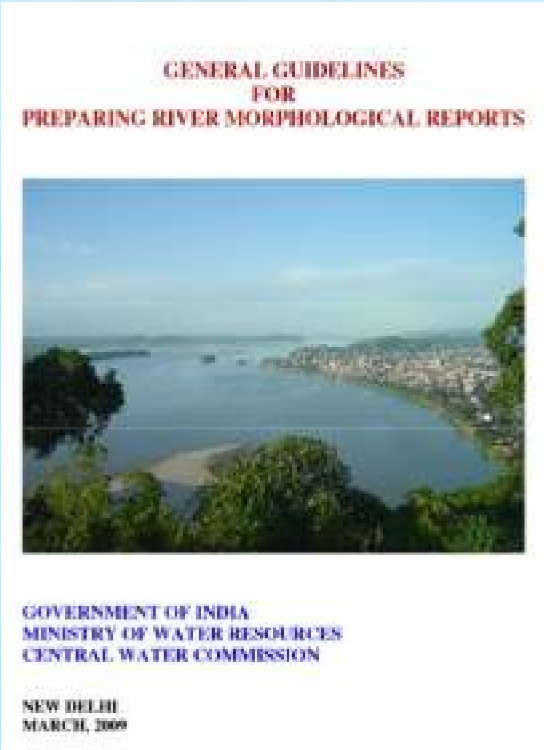
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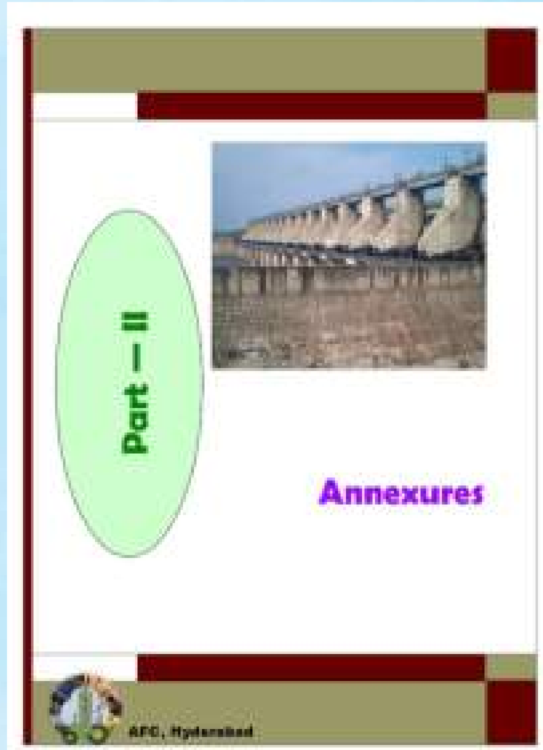
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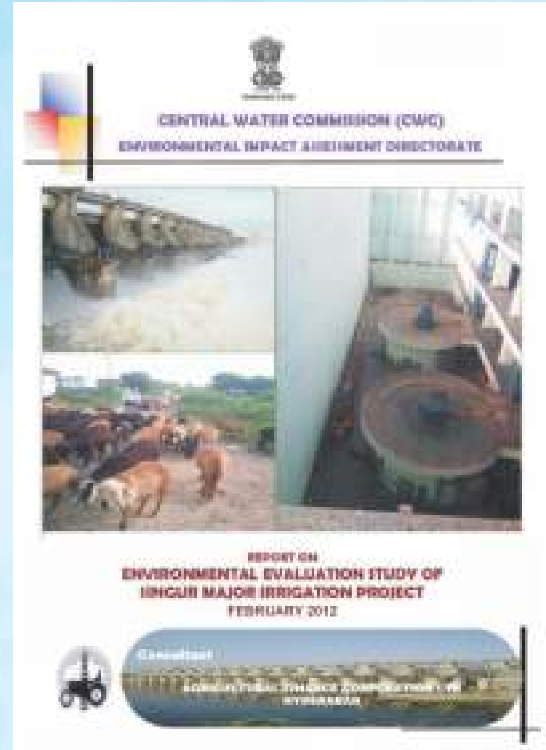
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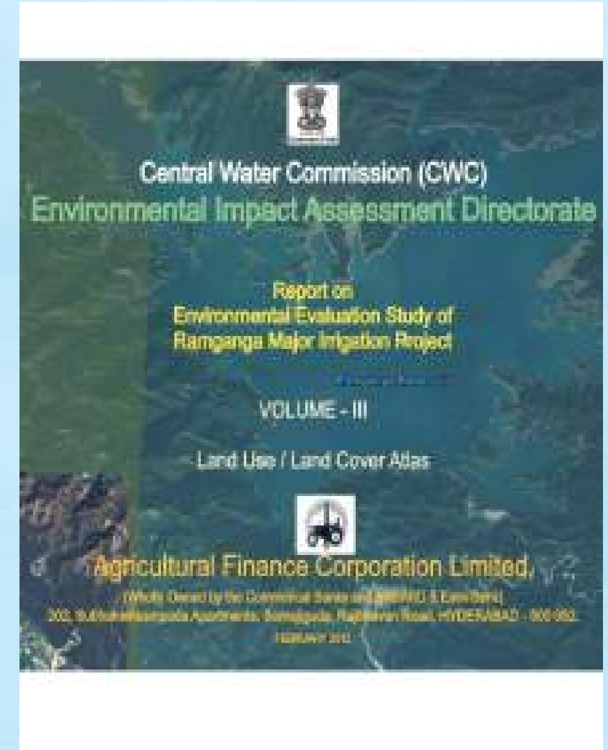
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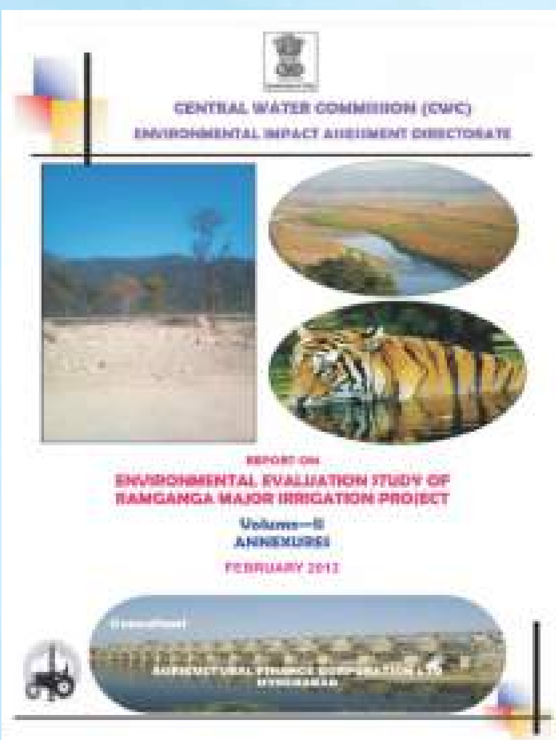
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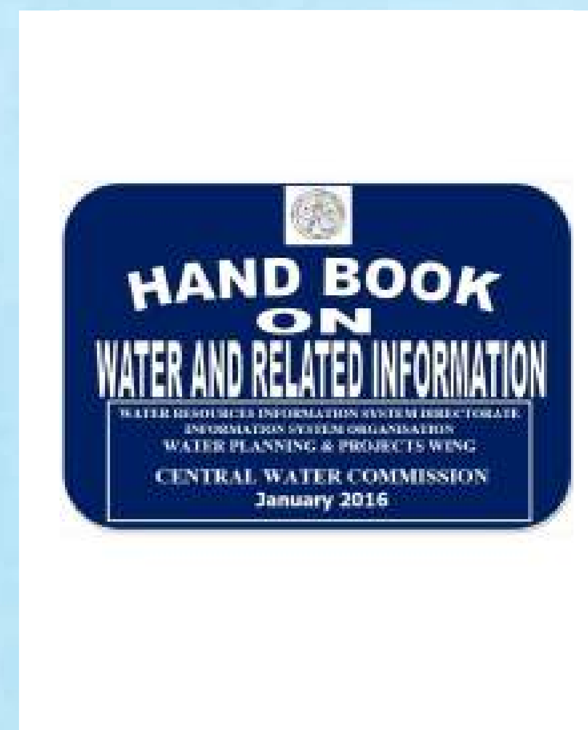
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