

Strategic Basin Planning for Ganga River Basin in India



Inception Report

April 2016

Analytical Work and Technical Assistance to support Strategic Basin Planning for Ganga River Basin in India

Inception Report

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all team members

1220123-000

Title

Analytical Work and Technical Assistance to support Strategic Basin Planning for Ganga River Basin in India – Inception Report

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Summary

This report describes the results of the inception phase of the project “Analytical Work and Technical Assistance to support Strategic Basin Planning for Ganga River Basin in India”. The objectives of the inception phase include:

- Establishing good working relations between World Bank, Ministry of Water Resources, Deltares, AECOM India Pvt.Ltd. and FutureWater;
- Identification of relevant stakeholders and institutions;
- Definition of data requirements and start of the data collection; and
- Preparation of a detailed work plan and project methods.

The terms of reference and the proposal distinguished six tasks. For each task the following information is presented:

- Objectives;
- Methods;
- Data requirements and data collected;
- Capacity building
- Links with other tasks;
- Contributions to project deliverables; and
- A detailed work plan.

The main challenges for the project in the coming months can be summed as follows:

- Establishing commitment to and ownership of the project with staff of the State Governments and other relevant actors basin and state level;
- Start of cooperation with counterpart staff in the dedicated project office; and
- Starting the stakeholder involvement in the collaborative modelling approach.

References

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Version	Date	Author	Initials	Review	Initials	Approval	Initials
0	Oct 2015	Marnix van der Vat		Ruben Dahm		Rinus Vis	
1	Feb 2016	Kees Bons		Ruben Dahm		Rinus Vis	
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State

Final

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1 Introduction

1.1 Background to the Project

The World Bank has assigned Deltares and its partners AECOM India and FutureWater to carry out the project "Analytical Work and Technical Assistance to support Strategic Basin Planning for Ganga River Basin in India".

1.2 Water Challenges in the Ganga Basin

The Ganges is the most populated river basin in the world and is home to half the population of India including two-thirds of the nation's poor people. The basin provides over one-third of the available surface water in India and is the focus of over half the national water use – 90 percent of this being in irrigation.

The ecological health of the Ganga River and some of its tributaries has deteriorated significantly as a result of high pollution loads (from point and non-point sources), high levels of water abstraction for consumptive use (mostly for irrigation but also for municipal and industrial uses), and other flow regime and river modifications caused by water resources infrastructure (dams and barrages for diverting and regulating the river and generating hydropower).

1.3 IWRM Institutional Setting

Water management is largely undertaken at the state level, and there has been no basin-wide effort for volumetric water planning and allocation. With increasing demand for water in multiple sectors a more strategic approach is now warranted.

The Government of India has committed to an ambitious goal of rejuvenating the Ganga and is committing significant funds to address the problem. However, in addition to the technical complexity and scale, Ganga rejuvenation is an inherently "wicked problem" given the wide diversity of stakeholder values and perspectives and the political and institutional dimensions that come from distributed responsibilities across multiple jurisdictions and institutions.

1.4 Objectives and Vision

As outlined in the Terms of Reference and our proposal, the key objectives of the project are:

- (i) Significantly strengthen the capability of relevant central and state government agencies to undertake comprehensive evidence-based strategic basin planning for the Ganga River basin
- (ii) Develop, document and disseminate (through detailed analytical work and stakeholder engagement) a set of plausible scenarios that balance significantly improving the health of the river and maintaining an acceptable level of economic productivity;
- (iii) Build stronger and more accessible information and knowledge base to guide on-going dialogue around and management of the Ganga River basin; and
- (iv) Establish on-going multi-stakeholder engagement processes in the basin to support strategic basin planning.

These objectives will be achieved by:

- (i) Developing a detailed and robust water resources planning model for the entire Ganga basin in India and training central and state government engineers and planners in its use;
- (ii) Characterizing and analysing surface-groundwater interactions across the basin using this information to refine the river modelling;
- (iii) Undertaking a multi-scale environmental flow assessment across the basin and using these assessments to inform the scenario modelling;
- (iv) Developing, modelling and disseminating a series of plausible scenarios that explore alternative options for improving water management including improving river health;
- (v) Establishing and facilitating a multi-stakeholder consultation process (inside and outside of government) to guide and share the work above; and
- (vi) Ensuring wide access to the models and analyses and quality documentation of these.

To achieve the objectives and carry out the tasks mentioned above, we base our approach on four pillars:

- *Pillar 1: Integrated computational framework* consisting of tested software, models and global data for integrated water resource management, all of which are available in the public domain. Local data will be used to verify the global data and to improve the quality of the data;
- *Pillar two: Collaborative modelling*, based on a well-structured interaction between water resource planning, scientific modelling and stakeholder participation;
- *Pillar three: Clear Phasing* with well-defined activities, deliverables and linkages for each of the six Tasks of the Project.
- *Pillar four: Result-oriented task teams* including world-wide experience in IWRM, hands-on knowledge of the Ganga River Basin and Indian Water Policy.

1.5 Institutional Setting of the project

The MoWR RD&GR is the key stakeholder and nodal point for the project at the central level. The Secretary, Joint Secretary and Special Secretary have all expressed strong interest and support to the project and appointed Dr. Avanish Kant, Sr.Hydrologist, NHP, MoWR, RD&GR, as nodal officer.

With support from the ministry the project will connect to State departments and Central Agencies that play important roles in the planning and management of the water resources within the basin. The project will reach out and involve Academic organisations and Non-Governmental Organisations in order to grasp the knowledge, ideas and interest of a wide group of stakeholders.

It has been decided to constitute a Committee for Monitoring the progress of the Consultancy on “Strategic Basin Planning for Ganga River Basin in India” to supervise, review, guide and coordinate the implementation of the Project (File No.21/123/2015-NHP/4235-4246). Accordingly the Committee is constituted with the members as presented in Table 1-1.

Table 1-1: Committee for Monitoring the progress of the Consultancy on “Strategic Basin Planning for Ganga River Basin in India”

Secretary (WR, RD&GR)	Chairman, CGWB
Chairman, CWC	Director, NIH
Special Secretary/Add;. Secy., MoWR, RD&GR	Member Secretary, CPCB
Joint Secretary (A), MoWR, RD&GR	Principal Secretaries of two Ganga Basin States (on rotational basis for six months)
Joint Secretary (PP), MoWR, RD&GR	World Bank’s representative
Mission Director, NMCG	Sr. Hydrologist, NHP, MoWR, RD&GR

1.6 Organization of the Team

The project will be carried out by an experienced team of national and international experts from the associated firms. They will work in close interaction with the technical team of Partners and the many other organizations and stakeholders involved in the project

The international and national consultants on a certain expertise will work together. National specialists will provide additional support in dialogue with government counterparts and collection and review of relevant documents. International Project leader will reside in India during project duration to enhance the success of the project. All consultants have very strong interpersonal skills and excellent written communication skills in English. We are very happy to present a well balanced team.

We keep the team organization as simple as possible and consist of a team leader (international: Mr Kees Bons) and co-team leader (national: Mr Anup Singh), who have the overall management responsibility. For the separate tasks a task leader is identified who will be responsible for the implementation and outputs for their respective tasks. The interaction between components of work and interaction with partners and stakeholders is coordinated by the two Project coordinators.

The team’s expertise and designated role are presented in the Table 1-2 below.

Table 1-2: Overview of Project Team

Area of Expertise	International Staff	National Staff	Designation
Project manager, IWRM expert	Mr. Kees Bons	-	Project Director / Leader
	Mr. Marnix van der Vat	Mr. Anup Singh	Project Coordinator
(mountain) hydrologist, hydraulic modeling expert, Flood forecasting expert, climate change expert,	Mr. Mark Hegnauer Mr. Peter Droogers Mr. Walter Immerzeel	Dr Sujana Dhar Mr. Pratul Shrivastava	Water resources / rivers modeler
Environmental hydrologist, Water quality expert, Water Resources specialist,	Mr. Pascal Boderie	Mr. Sunil Bagde	Environmental hydrologist
Environmental flow expert, River restoration, Aquatic ecosystem specialist, EIA/EMP expert	Mr. Victor Langenberg Mr. Fernando Magdaleno	Mrs. Deepti Parth Bapat Dr. Seema Srivastava	River ecologist
Geo-hydrologist, Groundwater modeling, Drought expert, Training & Capacity Building	Mr. Roelof Stuurman Mr. Frans Roelofsen	Dr D K Chadha Manoj Srivastava	Groundwater hydrologist / hydro-geologist
Social scientist, water governance specialist, Institutional Planning, Participatory Management	Mrs. Karen Meijer	Pranabeswar Baruah T G Ekande	Social and economic specialist
Stakeholder participation specialist, Training specialist, Communication expert, Community Outreach & Advocacy, Public Participation & Awareness, IEC	Mr. Bouke Ottow	R S Negi	Communications specialist
GIS/MIS-specialist, Spatial impact assessment expert, Decision support system specialist, DEM/DTM	Mr. Kymo Slager	Harendra Tiwari Paras Talwar	GIS specialist/Data specialist
IT Specialist	Mr. Gerrit Hendriksen	Mayank Soni	IT specialist

A critical part of the project will be establishing and facilitating a process of consultation and engagement with key technical partners and stakeholders to ensure understanding and acceptance of the modeling, and to obtain input to model conceptualization and scenario definition. The project will link to and support the Ganges Basin Modeling Community of Practice that has been established by the World Bank and through this will connect to broader basin dialogue processes. In the coming weeks we will discuss and finalize the best way to involve Partners and Stakeholders in the project with the MoWR RD&GR.

We will interact regularly with the project Progress Monitoring Committee with representatives from key involved organizations at Central and State level to allow all involved to provide their input and to create consensus on outputs and steps forward.

We also will form a Technical Working Group consisting of staff from the institutions who will participate as much as possible in the model development and application in order to fully understand and own the systems. Learning-by-doing and on-the-job training will be applied here, apart from the separate formal training that will be conducted. We do hope that an enthusiastic and active group can be formed and where possible we suggest to work as much on the premises of these counterparts, rather than isolated in a consultants office. In the Inception phase we intend to form the groups and agree on the modus of work. Also it can be decided if we will work as one group or in separate groups for River, Groundwater and Environmental flows.

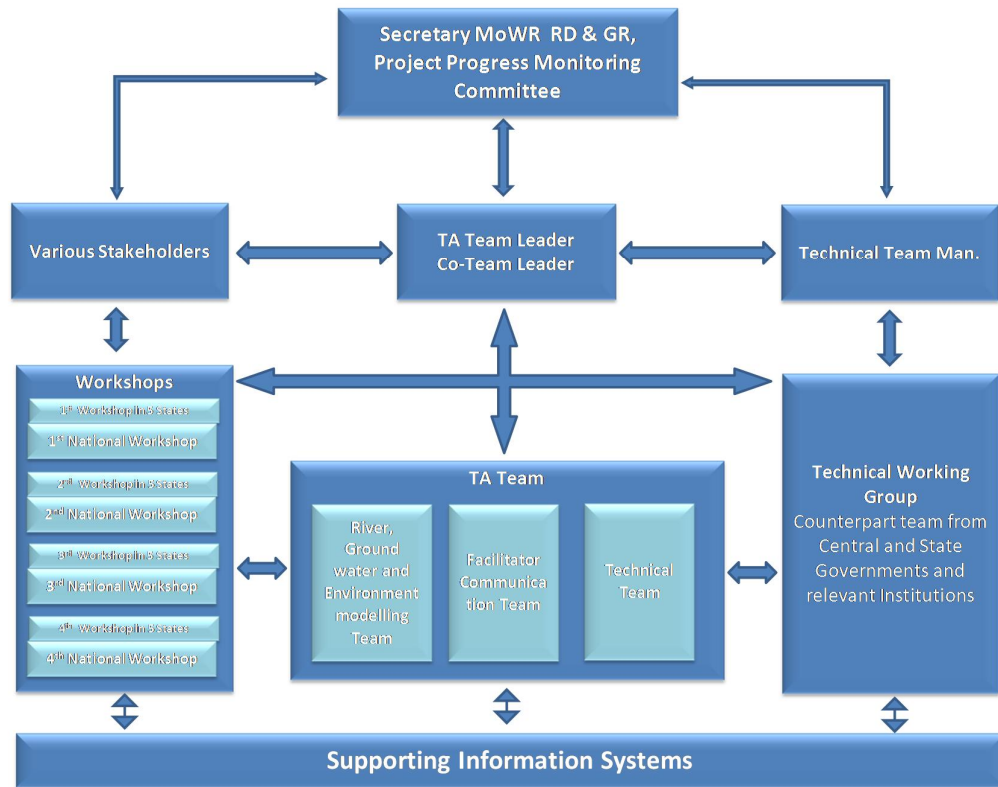


Figure 1-1: Organization and management of the project

2 Inception period

2.1 Timeline

The contract between The IBRD and Deltares came into effect on June 30th 2015. In July 2015 the Team leader was mobilized and started activities in India in order to set up the project.

In order to develop full ownership with the Ministry of Water Resources, River Development & Ganga Rejuvenation a number of meetings took place to discuss the project. The discussions were coordinated with Dr. Avanish Kant who has been appointed as nodal point of the MoWR,RD&GR as well as with the World Bank staff in Delhi. The main events were:

24 July 2015 First meeting with Shri Shashi Shekhar, IAS, Secretary MoWR,RD&GR introducing the project, its objectives and proposed approach.

28 October 2015 Second meeting with Shri Shashi Shekhar, IAS, Secretary MoWR,RD&GR elaborating on the project methodology and outcomes.

6 November 2015 Meeting with Sushri Uma Bharati, Minister Water Resources,RD&GR, in the presence of the Secretary and Joint Secretary (OO) discussing the project in relation to the River Basin planning approach.

On **7 December 2015** the Ministry wrote letter No.21/123/2015-NHP/4026-29 to the World Bank stating the in-principal approval of the Minister for the project.

In response by letter on **16 December 2015** the Bank agreed to finance the Deltares-led consortium undertaking the Strategic Basin Planning work as described in the attached terms of reference, which have been shared previously with the Ministry. The Bank also agreed to share with the Ministry at the conclusion of the project, all models and data associated with this work delivered to the Bank by Deltares. The Bank will happily assist in coordination of the project work and its important connections to the planned National Hydrology Project and on-going National Ganga River Basin Project. The Bank will ensure that the intellectual property rights of the Government of India are respected in all publications generated by the project

On **18 December 2015** a meeting was held with the state level stakeholders representing the relevant Uttarakhand state level organizations and regional organisations of central government at the conference Hall, National Institute of Hydrology, Roorkee, Uttarakhand. This was the first introductory meeting under the Ganga River Basin Planning Project in the Uttarakhand state. The participants were representatives from National Institute of Hydrology (NIH), regional office Central Water Commission (CWC), National Thermal Power Corporation (NTPC), Uttarakhand Irrigation Department, State Project Management Group (SPMG) under National Ganga River Basin Authority (NGRB), Uttarakhand Drinking Water and Sanitation Department, Indian Institute of Technology (IIT) Roorkee. Mr Avanish Kant, Sr. Hydrologist, MoWR, RD&GR, Govt. of India, and Project Consultants team (Deltares-AECOM) participated in the meeting. List of participants is annexed herewith. Shri Raj Dev Singh, Director, National Institute of Hydrology, Roorkee chaired the meeting and moderated the stakeholders' discussion.

On **19 December 2015** follow up meetings were held at IIT Roorkee, Irrigation Department Dehra Dun, Disaster Mitigation & Management Centre, Dehra Dun, and with Dr. Ranjit Kumar

Sinha, Additional Secretary Government of Uttarakhand and Director State Project Management Group which is the Uttarakhand part of Mission for Clean Ganga.

On **21 December 2015** Shri Shashi Shekhar, Secretary, MoWR, RD&GR, Govt. of India invited Senior Officers from the central organisations of the MoWR, RD&GR, i.e. Central Water Commission (CWC), Central Ground Water Board (CGWB), National Institute of Hydrology (NIH); Ministry of Drinking Water and sanitation, Ministry of Agriculture & Farmer Welfare; NGOs (TERI, WWF-India), World Bank and Project Consultants (Deltares-AECOM) for an introductory meeting to formally introduce the World Bank assisted “Analytical Work and Technical Assistance to Support Strategic Basin Planning for the Ganga River Project”. The agenda of the meeting comprised of -

- Introduction by Smt. Amita Prasad, Joint Secretary, MoWR, RD&GR, Govt. of India
- Key Remarks by Shri Shashi Shekhar, Secretary, MoWR, RD&GR, Govt. of India
- Approach and Methodology of the Project Assignment by Mr. Kees Bons, Team Leader Project Consultants (Deltares-AECOM)
- Open Questions and Answers on Project Assignment
- Group Work on
 - Ganga River Basin Issues, Interrelationships
 - Stakeholder Identification



Figure 2-1: Workshop session discussing stakeholders

On **28 December 2015**, by Office memorandum No.21/123/2015-NHP/4235-4246, it was decided to constitute a Committee for Monitoring the progress of the Consultancy on “Strategic Basin Planning for Ganga River Basin in India” to supervise, review, guide and coordinate the implementation of the Project.

On the same date an Office Memorandum was issued with No.21/123/2015-NHP/4229-4234 stating the support to the project under the conditions as assured the WorldBank in their letter and assuring the provision of the needed data in the possession of MoWR, RD&GR, the provision of Office space at Mohan Singh Place and assign nodal points.

On **29th January 2016** the National Level Stakeholders’ Participation Workshop was held at Shangri-La Hotel, New Delhi, under the chairmanship of Shri Shashi Shaker, Secretary,

MoWR, RD & GR, Govt. of India. This was the first national level inaugural workshop for the World Bank assisted project “Analytical Work and Technical Assistance to Support Strategic Planning for Ganga River Basin”. The main purpose of this workshop was to introduce the objectives and scope of this project to participants (national and the state level stakeholders), asking for proactive participation of the relevant stakeholders for accomplishment of this project assignment.

The invitation letters from the Secretary MoWR, RD&GR, Govt. of India were sent to the Chief Secretary of the respective 11 Ganga Basin states followed by a letter with workshop agenda from Joint Secretary, MoWR, RD&GR, Govt. of India to the relevant State and Central Government Departments/ Agencies. There were about 112 participants from the 11 states of the Ganga River Basin (i.e. Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, NCT of Delhi, Rajasthan, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, and West Bengal); central level ministries/ departments/ agencies, academic institutions, national and international organizations, World Bank, and Project Consultants.



Figure 2-2: Basin Workshop attendance



Figure 2-3: Secretary MoWR, RD&GR addressing the audience in presence of Joint Secretary and Special Secretary

2.2 Main findings

The Inception period required considerable more time than originally planned in order to embed the project properly with the beneficiary Ministry and establish ownership.

The Ministry of Water Resources, River Development & Ganga Rejuvenation has endorsed the project and fully supports its implementation.

The Secretary of MoWR, RD&GR, with the Joint Secretary and Special Secretary has actively mobilized nodal officers in the relevant central organizations and has informed all special secretaries of the eleven involved states regarding the project and encouraged cooperation.

The project is well established and ready to proceed to the next phases of the project.

Project implementation can be achieved if the project duration is extended from the middle to the end of 2017. The adapted time plan is presented in chapter 10.

2.3 Specific observations from the Inception phase

In this paragraph a number of specific observations are mentioned that have impact on the project execution. These observations are included in the elaboration of the tasks in the following chapters.

2.3.1 Consultation and engagement

The Ministry of Water Resources, River Development & Ganga Rejuvenation is the key stakeholder and nodal point for the project at the central level. With support from the ministry the project will connect to State departments and Central Agencies that play important roles in the planning and management of the water resources within the basin. The project will reach out and involve Academic organisations and Non-Governmental Organisations in order to grasp the knowledge, ideas and interest of a wide group of stakeholders.

In the inception period the project team in consultation with counterparts from the Ministry of Water Resources, River Development and Ganga Rejuvenation compiled a list of stakeholders with short descriptions and indications of their possible involvement at the national/basin level or at a state/sub-basin level. The list was adapted based on group meetings and checked again with the nodal officer. The list is provided as Annex 2 to this Inception report.

Apart from the continuous consultation and involvement through the Nodal officer of MoWR, RD&GR and the main partner organisations at the Central level, CWC, CGWB and NIH, three main rounds of consultation are planned in the project:

1. Raising interest and commitment. Meetings in the States and with individual organisations, aimed at policy level (secretary) staff to inform them about the project and its objectives and to invite them to raise issues to be incorporated in the modelling tools to enhance its use to the stakeholder. Group meetings, individual meetings and a questionnaire are used in this round. Period January-May 2016
2. Collaborative Modelling. Workshops in the States and with individual organisations, aimed at technical level staff. The identified objectives and needs will be translated into actual model schematisations during the workshops so that as much as possible local knowledge is included. Period June-December 2016

3. Scenario development. . Workshops in the States and with individual organisations, aimed at group of identified nodal staff. Basin wide and State Scenario's will be discussed where external factors (e.g. climate change, population growth) will be separated from interventions that can be done to form a strategy. Period January-June 2017

Chapter 8 further describes the Consultation and engagement process of the project.

2.3.2 Training and Capacity Building

During the Inception Phase it became clear that there are different objectives to be reached regarding training and capacity building, each requiring its own approach:

1. Creating awareness and capacity in Integrated River Basin Planning. This mainly achieved through the meetings and workshops with the stakeholders.
2. Training in using the modelling tools developed in the project for the assessment of plans, projects and strategies. This will be achieved through formal training in the second half of the project as well as through the scenario development workshops where the tools play a supporting role.
3. Training in further development and operation and maintenance of the modelling tools. Professionals from NIH, CWC, CGWB and educational institutes will receive formal training, but will also be involved in on-the-job training during joint model development. These trainees can also function as trainers in using the models during and after the project period.

In the following Chapters the training identified on the relevant task is described.

Chapter 10 provides the resulting overall work plan and details for the period till the next progress report.

3 Task 1: River Basin Model Development

3.1 Objectives

The main purpose in this Task is to build and apply a comprehensive rainfall-runoff and river system model including a water quality and ecological health module for the entire Ganga river basin. A robust modelling framework will be developed that can assess the consequences of alternative strategies or development scenarios on the environment and for different water use sectors. Typical interventions include construction of additional sewage treatment facilities, treatment of industrial effluent, environmental flows, increased water use efficiency, additional water storage and changed operation of existing water resources infrastructure.

3.2 Methods

To meet the specified requirements for the river basin modelling, a framework based on the following individual sub-models will be set-up, tested and applied for the Ganga basin:

1. Distributed catchment hydrological models for the simulation of rainfall runoff and sub-surface flows on a daily time step and fine spatial resolution (WFLOW – SPHY);
2. 3D geo-hydrological model to simulate the groundwater dynamics, the interaction with the surface water such as the Ganga River and the impact of groundwater extraction (iMOD-MODFLOW, described in more detail in Chapter 3 as part of Task 2);
3. A water management tool to simulate the Ganga River Basin, the operation of its water resources infrastructure, water demand and allocation (RIBASIM);
4. A catchment water quality and ecology model to quantify catchment loads and pollutant concentrations as well as the impact on the ecology of the river and its floodplains and the ecosystem services (River Basin Explorer);
5. The Ganga Water Information System (WIS) and dashboard to store and manage all data and model results in a geo-database and to allow dedicated querying of model results; and
6. Delft-FEWS as a connector between the models and the information system.

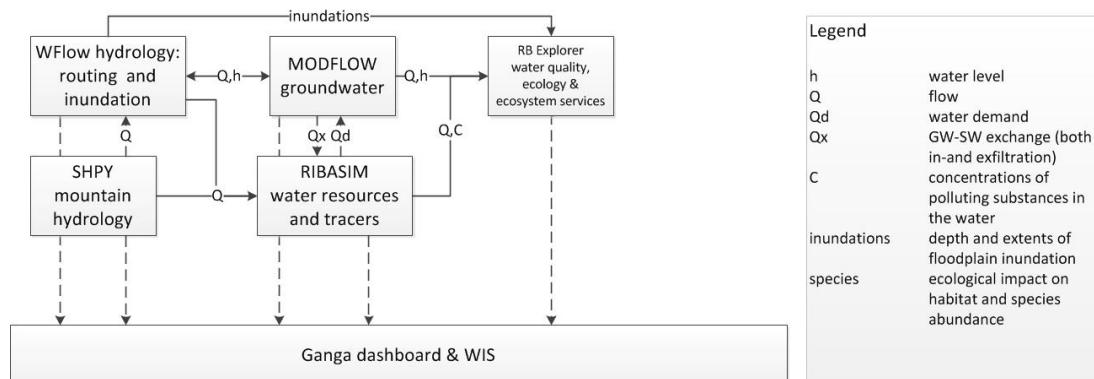


Figure 3-1: Schematic overview computational framework

A schematic overview of the complete river basin modelling framework and individual sub-models is presented in Figure 3-1. The modelling software and its license status are presented in Table 3-1. All software is open source or at least the executable version is free. Each individual module of the framework is described in more detail in the following sections.

Table 3-1 List of proposed modeling software and their status with respect to licensing

Model	Originator	Description	License status
WFLOW	Deltares	Surface water hydrology	Open source
SPHY	FutureWater	Mountain hydrology	Open source
RIBASIM	Deltares	Water resources	Free ¹
MODFLOW	USGS	Groundwater flow	Open source
iMOD	Deltares	Graphical user interface for and an accelerated version of MODFLOW	Open source
Delft-FEWS	Deltares	Data, workflow and visualization platform	Free
River Basin Explorer	Deltares	Water quality, ecology and ecosystem services	Free

The computational framework will be focused on answering the questions of policy makers, planners and stakeholders. Therefore, it will be adapted during project execution based on the results of the stakeholder interaction (Task 5). The framework is focused on assessment of indicators related to water availability, water quality and ecology. The hydrology and the interaction between surface and groundwater form the basis for this assessment. The application of the models will be developed in close cooperation with counterparts and stakeholders following the Collaborative Modelling approach outlined further under Task 5. Furthermore, existing model applications might be integrated in our computational framework, if they become available.

Two different models, WFLOW and SPHY, will be used for the description of the hydrology. The SPHY model developed by FutureWater is especially suitable for mountain hydrology including snowfall and glaciers. A first application for the Himalayas has already been developed by FutureWater. This will allow for robust assessment of flows entering the Ganga River from the Nepalese tributaries.

The hydrology of the non-mountainous part of the basin will be modelled using Deltares' WFLOW model (Schellekens, 2011), which is especially developed to construct hydrological models based on globally available data sets, allowing incorporation of local data where they are available and where additional accuracy is required for the analysis. WFLOW also provides the possibility to calculate flood extent and depth from simulated discharge and topographical data.

USGS groundwater model MODFLOW – and the Deltares application iMOD - will be applied to model the groundwater in the whole Ganga Basin on a course scale and the interaction between surface and groundwater in particular (Task 2).

The hydrological models provide input on water availability for the water resources model RIBASIM. In RIBASIM the flow of water is described in a more aggregated way than in the hydrological models as a flow through a series of linked reservoirs with a time step of typically a week, a decade or (half a) month. Furthermore, RIBASIM uses information on water demanding activities such as agriculture, industry and population to estimate water demand. Within RIBASIM water demand is confronted with water availability and where there is not enough water to satisfy the whole demand, water is allocated based on priority rules. These

¹ RIBASIM is currently licensed software, but will become available as freeware or open source in the near future. Deltares guarantees that RIBASIM will be supplied free of costs to all participants in this project during and after project execution.

also apply to the operation of reservoirs and groundwater withdrawals. The impact of groundwater extraction on groundwater levels can be assessed using the extraction rates as input for the MODFLOW model (see Task 2).

The flows calculated in RIBASIM and the flood extent calculated in WFLOW are combined in the River Basin Explorer with the results of the emission inventory to assess water quality and ecology in the rivers, groundwater and on the floodplain. The Explorer is a very flexible tool where the water manager can include ecological knowledge rules that have been specifically derived for the Ganga Basin. This makes it an ideal tool to include local knowledge in the assessment.

The RB Explorer will also be used to assess the impact of scenarios on ecosystem services. This allows for a combination of information on flows, water levels, floods and water quality with information on the production of ecosystem services by the river system. The combination of RIBASIM and the RB Explorer is well suited for the assessment of the impact of different environmental flow scenarios, since operation rules for dams can be directly entered and evaluated in the RIBASIM model. Measures regarding the reduction of point and non-point sources of pollution can be entered and evaluated in the RB Explorer.

All input for all modules will be retrieved from the Ganga Water Information System (Task 6) using Delft-FEWS as connector. All model results will also be stored in this information system through Delft-FEWS. The dashboards and scorecards that will be developed to select measures and interventions and to present their impact on the selected indicators will work directly on the results of the different modules available in the Ganga Water Information System.

The next sections present the modules WFLOW, SPHY, Delft-FEWS, RIBASIM and the RB Explorer. iMOD-MODFLOW is presented in more detail in Chapter 3 dealing with Task 2 and the Ganga WIS, dashboard and scorecards are presented in more detail in Chapter 7 dealing with Task 6.

3.2.1 WFLOW hydrological model

WFLOW (Schellekens, 2011) is a process-based distributed hydrological model developed by Deltares. Conceptually WFLOW is based on the HBV-96 model (Bergström, 1995). Hydrological processes are simulated at the spatial scale of model elements, which in the case of WFLOW are cells on a square grid. The model is programmed in Python-PCRASTER, a dynamic GIS environment (Burrough et al., 2005), and is especially developed for spatial grid computations.

WFLOW incorporates the most important processes of the hydrological cycle as schematized in Figure 3-2. Different components of the hydrological cycle are modelled through a combination of sub-models nested in the model code, including:

1. Rainfall interception schematized by the Gash model (Gash, 1979, 1995).
2. Channel and overland flow modelled with the kinematic wave model.
3. Soil processes schematized by the HBV-96 model (Bergström, 1995). Alternatively, soil processes can be modelled with the TOPOG_SBM model concept (Vertessy and Elsenbeer, 1999).
4. Unsaturated zone.
5. Saturated zone.

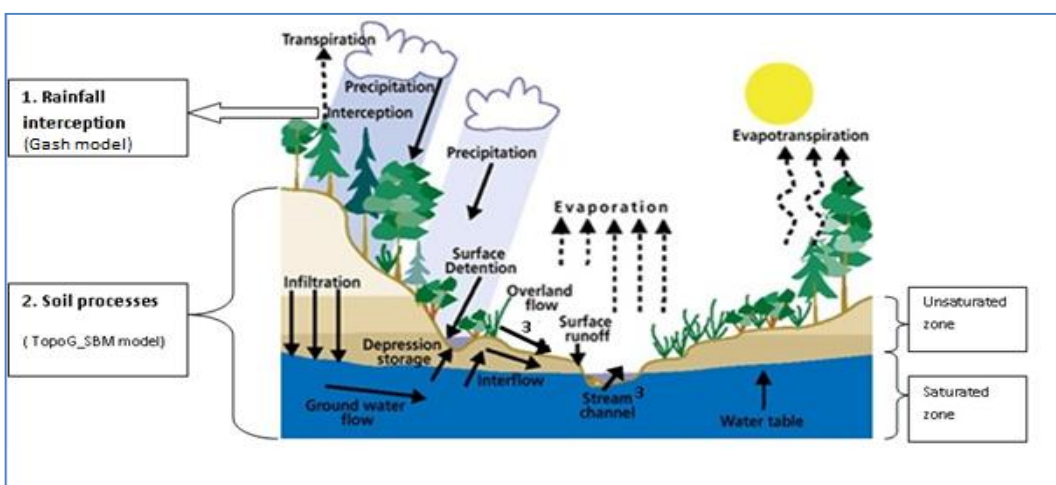


Figure 3-2: Basic components of the hydrological cycle represented in the WFLOW model

The WFLOW model solves the governing equations for the surface and subsurface flow routines using the finite difference scheme. The equations are solved in time for each grid cell, providing continuous simulated values for the hydrological state variables (runoff volumes, saturation) for each cell. Channel flow processes are simulated using the kinematic wave model. The model output can be visualized as a sequence of spatial maps (gridded raster data) of hydrological variables. For selected locations across the catchment, time series of hydrological variables such as discharge or soil saturation can be generated.

WFLOW has been developed to simulate surface and the shallow sub-surface flow paths. Deeper, regional groundwater flows are not modelled in Wflow. In our computational framework iMOD-MODFLOW is used to simulate groundwater and the interaction between surface and groundwater.

WFLOW flood maps

A special module of the WFLOW model is used to produce flood maps. This module determines flood extent and flood depth from the output of a previous run, based on the stored water level and discharge output map stacks. A flood will occur if the water level in the river exceeds the bankfull depth. Cells with an elevation below the river water level and connected to the flood path (through the local drainage direction map derived from a digital elevation model) are flooded with the same level as that river water level. To create realistic flood maps, a maximum flood velocity can be set so that only cells that can be flooded within a reasonable time are flooded within each time-step.

3.2.2 SPHY hydrological model for mountainous areas

The Spatial Processes in Hydrology (SPHY) model (Terink et al., 2015, Figure 3-3, see also www.sphy-model.org) is a distributed cryospheric-hydrological model widely applied in the mountainous regions of Asia. Its strong representation of processes related to glacier melt and snow melt combined with low input data requirements make it very useful for the regions with high mountains surrounding the Tibetan Plateau, often facing data scarcity. The model explicitly simulates glacier melt with different melt rates for clean ice glaciers and debris covered glaciers, distinguishes snowfall and rainfall at the grid cell level, keeps track of dynamic snow storage and simulates rainfall-runoff processes including soil water fluxes and evapotranspiration. Contributions of runoff from these different sources are calculated at grid cell level and generated runoff is transported downstream using a routing module. The model

can be set up and forced entirely with remote sensing and public domain datasets and can be refined using local data where necessary/available.

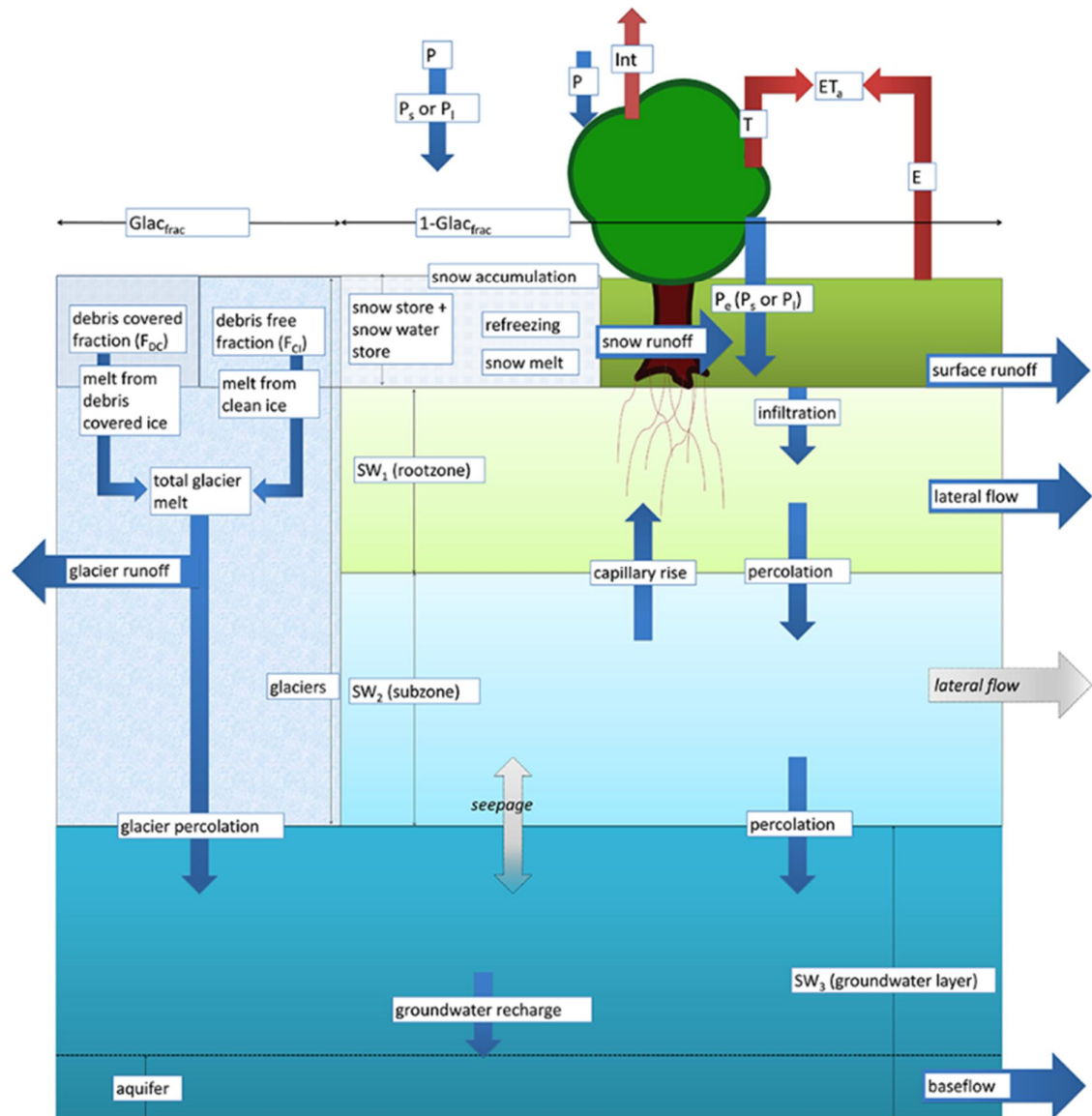


Figure 3-3 SPHY model diagram showing fluxes and processes simulated in SPHY

The SPHY model has been applied successfully in the Indus (Lutz et al., 2014) and in the combined Indus, Ganga, Brahmaputra, Salween and Mekong basins (Lutz and Immerzeel, 2013; Lutz et al., 2014) with their sources in the Himalayan and Karakoram mountain ranges. SPHY was also applied in the Amu Darya and Syr Darya river basins in the Central Asian Aral Sea basin (ADB, 2012; Immerzeel et al., 2012; Lutz et al., 2012, 2013). The SPHY model is currently available for the upper Indus, Ganga, Brahmaputra, Salween and Mekong basins at 1x1 km spatial resolution and daily time step.

For this project SPHY will be set up for the mountainous parts of the Ganga basin (Figure 3-4), including the Nepalese tributaries at 1x1 km spatial resolution and daily time step. The model will be initially calibrated and validated using the available discharge data in the Koshi basin, a mountainous sub-basin of the Ganga in Nepal. Earlier calibration of the large-scale model for the upstream basins indicated good performance in the upper Ganga (Figure 3-5). Discharge simulated in the upstream mountainous part of the basin will feed into the RIBASIM and WFLOW model at the outflow locations.

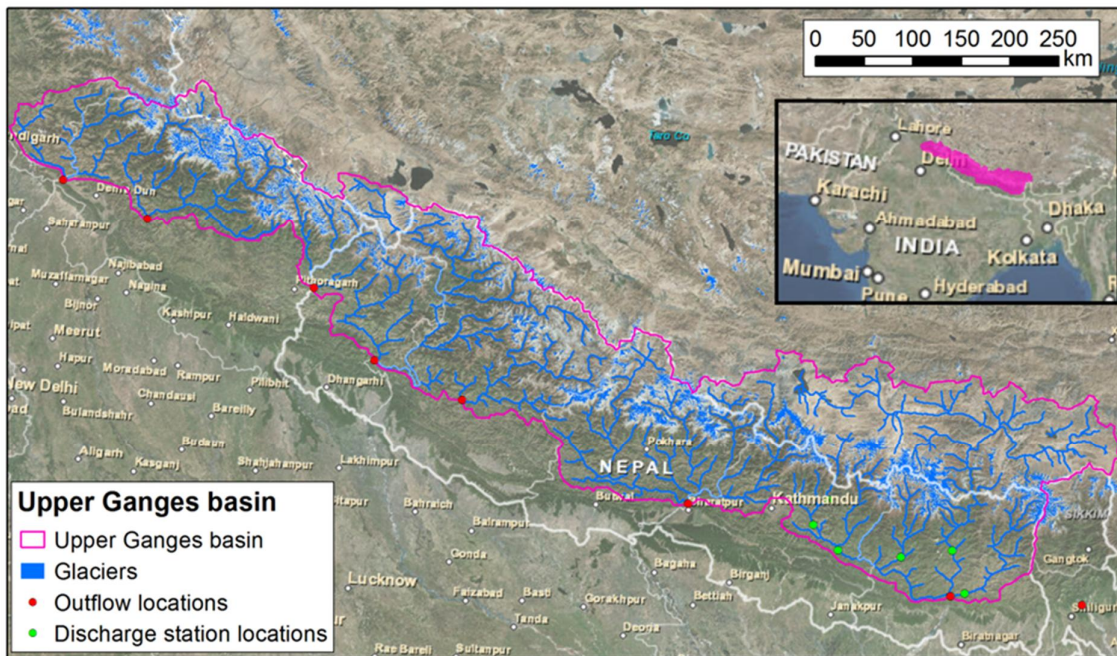


Figure 3-4 Mountainous part of Ganga basin including Nepalese tributaries

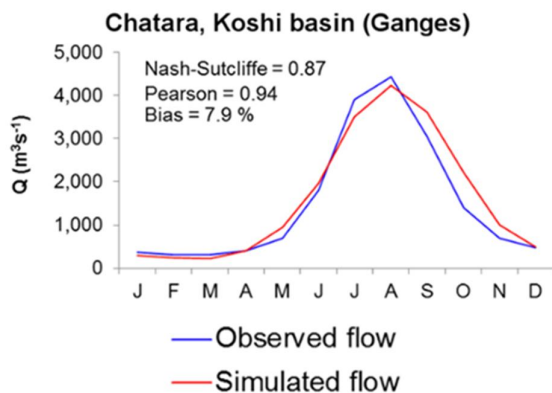


Figure 3-5 SPHY model performance in the Koshi basin (mountainous sub basin of the Ganga) for 1998-2007.

3.2.3 FEWS platform environment

Delft FEWS is used in our computational framework as a data management system for importing and retrieving model inputs and outputs. It thereby provides a two-way connection between the models and the Ganga Water Information System (see Task 6).

Delft-FEWS is an *open software* environment utilized for the application of various modeling tools built around a central database. A set of standard tools related to data handling are also incorporated, including modules for importing and exporting data, validating and interpolating data (both temporally and spatially) and transforming data (aggregation, disaggregation and transformation). The philosophy of Delft-FEWS is to provide an open system to allow a wide range of existing models to be used. This concept is supported by the provision of a General Adapter module, which allows communication to external modules using an open, XML based, published interface. The XML published interface in combination with the General Adapter effectively enables “plugging-in” of any module to Delft-FEWS. A module adapter will typically be required to convert the published interface files to the native module data formats.

The module adapter will also need to be aware of specific requirements of the external module. A module adapter is the only requirement for any external module to be compatible with Delft-FEWS. A module adapter can be made by any third party. Such adapters are already available to support a wide range of hydraulic and hydrological models, including WFLOW, RIBASIM, RB Explorer and MODFLOW-iMOD.

3.2.4 RIBASIM water resources model

RIBASIM is a generic model package for simulating the behaviour of river basins under various hydrological conditions. The model package is a comprehensive and flexible tool which links the hydrological water inputs at various locations with the specific water-users in the basin. RIBASIM enables the user to evaluate a variety of measures related to infrastructure, operational and demand management and to see the results in terms of water quantity, demand fulfilled and flow composition (see Figure 3-6 for an example).

RIBASIM enables a schematization of the river basin to be prepared interactively from a map. This schematization consists of a network of nodes connected by branches. The nodes represent reservoirs, dams, weirs, pumps, hydro-power stations, water users, inflows, man-made and natural bifurcations, intake structures, natural lakes, swamps, wetlands, etc.. The branches transport water between the different nodes. Such a network represents all of the basin's features which are significant for its water balance and it can be adjusted to provide the exact level of detail required. The river basin is presented as a map over which the network schematization is superimposed as a separate map layer. The attribute data of the network elements are entered interactively and linked to the map of the river basin and its network schematization. Data consistency tests are an integral part of this. Figure 3-7 presents an example of a RIBASIM schematization for West-Java.

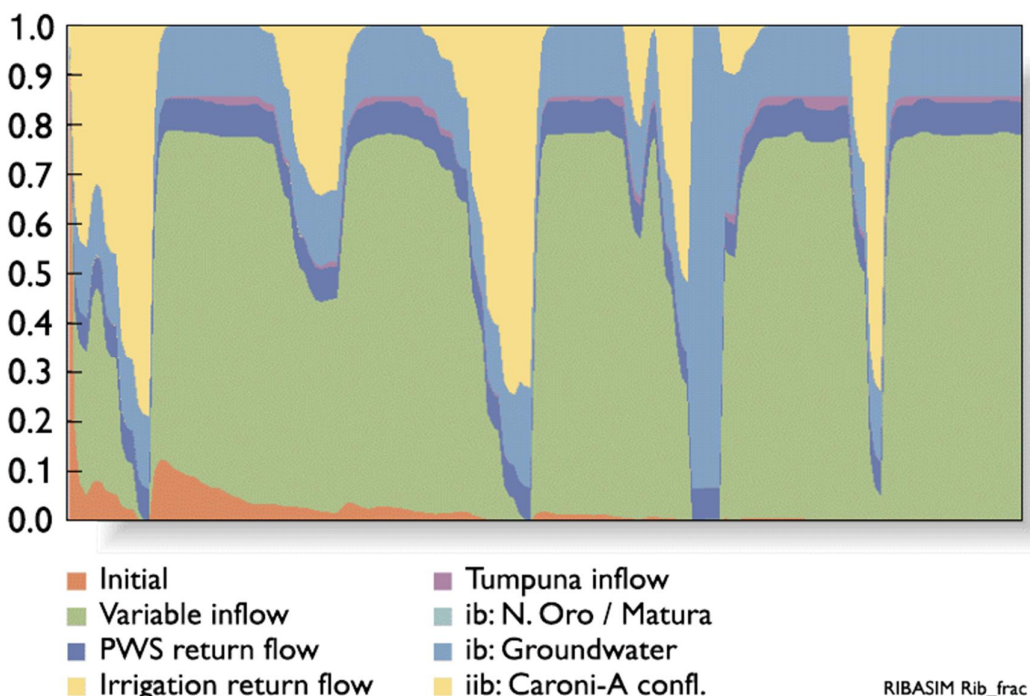


Figure 3-6: The origin of the flow at a downstream location in the Caroni Basin, Trinidad (5 year period).

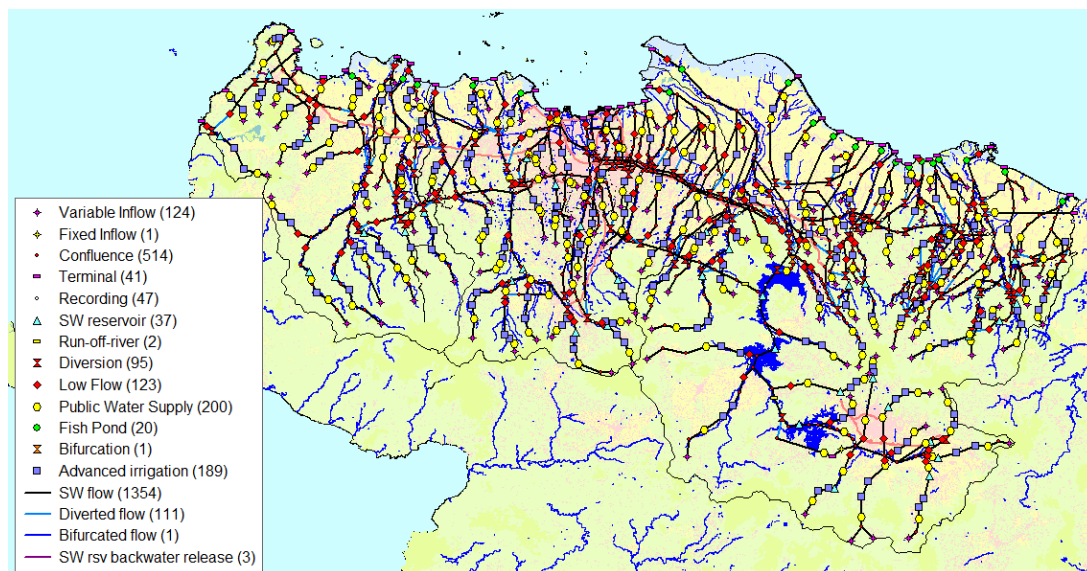


Figure 3-7 RIBASIM schematization for West-Java (Van der Krogt, 2012)

3.2.5 River Basin Explorer water quality and ecology model

The RB Explorer uses the results of RIBASIM to describe the flow regime of the rivers, results of iMOD-MODFLOW for the groundwater and results of WFLOW for the flooding extent.

The RB Explorer calculates the exchange of substances between the units and between water bodies within a catchment. Measures to reduce emissions can be simulated in various ways, for instance by defining a higher purification performance for a sewage treatment plant or by simulating a filter system in wetlands or agricultural drains (see Figure 3-8). Available

emission information can be easily translated by the RB Explorer to meaningful boundary conditions for the calculation.

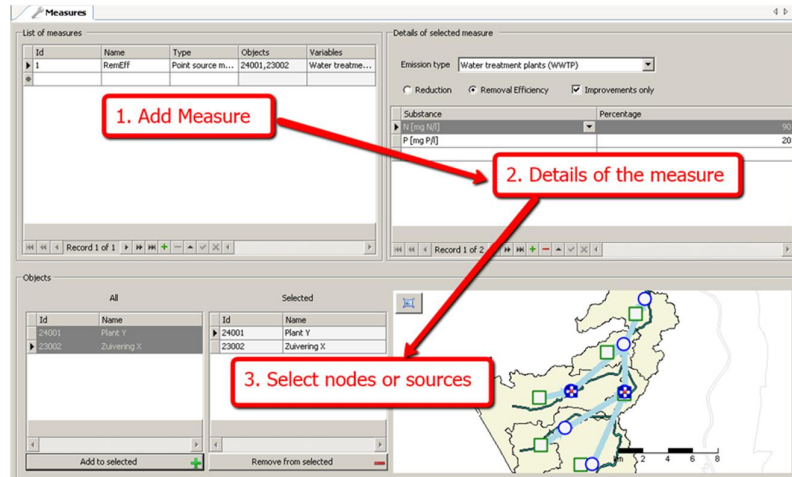


Figure 3-8: Screenshot of the interactive input of measures and scenarios in the RB Explorer

The RB Explorer was developed to support water managers in making decisions on what measures should be implemented to improve the chemical and ecological functioning of a water body. Moreover, the Explorer is also extremely useful as a communication tool to assist stakeholders with identifying different management options and outcomes in an interactive way. The model was initially developed in response to modelling requirements for the Water Framework Directive (WFD) in the European Union but the approach and set-up is equally suitable for the Ganga river basin.

The RB Explorer consists of a water balance, a substance balance, an ecological module and a mitigation module (including a cost module) as is presented in Figure 3-9. In short, the Explorer works as follows: the water balance constructs a water flow through a network of water bodies, such as streams, rivers and lakes.

The water balance is then used as input for the substance balance, which transports the substances over the network. The selection of substances to be modelled depends on the demands of stakeholders in the collaborative modelling workshops and the data availability. Faecal coliform bacteria (FC), Biological Oxygen Demand (BOD) and associated dissolved oxygen concentration (DO), total nitrogen (TN) and total phosphorus (TP) are the most likely candidates to be included.

Next, information on pollutant concentrations, flow regime, groundwater levels and flooding together with characteristics of the water body (e.g., sheet piling, weirs) is used in the ecological module. The ecological module allows combination of quantitative and qualitative information in a semi-quantitative evaluation framework based on location specific knowledge rules that have to be defined together with experts and stakeholders. The assessment of ecosystem services will use the evaluation framework and will also be expressed in semi-quantitative terms, such as a value on a 1 to 10 measurement stick.

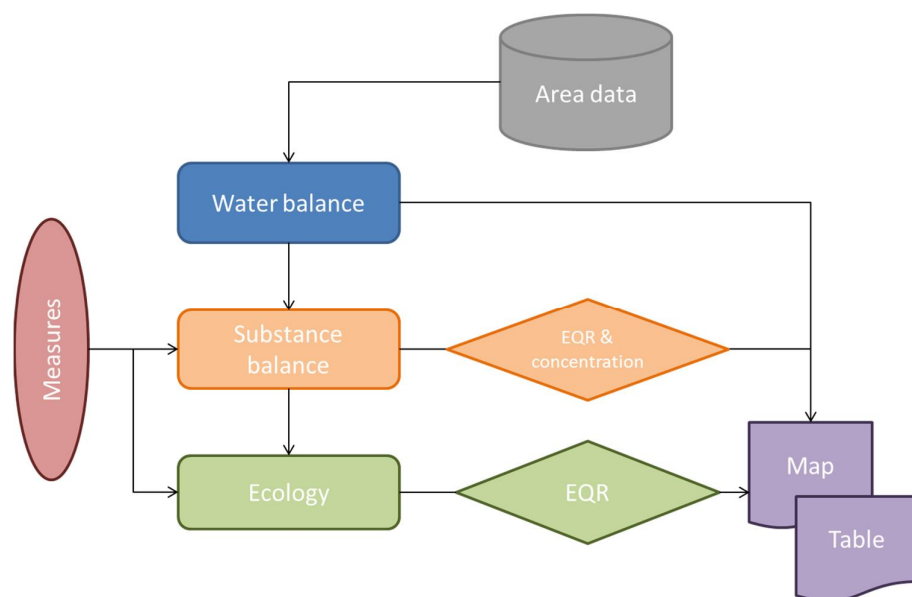


Figure 3-9: Flow chart of the RB Explorer

The final workflow for the water quality calculations can be summarized as:

1. Pre-processing scripts convert the RIBASIM data to RB Explorer format, including spatial and time aggregation and convert the load sources to RB Explorer format, including a seasonal distribution;
2. The Explorer interface imports data from the pre-processing script, combines the loads of point sources with the loads of non-point sources and calculates the concentrations of all substances for the schematized parts of the river network;
3. Within the RB Explorer different emission scenarios are defined and calculated, either by varying the load input files or manipulation of the loads related to specific activities, soil type or geographical location;
4. Post processing scripts combine measured and computed values for concentrations and loads, generate maps with loads, and present overviews with the contribution of the flows from the different sub-catchments to the Ganga river basin.

The workflow for ecology and ecosystem services a set of steps similar as those for water quality:

1. Task 3 will provide relationships (knowledge rules) between variations in flow statistics and the resulting ecosystem condition and availability of ecosystem services. These relationships will be used to make a flow-ecosystem-service component in the RB explorer.
2. Pre-processing scripts compute ecologically relevant flow statistics (Task 3 will provide the information on the flow statistics to be computed).
3. The Explorer interface imports data from the pre-processing script for the schematized parts of the river network;
4. Post processing scripts integrated in the explorer return the resulting ecosystem condition and ecosystem service availability for various different stretches of the Ganga river basin.

3.3 Data requirements and data collected

The paragraphs below present a general overview of the data required for the River Basin Model. Annex 1 presents a more detailed note on the data collection required for all tasks.

3.3.1 WFLOW and SPHY hydrological model application

The goal of the hydrological models is to produce spatially distributed estimations of rainfall runoff from the Ganga catchment through the drainage network. The input data required to execute simulations in WFLOW and SPHY can be separated into *i)* static data concerning the description of the land surface, and *ii)* dynamic data, represented by the hydro-meteorological forcing of the model. Table 3-2 reports the key data requirements for the model.

Table 3-2: WFLOW data requirements and sources

Static Data	
Digital elevation model (DEM)	Topography data
Soil physical parameters	Topo-climate soil layer (1:50 000 scale)
Land use	GIS database
River cross sections and stage-discharge relations	Required only where flood extent will be calculated in WFLOW
Glacier extent	Required for the simulation of the Himalayas in SPHY
Dynamic data	
Precipitation, temperature and potential evaporation	Global and local data sets (daily data at detailed grid)
Discharge data (calibration & validation)	Daily discharge data
Water level data (calibration & validation)	Daily/monthly data for the main reservoirs and where flood extent will be estimated
Flood extent	Monthly and maximum flood extent where flood extent will be estimated

Digital elevation data, time step and river network

Elevation data will be derived from the publicly available 90x90m version of the NASA's SRTM (Shuttle Radar Topography Mission). The original DEM resolution will be aggregated to the final resolution to reduce the computational effort to run the SPHY and WFLOW models over extended periods. A spatial resolution for the Ganga basin of 1x1 kilometres appears to be most appropriate. A temporal resolution of 1 day will be used. The catchment river network will be derived from a GIS layer provided by the Client or the DEM. Sub-catchments will be also be derived from the DEM.

Land use and soil type

Catchment land-use, used by the model to estimate surface runoff and evapotranspiration, is based on output from the land-use database. The land-use information will be rescaled to align with the final hydrological grid resolution. Catchment soil type, used by the model to determine soil water holding capacity and water storage depth, will be derived from a Topo-climate database. This data must represent the soil across the entire Ganga basin on a relatively detailed scale.

Glacier outlines

Glacier outlines will be extracted from the most up to date global glacier inventory, the Randolph Glacier Inventory (Pfeffer et al, 2014). The most recent version (version 5.0) which was released in July 2015 will be used. The Randolph Glacier Inventory (RGI) is a globally complete collection of digital outlines of glaciers, excluding the ice sheets, developed to meet the needs of the Fifth Assessment of the Intergovernmental Panel on Climate Change for

estimates of past and future mass balance. The outlines are suitable to derive fractional glacier cover for grid cells in the SPHY model.

Precipitation, temperature and potential evapotranspiration

Precipitation, the principal forcing variable for the hydrological model, temperature and potential evapotranspiration will initially be derived from publicly available global data sets, such as WFD and WFDEI (Weedon et al., 2011, 2014). These data sets provide long time series based on a combination of local measurements and climate model results at a daily time step (at least) and at a spatial resolution of approximately 50x50km. These data sets have been made available for the Ganga Basin during the inception phase. Their advantage is not only their availability, but also the long time series available (e.g. 1901 to 2001 for WFD and 1979 to 2012 for WFDEI).

An initial comparison of four established global meteorological forcing products is made (Figure 3-10, Figure 3-11, Table 3-3 and Table 3-4). Averages for 1998-2007 are compared. Since WATCH forcing does not reach until 2007, the years 1992-2001 are used. Besides the differences in spatial resolution (0.5° for WATCH and WFDEI, 0.75° for ERA-INTERIM (Dee et al., 2011) and 0.25° for APHRODITE (Yatagai et al., 2012), the products yield considerable differences in the basin-averaged precipitation totals. Especially for the upper basin, the estimates have large variation. The ERA-Interim dataset clearly lacks detail in the spatial distribution of precipitation.

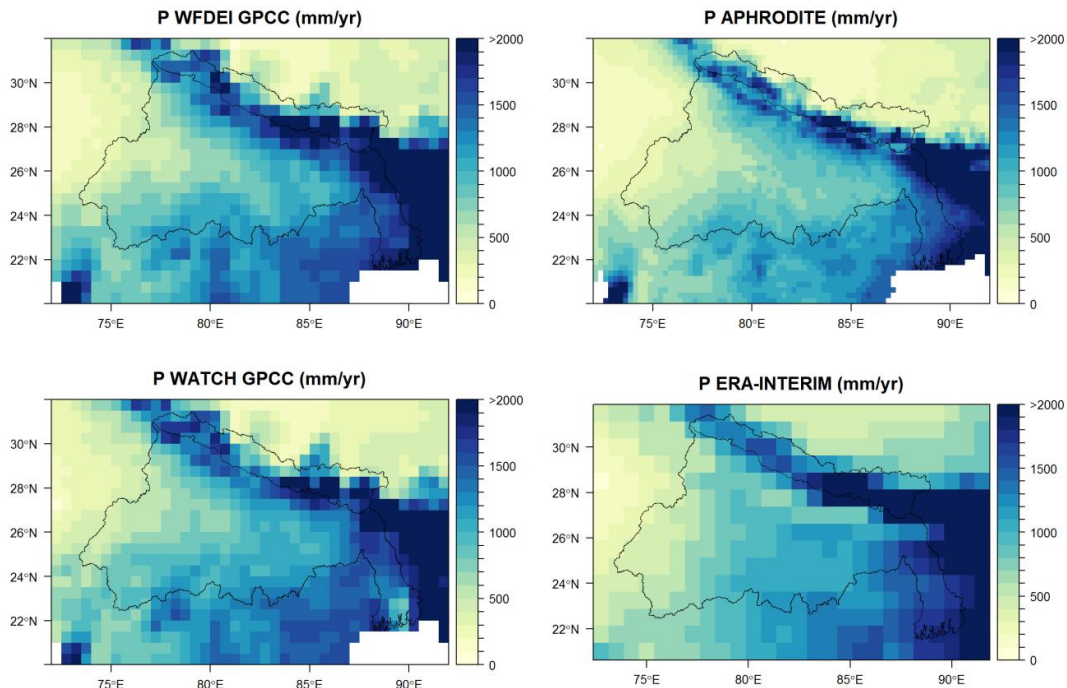


Figure 3-10: 10 year average annual precipitation according to different precipitation products

Table 3-3: 10 year average annual precipitation (mm/yr) in upper and lower Ganga basin according to different precipitation products

	WFDEI	APHRODITE	WATCH	ERA-INTERIM
Upper Ganga	1482	995	1409	1704
Lower Ganga	1130	964	1113	1106

Also for air temperature differences in the spatial patterns are visible in the spatial maps. Variation in the zonal averaged temperature values are large for the upstream basin, but small for the downstream part.

The final decision which dataset will be used for the model forcing will largely depend on the length of the period covered that is needed for all aspects of the assignment. The datasets cover different periods. ERA-INTERIM covers 1979-present, APHRODITE covers 1961-2007, WATCH covers 1901-2001 and WFDEI covers 1979-2012. Although APHRODITE has the highest spatial resolution, this dataset has the large disadvantage that only precipitation and average air temperature are included (no maximum and minimum air temperature), whereas the other datasets have a large number of variables. The WATCH dataset also includes future climate change scenarios, which may be an advantage over the other datasets.

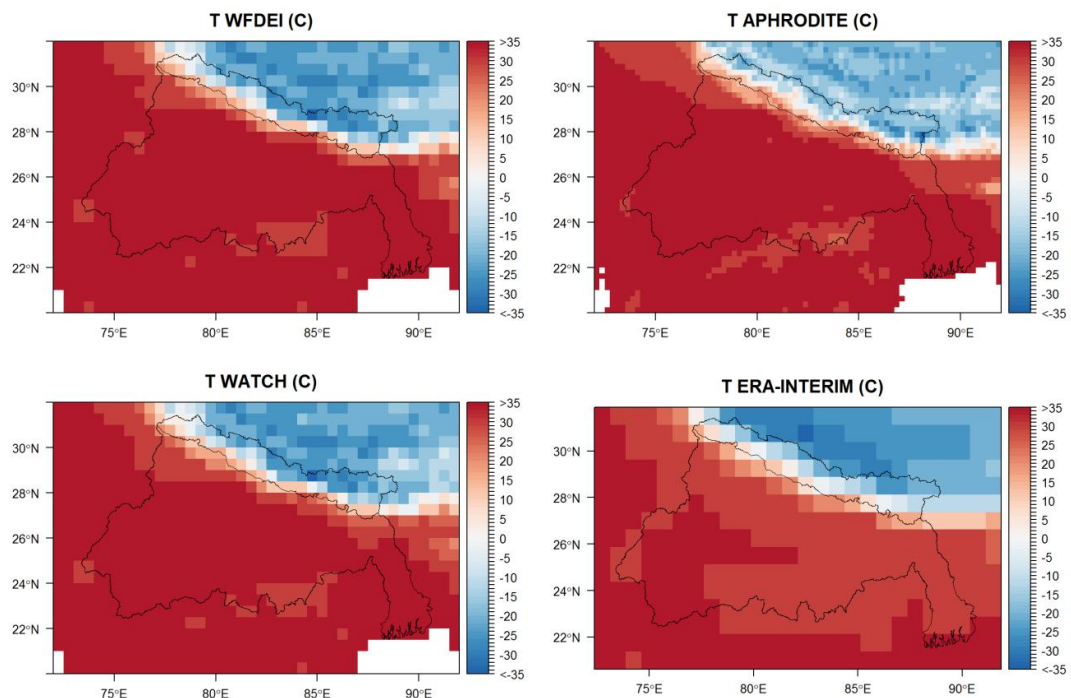


Figure 3-11: 10 year mean air temperature according to different precipitation products

Table 3-4: 10 year average mean air temperature (°C) in upper and lower Ganga basin according to different temperature products

	WFDEI	APHRODITE	WATCH	ERA-INTERIM
Upper Ganga	5.0	7.8	4.5	4.1
Lower Ganga	25.4	25.3	25.2	23.9

If and when measured data become available, a number of years will be selected for which the global data will be verified with local data. If the results of the verification shows that improvement is possible by using local data, local and global data will be combined using statistic interpolation techniques to achieve the best possible result. However, this improvement can only be achieved for the years for which sufficient good quality local data become available.

Discharge data

Discharge data are required to calibrate and validate the results of the hydrological models. To evaluate model achievement the most important parameter is the volume of flow at key locations accumulated over a longer period of time, such as monthly. A finer temporal resolution has limited use in a study focused on water resources, water quality and ecology, because the run-off volume will be stored in large reservoirs that dampen the peaks and lows of the hydrograph, before the water is used by the different functions. In other words, it is not very relevant whether the timing of peak flows in hydrological models is correct; it does little matter whether the peak comes today or tomorrow. However, it is most important that the total simulated volume of run-off on a monthly basis is well in accordance with the real-world flows.

3.3.2 RIBASIM Water resources model

RIBASIM derives its hydrological input from the results of the hydrological models WFLOW and SPHY. Locations will be defined where the results of the distributed hydrological models will be stored in the Ganga WIS for use in RIBASIM.

Data on discharges in the Ganga River are required to validate the RIBASIM model application. Validation will take place combined with validation of WFLOW and SPHY. For the validation of RIBASIM data on reservoir level, inflow and outflow are very important.

Specific data needs for RIBASIM include the following:

- Characteristics of all reservoirs in the Ganga Basin, including the level and capacity of different outflow mechanisms (irrigation water intake, hydropower release, flow release, spillway) and the steps to regulate outflow (if available);
- Operation rules for the reservoir releases for all reservoirs as a function of demand for water and hydropower and actual level and inflow of the reservoir. Actual and historic rules are required for the period since establishment of the reservoir.
- Bathymetry of the four reservoirs expressed as a relation between water level, volume and surface area. Besides the most recent data, historic bathymetry data are important to assess reservoir sedimentation;
- Hydropower capacity installed, hydropower demand (for each month of the year and divided over peak and baseload demand) and relation between head, discharge and power generation;
- Data on geometry, capacity and operation of all other major structures such weirs and gates;
- Data on irrigation water demand:
 - Location of irrigated area;
 - Lay-out, capacity and leakage of major irrigation canals;
 - Efficiency of irrigation at plot level;
 - Origin of irrigation water (from surface water and/or groundwater);
 - Fraction of return flow;
 - Destination of return flow (to surface water and/or groundwater)
 - Surface area;

- Cropping pattern;
- Specific crop water demand; and
- Specific crop yield damage functions.
- Data on domestic and industrial water supply:
 - Location;
 - Amount of water extracted for each month of the year;
 - Origin of water (from surface and/or groundwater);
 - Fraction of return flow; and
 - Destination of return flow (to surface water and/or groundwater).
- Data on minimum flow requirements for flushing and/or ecology; and
- Priorities in water allocation.

3.3.3 River Basin Explorer

Waste loads have to be estimated to prepare substance balances for the selected pollutants, such as BOD, TN and TP. Waste loads are separated into point sources and non-point sources (diffuse loads) for each basin in the Explorer schematization. It is proposed to include seven types of load sources in the Ganga model framework:

1. Domestic sources (through sewers and open drains, Nullah, as point sources);
2. Domestic sources (as non-point sources);
3. Industrial sources (end of pipe, with or without pre-treatment);
4. Agricultural sources (farms);
5. Non-agricultural land-use losses – waste loads associated with non-productive land use types in the catchment (wetlands, forestry and residential/commercial);
6. Septic tanks – loads derived from household septic tanks located in the catchments;
7. Other sources, such as bank erosion.

Waste loads will be estimated for each type separately based on an emission explaining variable and emission and retention factors (see Table 3-5). Results of waste load estimation have a high degree of uncertainty. Therefore, calibration on discharge and concentration data in rivers, canals and reservoirs is essential.

All information on waste loads and pollutant concentrations for the selected substances has to be made available by the client through the different ministries involved or as available in the Statistical Yearbooks of the ministry of Economic Affairs and dedicated research reports prepared by Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCBs), Ministry of Environment and Forest, etc. Furthermore, for the ecological analysis data is required on chlorophyll-a, algae species composition and/or abundance of phytoplankton, macro fauna, macrophytes and fish. The exact species for which data are required depends on the outcome of the collaborative process.

3.4 Capacity building

Capacity building of stakeholders is aimed to provide them an accurate picture of the use and limitations of modelling in policy preparation. This aspect of capacity building will form part of the basin and state workshops in the framework of the collaborative modelling process.

Capacity building in model application aims at dedicated employees of central, basin and state agencies dealing with water management. The aim is to teach them how to operate the models from the dashboard and how to change relevant input data for the models to represent different scenarios and interventions. This capacity building will be most effective if employees are available for on-the-job training by international and Indian experts during the whole project. Formal training in the use of the River Basin Model will be concentrated around the start of the Scenario Building phase to allow counterpart staff to participate fully in the

scenario analysis. Training will also accompany the delivery of the models and data at the end of the project.

The following training activities are planned:

- Hands-on training by international experts in hydrological modelling using SPHY and Wflow for local experts and staff of counterparts at the central level;
- Hands-on training by international expert in water resources modelling using RIBASIM for local experts and staff of counterparts at the central level;
- Hands-on training by international expert in modelling of water quality, ecology and ecosystem services using the River Basin Explorer for local experts and staff of counterparts at the central level;
- On-the-job training in all the components of river basin modelling while jointly developing the models by international and local experts and counterpart staff at the central level (if available); and
- Hands-on training by local experts in use of the River Basin Model for counterpart staff from Central and State level.

Table 3-5 Waste load estimation

Type	Emission variable explaining	Emission factor
Domestic point	Number of persons connected to the sewer system	Inhabitant equivalent (per capita daily waste production) and retention factors for sewer and treatment
Domestic non-point	Number of persons	Inhabitant equivalent (per capita daily waste production) and retention factors
Industrial	Amount of waste water discharged per type of industry	Per type of industry the waste concentration and treatment factors
Agricultural	Surface area per crop and input level Number of livestock per type	Run-off and retention factors Per head waste production and retention factors
Non-agricultural land use	Surface area per type	Run-off and retention factors
Septic tanks	Number of persons connected	Inhabitant equivalent (per capita daily waste production) and retention factors
Other	Amount of the activity	Emission and retention factors

3.5 Links with other tasks

Task 1 provides the River Basin Model for the other tasks. Task 2 provides the geo-hydrological iMOD-MODFLOW model that forms part of the computational framework (see Figure 3-1). iMOD-MODFLOW will be linked with WFLOW to describe the interaction between surface and groundwater. This requires exchanges between the two models of data on water levels and discharges.

The iMOD-MODFLOW model is also linked to RIBASIM by the groundwater demands for irrigation and domestic and industrial water supply. RIBASIM defines the water demand and iMOD-MODFLOW calculates the impact of the extraction on the groundwater table.

The River Basin Model will be used by the Task 3 to analyse impact of different flow regimes on the ecology and on ecosystem services. Low flow requirements and reservoir operation rules can be modified in RIBASIM. The RB Explorer can then calculate the impacts, if suitable knowledge rules have been made available. Task 3 will provide the input for these rules.

Task 4 will use the River Basin Model for the scenario analysis. The different scenarios will be incorporated as modifications to the input of the models.

The collaborative modelling of Task 5 will provide input on the questions that have to be answered by the River Basin Model and the indicators that should be calculated. The description of the River Basin Model in this Chapter provides a starting point that will be further focused on the topics arising from the collaborative modelling process. Furthermore, the collaborative modelling process will provide input on model schematization and knowledge rules for ecology and ecosystems services. Finally, feedback will be generated on the model results and will be used to improve the River Basin Model.

The Ganga WIS, dashboard and scorecards developed in Task 5 form part of our computational framework (see Figure 3-1) to store data, model input and output and to present results in a meaningful way to the stakeholders.

3.6 Contributions to project deliverables

Task 1 will contribute to the progress reports, the report on the surface groundwater analysis, the scenario modelling report and the final project report as well as to each of the three cycles of basin-wide and state workshops in the framework of the collaborative modelling approach. Contributions to the workshops will take the form of presentations and facilitating group model building sessions. Task 1 will prepare the following deliverables:

- Report describing model conceptualization and setup
- River Basin Modelling Report
- Delivery of all model software developed and associated data files

3.7 Detailed work plan

Figure 3-12 presents the detailed workplan for Task 1, including activities, staff input and deliverables and reports.

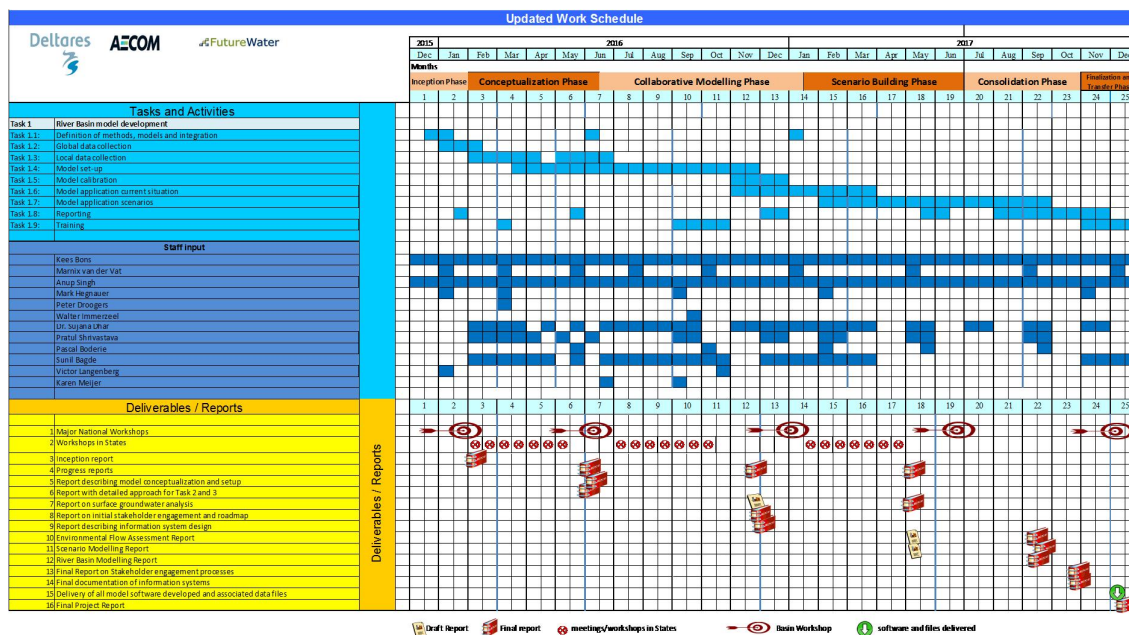


Figure 3-12 : Detailed work plan for Task 1 River Basin Model Development

4 Task 2: Surface-Groundwater Interaction Analyses

4.1 Objectives

The main purpose in this Task is to understand the ground water system including the surface water interaction and to disseminate this knowledge. The description is given in text, pictures, and maps and brought together in a numerical groundwater model including an overview of groundwater needs by agricultural, industrial and urban users. The model will provide input for the River Basin Model and the Environmental Flow study and will be used to help identify groundwater management solutions to restore the river system.

Important objective is to involve the groundwater community in this process by organizing collaboration and knowledge exchange through workshops and a transparent process. After finishing the project, groundwater management organisations will continue working with the model(results) because of their confidence in the product.

4.2 Methods

To achieve this goal, three parallel activities are defined.

- In a first approach the existing Global Groundwater Model is used for a quick assessment of the groundwater system.
- Secondly, existing studies and data is used to define a conceptual hydrogeological model.
- In the third place, additional geographical information will be brought together to constructing a basin wide numerical groundwater model (iMOD).

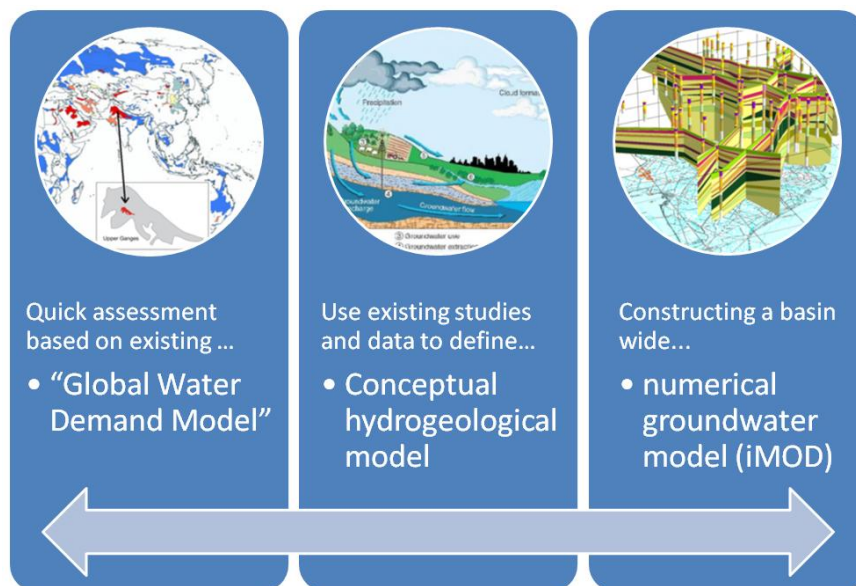


Figure 4-1 Three parallel approaches

Based on the groundwater modelling results, supported by existing knowledge, a classification for groundwater – surface water interaction will be developed. The figure below shows a very simple characterization that can be used as starting point. We will adapt this classification on the basis of geology information (permeability of the shallow deposits) and on geochemical information (organic content, clay minerals etc.) to classify the purifying characteristics, on the surface water – groundwater levels gradient (steep, low). Also time-

dependent aspects (i.e. draining river during monsoon, while infiltrating during dry periods) will be taken into account.

Using the groundwater model and additional information, the amount of river water loss into the ground (infiltration) or the amount of groundwater drainage will be determined. Based on these results, the geochemical information and existing literature information the hydro chemical and ecological vulnerability of groundwater (or surface water) will be determined. We will consider the transport into the subsurface of bacteria, viruses etc. (untreated waste water), the transport of macro-parameters, especially nitrates (considered as a growing water quality problem) and other chemicals (pesticides, fertilizers, medicines etc.) Hereby we will attempt to estimate (based on existing information) the existing polluted ground water zones adjacent to the river. The presence of arsenic (As) in water and its effect on human health through both drinking and agricultural practices is of serious concern worldwide. In an article on this issue A. K. Singh (NERIWALM) emphasizes that the number of people at risk of arsenic poisoning, through drinking water from sunken wells, may be considerably larger than previously thought of, especially in the Ganges basin.

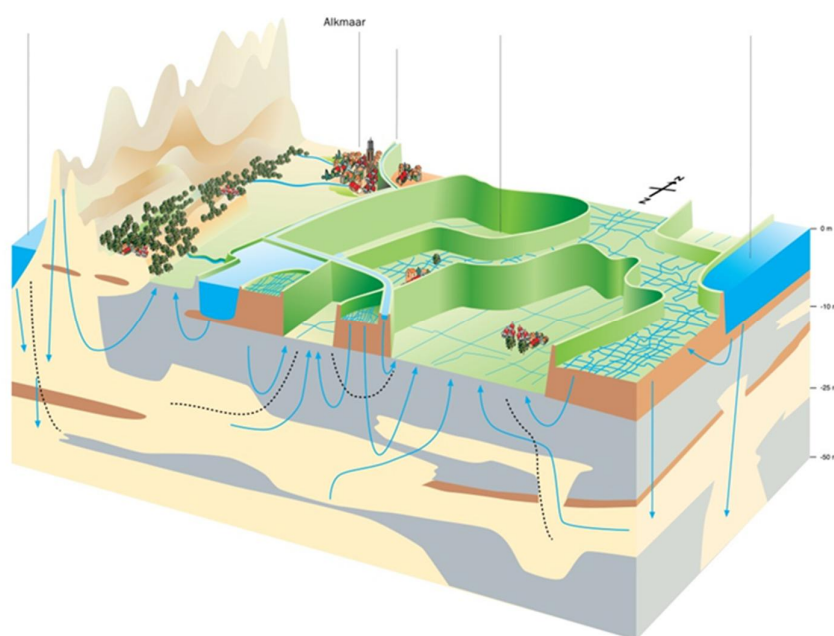


Figure 4-2 Example of visualization of groundwater flow and surface water – groundwater interaction in The Netherlands

4.2.1 Graphical user interface iMOD

Deltares developed the iMOD software package to support the analytical work of understanding the groundwater system. iMOD is an easy to use Graphical User Interface combined with an accelerated Deltares-version of MODFLOW with fast, flexible and consistent sub-domain modelling techniques. iMOD facilitates very large, high resolution MODFLOW groundwater modelling and also geo-editing of the subsurface and is very powerful in the visualization of model data from different sources. iMOD is open source (<http://oss.deltares.nl/web/imod>) since June 2014

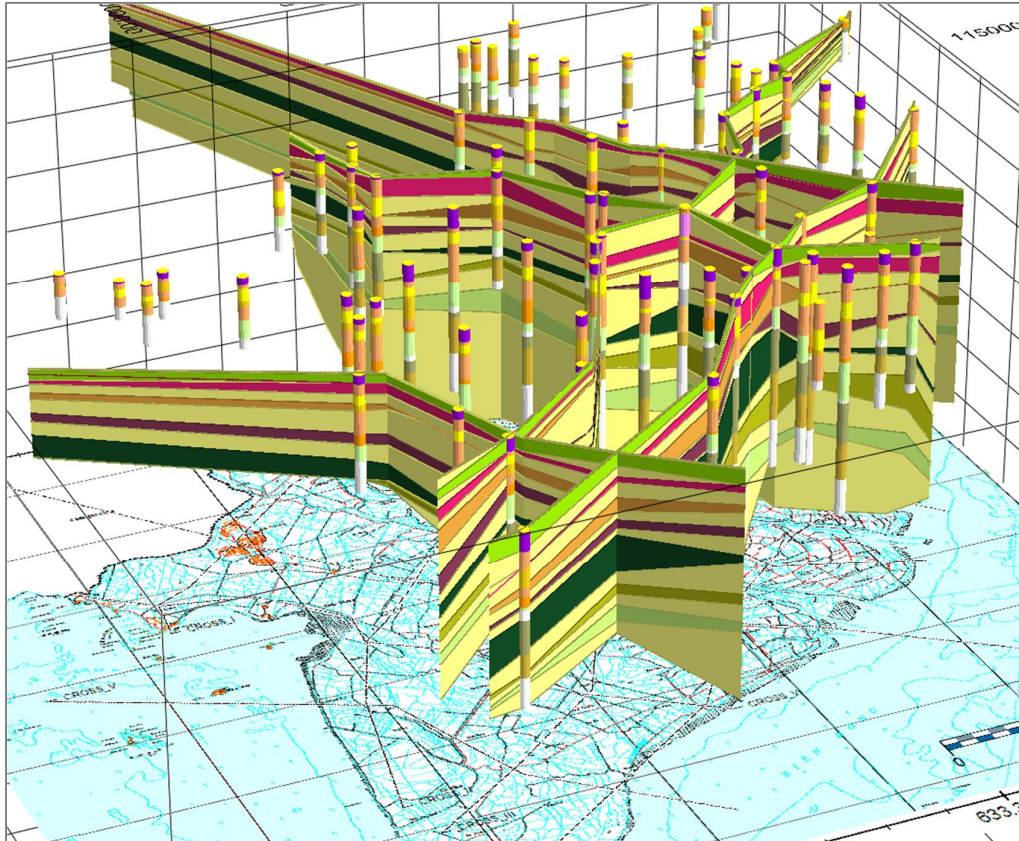


Figure 4-3 iMOD - borehole data and (existing) hydrogeological transects as a basis for creating 3D geological model of the subsurface

Deltares' modelling techniques are built on MODFLOW as it is considered the standard finite difference source code. Still, modellers ideally need an approach that allows 1) flexibility to generate high resolution model grids everywhere when needed, 2) flexibility to use or start with a coarser model grid, 3) reasonable runtimes / high performance computing and 4) conceptual consistency over time for any part of the area within their administrative boundary. iMOD was developed to meet these demands.

In a sequence of two improvement steps the original Global Demand Model will be detailed in both resolution and information. Based on the Collaborative Modelling approach, stakeholders are invited to share hydrogeological data/knowledge and to reflect on model updates. The information system to be developed in task 6 will provide for the necessary access and presentation of the data.

4.2.2 Focus on Groundwater Management Units

With a length of over 2.500 km, the Ganga River is very extensive. Therefore the model improvement will focus most effort on the most important Groundwater Management Units. These 3D units will be defined along the basin. The boundaries will be defined in an open process based on specific characteristics like geology, catchment boundaries, river characteristic (e.g. dimensions, drainage or infiltration), stresses and administrative

boundaries. These units are prioritized in a risk framework based on water use, future demand, connectivity to surface water and water quality threats.

4.3 Data requirements and data collected

The approach is built on making use of existing data and provisions have not been included for field data collection. All data is compiled into a GIS-based information system including metadata according to standards.

The table below gives an overview of the data required. During the project, items van the added to the list.

Table 4-1 Data requirements groundwater analysis and modelling

Static Data	
Digital elevation model (DEM)	Topography data
Soil physical parameters	Topo-climate soil layer
Land use	GIS database. Distinguished by (1) Urban, (2) non irrigated agriculture, (3) irrigated agriculture using surface water (incl. number of harvests), (4) irrigated agriculture using groundwater (incl. number of harvests), (5) natural vegetation
Hydrogeology	Collect existing hydrogeological transects, determine hydrogeological basis (as low as possible, below groundwater pumps). Additional: <ul style="list-style-type: none"> Map with depth to hydrogeological base
Faults	Information on horizontal hydraulic resistivity
Dynamic data	
Precipitation and potential evapotranspiration	Global and local data sets (daily grid data for at least 2000-2014)
Drainage system	Rivers, canals, lakes, ponds <ul style="list-style-type: none"> Depth, width Water level (low, high, mean)
groundwater level data (calibration & validation)	Available Time series including location and depth (aquifer) of observation wells. Additional: <ul style="list-style-type: none"> Map with groundwater Isohyps / depth to Surface Level.
Surface water discharge data	Available Time series including location
Groundwater extractions	(1) Drinking water, (2) industry, (3) agriculture
Irrigation method	Irrigation from groundwater or surface water

Annex 1 presents a more detailed note on the data collection required for all tasks.

4.3.1 Data collected

During this inception phase the first steps were made to collect data and investigate which data sources are useful and what studies have been performed.

Existing data is gathered from several organizations/databases and is to be placed in the Ganga Water Information System (Task 6). These include data among others from:

- Ground Water Estimation and Management System (GEMS)
- Ganga River Basin Management Plan (GeoSpatial Database, <http://gissserver.civil.iitd.ac.in/grbmp>)

- Global data providers like the International Steering Committee for Global Mapping (ISCGM) and Natural Earth (<http://www.naturalearthdata.com/downloads/>)

We mention two important studies that were performed commissioned by or in relation with the World Bank.

- Surface and Groundwater Modelling of the Ganga River Basin (aug 2014). GRBMP: Ganga River Basin Management Plan. Indian Institutes of Technology. (Report 057_GBP_IIT_WRM_ANL_02_Ver)
- Water Systems Modelling for Ganga Basin. INRM Consultants Pvt. Ltd. New Delhi. Submitted to the World Bank CONTRACT NO. 7152490

These studies seems to have produced a lot of interesting datasets. At the moment these reports are studied and we will get in touch with the authors.

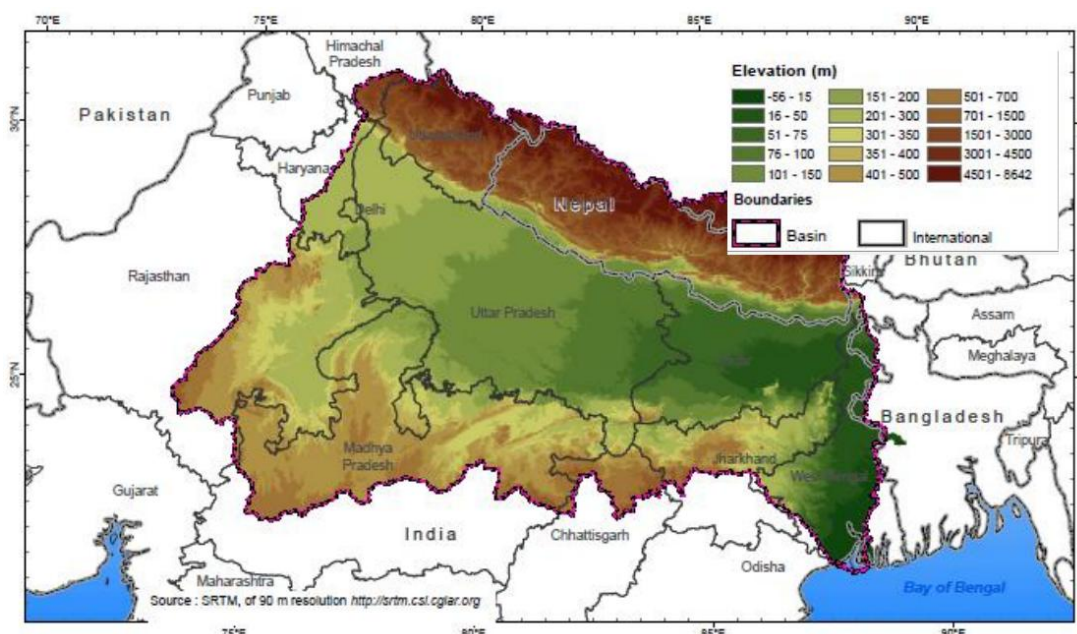


Figure 4-4 Digital Elevation Model of the Ganga river basin

4.4 Capacity building

Stakeholder participation is essential to develop shared ideas about the groundwater-surface water system and the exchange of data and knowledge. Deltares organizes participation for both the short term and long term. For the short term, the collection of data and the development of a groundwater model is a primary goal. For the long term participation is essential for the continuation of Strategic Basin Planning after this project is completed

Participation will be organized through the Collaborative Modelling approach as well as through the web portal for a 'remote' involvement in the process e.g. reflect on interim results or additional field data (Task 6).

At Central level, and in line with the overall schedule of Central and Regional Workshops and in close coordination with Task 1 and 3, several meetings are foreseen:

- The activity starts with workshops at the State level followed by a central workshop where the stakeholders and scientists with knowledge on the subject “hydrogeology of the Ganga Basin - surface water groundwater interaction” will meet in dedicated sessions. Important item on the agenda is a discussion on existing groundwater studies presented by stakeholders. The workshop is followed by a meeting with a Technical Resonance Group formed by representatives of the Central Ground Water Board and other stakeholders. The members of this Technical Resonance Group will be determined in close consultation with the counterpart;
- Within a period of 4-6 months, a second round of workshops will focus on model development and output.
- Meetings with the Technical Resonance Group are organized for the mid-term discussions of the components and first results of the groundwater model; and to discuss the Draft Comprehensive Report to be delivered.

Important for stakeholder participation is training of skills to the extent needed. Technical employees for instance might need training on the Graphical User Interface iMOD or a course on the basics of groundwater modelling.

The following training activities are planned:

- Hands-on training by international expert in geo-hydrological modelling using iMOD-MODFLOW for local experts and staff of counterparts at the central level;
- On-the-job training in the application of iMOD-MODFLOW while jointly developing the model by international and local experts and counterpart staff at the central level (if available); and
- Hands-on training by local experts in use of the iMOD-MODFLOW model for the Ganga Basin for counterpart staff from Central and State level.

For a successful collaboration with the necessary state, private and non-governmental organisations an organogram is set up to get an right understanding of the interactions within the groundwater community.

4.5 Links with other tasks

Task 2 has a clear relation with all of the other tasks. A summary of the relation is given in the table below.

Table 4-2: Description of relation with other project tasks

Task	Relations with task 2 “groundwater – surface water interaction”
1 River Basin Model Development	Initial data for RIBASIM is in the original Global Water Demand Model (e.g. daily climate data, land cover and socio-economic parameters as population density and electricity use. Providing data to the river modelling
3 Environmental Flow Assessments	Providing necessary groundwater component now and in the future
4 Scenario Modelling	Exploring the effect of the scenario's to be determined
5 Consultation and Engagement	Obviously the partner and stakeholder involvement is a crucial activity
6 Information Systems and Documentation	All information both collected and produced will be available via an online data portal and presented in reports Data exchange to e.g. the River Basin Model is established through a central database.

4.6 Contributions to project results

Task 2 will contribute to several progress reports, the report describing model conceptualization and setup, the report on surface groundwater analysis and the final project report. Besides that, task 2 contributes to each of the cycles of basin-wide and state workshops in the framework of the collaborative modelling approach. Contributions to the workshops will take the form of presentations and facilitating group model building sessions.

Task 2 will prepare the following deliverables:

- Report describing model conceptualization and setup
- Ground water analysis Report
- Delivery of all model software developed and associated data files

4.7 Detailed work plan

Figure 4-5 presents the detailed work plan for Task 2, including tasks and activities, timing of staff input and deliverables and reports.

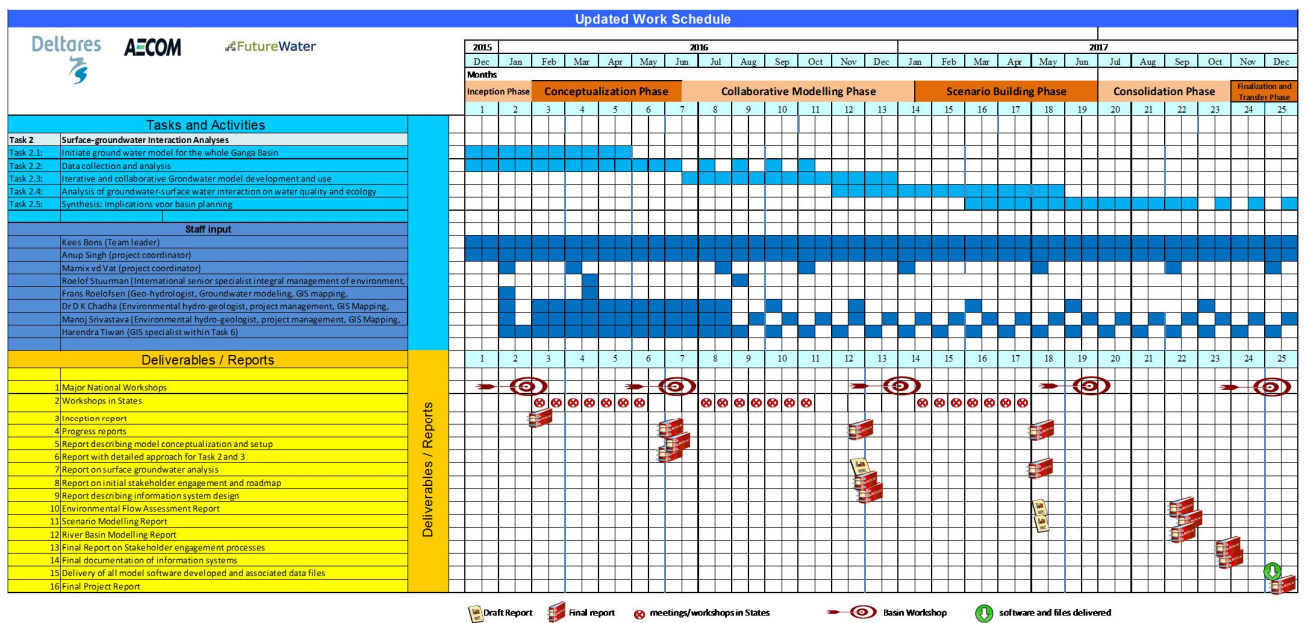


Figure 4-5: Detailed work plan for Task 2 Ground water – Surface water interaction

4.7.1 Short term activities to be performed

In de Conceptualization Phase, following the Inception Phase, work is planned on task 2.1 (initiate groundwater model) and task 2.2 (data collection and analysis).

A detailed listing of the activities is given in this paragraph.

- Identification of Departments, agencies for availability of data like;
 - No. of monitoring stations and their distribution in the entire Ganga Basin.
 - Depth to water level- 5 years pre and post monsoon data
 - Hydrogeological maps- depth to water, water table contour
 - Groundwater fluctuation- last 10 years
 - Sub-surface lithology and the lithological cross-sections
 - Electrical logging
 - Aquifer parameters

- Groundwater quality for major elements-Arsenic, Nitrate and Fluoride & Heavy metals
- Ground water abstraction data
- Long-term Hydro-meteorological data.

Letters from the Ministry of Water Resources are organized for obtaining the data (Critical Task). Follow up letters to different agencies identified. AECOM offices in respective states will be involved to make attempt to obtain the data; failing which Task-2 team to visit the states to obtain the data personally for using the data officially in the project.

As important as numerical data is the availability of important (recent) groundwater studies/reports. The network in the groundwater community is used to gather the useful studies.

- Data Collection & Analysis
 - Digitisation and processing of all data related to modelling
 - Analysing available studies
 - Identification of Data Gaps
 - Task-2 Team meeting to initiate the modelling on a scale 10km x 10km grid
 - Familiarisation with iMOD application for modelling when Frans Roelofsen / Roelof Stuurman are available in India.

- Iterative and collaborative Groundwater model development and use
 - Devising of the conceptual model, number of layers to be simulated, data selection for the use in the model esp. for the gaps identified
 - **River stage data to be used shall be obtained by the Task-1 team (Critical task)**
 - Steady State simulation and calibration process to begin subject to availability of the input (river stage data) from Task-1 team.

Network

The phase is also used to start exploring and expanding our network in the groundwater community. Key organisations and their objectives, working methods, key persons and mutual relations are reported in a diagram.

Staffing and Level of Effort

For the activities stated above, we need the whole team of task 2 to participate in this phase. To perform these activities within 3 months, a lot of effort of the team is necessary. Most of the data gathering is in India with Indian organisations therefor a considerable part (almost full time) of the activities is performed by the National experts: dr. Chadha and mr Manoj Srivastava.

5 Task 3: Environmental Flow Assessments

5.1 Objectives

The environmental flow assessment will be conducted in order to detect and describe the flow regime components that should be protected or restored to ensure the achievement of the environmental and social goals of river management in the Ganga Basin. It will consider the representative range of hydrological, geomorphological, ecological, social, economic and cultural processes which sustain or derive from the present status and functioning of the river system, and their expected or desired future status and functioning.

The environmental flow assessment in the Ganga Basin will thus be based on the necessary balance between ecological and social dynamics, and will be formulated on a thorough understanding of the essentials of water requirements of native species and habitats, water demands of societal communities (be they linked to water supply, irrigation, hydroelectricity, industry, navigation, recreation in any of its forms, landscape services and spiritual needs), and water necessities for the encompassed functioning of all the river components.

5.2 Methods

With the aim of satisfying the objectives described for this task, the environmental flow assessment for the Ganga River Basin will adopt a holistic approach, enriched with the evaluation of the relationships between flow components (including low flows, average flows and high flows, and their magnitude, duration, frequency, and rate of change) and the functioning of the ecosystems, as well as the ecosystem services the river provides for people. This approach will allow the construction of environmental flow regimes with a solid hydrologic foundation (basic “block”), by means of the incorporation of the specific requirements of river ecosystems and people; some of these will be described, quantified and incorporated as additional “blocks” in the proposed environmental regime, while for others the relationships between ecological processes, flows and ecosystem services will be studied and modelled, allowing Ganga managers to quantify them in future, according to new data availability or to the shifts in water demand, biological requirement and social choices. These relationships will be incorporated in the River Basin Explorer (Task 1). The RB Explorer will be used to estimate ecosystem functioning and ecosystem service availability for different development scenarios.

In order to accomplish the methods, this Task 3 will consider previous works done on environmental flow assessment in the Ganga (e.g. by WWF-India and IIT - these studies adopted the ‘Building Block Method’ to derive desired flow regimes for the Upper Ganga; Gangotri to Kanpur). The project will adopt a ‘scenario-based’ approach which not only states desired flow regimes, but can also be used to estimate the resulting ecosystem functioning and services for deviations from this desired flow regime for a range of scenarios. In doing so, and in addition to the expertise of the International and Indian Task 3 team members, we will involve technical professionals in the different steps of the assessment to build capacity through ‘learning by doing’.

The fulfilment of task 3 will entail the development of the following sub-tasks:

5.2.1 Activity 3.1 Basin-wide analysis of flow regime changes.

i. Revision of the legal framework for environmental flows: this includes collating and reviewing the Indian legal texts on nature/biodiversity protection, conservation and restoration, water planning and management, and water users' satisfaction. The review will help describe the legal background for environmental flows and for any of the issues involved in their definition, establishment and monitoring/control. Also the international treaties and agreements officially signed by India (and related to the former topics) should be taken into consideration, in order to get the full legal picture for the issue's development:

- International framework:
 - i. Water treaties concerning navigation and non-navigational utilization of international rivers.
 - ii. Environmental treaties concerning biological diversity, impact assessment in a transboundary context, desertification or wetlands management.
 - iii. Non-binding instruments concerning water and the environment.
- National framework:
 - i. Nation and state scale:
 1. Laws on water: irrigation and canals, drinking water supply, water storage, groundwater, embankments, floods, water conservation, river water pollution, rehabilitation of evacuees and displaced persons, fisheries, hydropower and ferries. Laws on water disputes.
 2. Laws on environment and biodiversity: environmental impact assessment, protection and conservation of biodiversity and ecosystems.
 - ii. Local scale:
 1. Written or unwritten arrangements regulating access to and use of water for irrigation, drinking water supply or other objectives.
 2. Interaction of local level arrangements with former or new laws.

ii. Identification of river reaches with distinct characteristics and requirements: the Ganga basin is vast and of high historical, cultural and economic significance. Its river systems, including a near 400 million people depending on them, vary widely within the basin. In spite of its significance not much has been published in primary literature about its health, integrity and management.

To still be able to capture the ecological and economic significance in relation to the Environmental flow requirements for the different reaches of the Ganga River a longitudinal river zonation will be performed, taking into account the main physical, environmental and socio-cultural features and gradients found from the headwaters to the river mouth. We suggest defining the longitudinal river zonation by:

- Hydromorphological features, as they are the drivers for many critical river processes for ecosystems and people. Hydromorphology influences river dimensions, river dynamics, erosion and sedimentary processes, distribution/composition/age structure of river species and communities, habitats dynamics, etc., and from them, many of the human uses and activities associated to the river. We consider the hydromorphological features by assessing:
 - longitudinal and transversal flow gradients;
 - geomorphic patterns: river width and width to depth ratio, fluvial forms (including sediment bars and islands), other features like floodplains, terraces and valley types;
 - morphological connectivity and fragmentation;
 - geomorphological dynamics ;
 - junctures with tributaries;
 - connection with groundwater.

- Ecological processes, since they define the dynamic exchanges (both biotic and abiotic) and interactions with the physical river features. We consider the ecological processes by assessing:
 - ecological connectivity of aquatic zones (e.g., distribution of transversal obstacles like dams and weirs);
 - ecological connectivity of riparian zones (structural and functional continuity of riparian stands);
 - distribution of habitats and species relevant for conservation.
- Cultural and livelihood characteristics, as they represent a core component of the socio-environmental scenario-approach devised for this project, and their consideration is essential for an adequate scoping of the environmental flow requirements for ecosystems and people.
- Human drivers and pressures directly and indirectly impacting the river system's health, integrity and management at different scales, including:
 - significant sources of punctual pollution;
 - significant sources of diffuse pollution;
 - significant water abstractions and flow returns;
 - significant regulation works;
 - other significant anthropogenic incidences;
 - land uses.

Earlier work on longitudinal river zonation based elsewhere is mostly based on the distribution of faunal communities (especially fishes) or on the physicochemical river features (velocity, temperature, concentration of oxygen and carbon dioxide, dissolved salts, etc.). However, with the present knowledge and data availability these seem not applicable for Ganga River.

We therefore propose to define the zonation on the basis of the global physical, environmental and social attributes of the river system only, rather than on scarce biological and chemical data.

Lateral zonation is also important for social and environmental inputs, requirements and interactions. Size and complexity of the Ganga basin demands lateral zonation to be determined by buffers of changing (downstream increasing) width. Minimum width thresholds will be 50 meters along both banks (in coherence with previous works on environmental flows in the upper Ganga basin), while maximum thresholds will only be determined after a detailed analysis of the physical, environmental and social features of the river is performed, from the upper headwaters to its mouth.

For each river zone, a river reach will be selected for developing an in-depth calculation of environmental flow requirements. These river reaches will be selected according to:

- Data availability
- Possibility of collecting additional data
- Strategic importance for conservation or management: a combination of high ecological, social and cultural values and impacted by current or potential future river regulation, pollution or other use.
- Adequacy within the Project, in terms of feasibility and relevance, but also considering coherence with other tasks and products of the project.

The selection of study reaches will also be built on previous studies on the identification of Ganga river reaches. As part of the stakeholder involvement process in Task 5, the identification of river reaches will be discussed. This procedure allows for the setting of:

- Objectives and status for all river reaches (based on stakeholder insights and expectations)

- Flow-ecosystem-response relationships for a number of reaches, applying the relationships to investigated management measures for similar types of reaches.

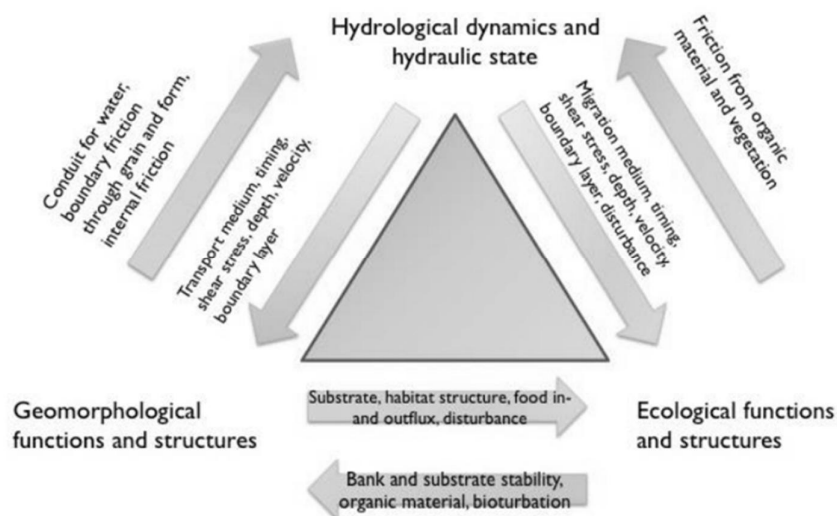


Figure 5-1: Interactions between hydrological, geomorphological and ecological features of river systems, to be studied in Ganga River during the identification of study reaches and the evaluation of their environmental flow requirements (Source: J.Kling, CIS Guida)

5.2.2 Activity 3.2 Flow regime analysis

As formerly stated, the environmental flow assessment for the Ganga basin will be developed on the basis of a solid hydrologic foundation. The analysis of the magnitude, location and timing of flows occurring along Ganga will allow flow characterization and quantification of flow alteration, and will help with the hydromorphological featuring of the different river zones, and with the evaluation of preliminary ecology-flow-ecosystem services responses.

Flow regime analysis will be specifically developed in those river reaches where environmental flows are going to be calculated and potentially discharged. Also it will be of much help in much altered reaches or in those lacking data on biota and flow services.

In order to develop the EFA hydrologic foundation, available monthly, weekly and daily flow data for Ganga River will be collected. Flow regime analysis will only be as accurate as flow data being used for calculation. Degree of non-regulated character of flow data will be estimated by considering the construction and exploitation timing of the main hydraulic facilities existing in the basin, their magnitude and location. Flow alteration will be determined by: i. obtaining the available flow records (or flow simulations) for gauged and ungauged sites; ii. defining a minimum period for non-regulated and regulated (altered) data; iii. comparing pre- and post-regulation series with the help of different hydrologic alteration procedures (Figure 5-2).

The analysis of flow regimes will thus be carried out by studying the hydrological alteration (HA) of present flows from non-regulated or reference condition, in relation to habitual and extreme flows (floods and droughts) for each study section, and to corresponding changes in the condition of the ecosystem and services it provides. Long time series of regulated and non-regulated (reference) conditions and scenarios will result from Tasks 1 and 2. For a quick analysis of the present degree of alteration of flow regimes in each river section during the first stage of the project, use can be made of existing sets of indicators. There is a number of

hydrologic alteration procedures, such as the IHA (Indicators of Hydrologic Alteration, Richter *et al.*, 1996), FDC-Ecosurplus/Ecodeficit (Vogel *et al.*, 2007; Gao *et al.*, 2009), and IAHRIS (Índices de Alteración Hidrológica en Ríos, Fernández-Yuste *et al.*, 2012). However, not all of these indicators are suitable for the hydrologic pattern of the Ganga basin. Indicators will be selected as those better fitting the hydrologic features of the Ganga River, and better defining interactions of flow with ecological processes and ecosystem services. More particularly, they will be chosen as those committing the following properties:

- Environmentally relevant: they must assess hydrologic aspects of high environmental significance.
- Efficient and effective: easy to measure, not susceptible to ambiguous or doubtful interpretations, and capable of providing an adequate indication of the most common alterations downstream from reservoirs or water abstractions.
- Legally based: they should cover the entire range of aspects, periodicity, scales and representation of the natural variability that the legal framework demands.

Also specific hydrological thresholds will be developed that are relevant to the specific ecosystem and ecosystem services of the Ganga river basin, trying to avoid the definition of critical HA thresholds which do not produce significant alterations in the system, or are totally arbitrary. Parallel, climatic differences between the regulated and non-regulated periods must be studied, since they may exert a significant influence on the HA results. This would not allow distinguishing changes caused by reservoirs or water abstractions from changes occurring even with no activity starting in the river reach.

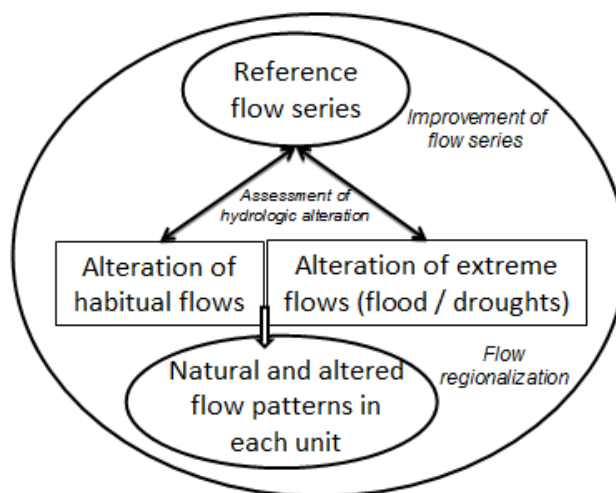


Figure 5-2: Scheme for sub-task 3.2, indicating main steps and results.

Regarding the flow events and types to be assessed in this sub-task, the most relevant would be the following:

- Extreme low flows, which are very relevant for ecological (e.g., modifying connectivity and movements of certain aquatic organisms) and physico-chemical process in the river (e.g., temperature increase or reduction of dissolved oxygen conditions). They have also large influence on the colonization of the river channel by alien species (flora and fauna), since native species are usually very well adapted to these extreme conditions. Examples of biological groups largely influenced by the pattern of extreme low flows are fishes and riparian vegetation.
- Low flows, which occur during much of the year time and are responsible for many of the processes and interactions which may be found in the river channel. They are main drivers for the adequate structure and functioning of many river components and processes, including those related to habitat suitability for fishes, mammals, amphibians and macroinvertebrates. Their magnitude and overall attributes also exert influence on many of the river-based activities for riverine communities, since they are an essential ingredient of the river landscape and the cultural references attached to it.

- High flows, characterized for being notably bigger than low flows, but not yet overtopping the channel banks. They are important for avoiding prolonged stress from low or very low flow conditions. They are also much relevant for the ecological and physico-chemical processes cited before, including the reconnection of aquatic habitats, the improvement of refuge and connectivity conditions for different faunal species or the amelioration of the thermal and oxygen regimes.
- Small floods, whose frequency is very variable for each region and basin, as controlled by physical and hydro-meteorological reasons. They are responsible for ensuring reconnection and ecological transfers between channel and floodplain, and most importantly for allowing geomorphic activity which helps regenerate habitats and fluvial forms.
- Large floods, whose importance is based on their capacity to transport large amounts of sediments and organic matter, and to allow the transfer of nutrients between the channel and distal areas of the floodplain, where large accumulations of valuable substances for the river's trophic networks occur.

The detailed characterization of non-regulated and regulated (present) flows for different river zones and reaches will enhance determining patterns of flow intra-annual and inter-annual variability for environmental flow regimes. This variability is a crucial aspect of EFA, ensuring long-term sustainability of river flows and socio-environmental responses to the discharged environmental flows.

5.2.3 Activity 3.3 Assessment of species and habitats requirements

The main aim of this activity is to develop relationships between flow characteristics, ecosystem elements (species or habitats) and ecosystem services to society. The focus of the ecosystem services part is on the importance of the river ecosystem components and natural flow regimes. The societal and economic importance of abstractions and flow regime regulation is part of the river basin modelling in Task 1.

To develop flow-ecosystem-service relationships will be make use of two sources:

- Flow- ecosystem-service relationships as established during previous research projects
- Expert judgment based on field visits on selected sites

The zonation discussed in the previous step will be used as the basis to select the most relevant reaches and sites. It is envisaged that 3-4 sites will be analysed by the international and national team together, after which the national team will continue this approach for another 3-4 sites. Site studies will involve drawing a diagram of the cross section of the river, describing geomorphology, vegetation and other species availability, estimating discharge/flow regime, and discussing the ecosystem condition and service availability in relation to flow regime variations with the local population.

Although flow-ecosystem-service relationships will only be derived for a limited number of sites, the zonation will allow scaling up the results and identifying sites with similar characteristics to which the relationships will apply as well. Additional studies and monitoring should be used to gradually strengthen the database of flow-ecosystem-service relationships over time.

5.2.4 Activity 3.4 Environmental flow implementation and adaptive management

An approach that may help discussing ecosystem objectives may be the approach used in both the EU and in South Africa, in which ecosystem condition are classified according to their deviation of a reference condition, e.g. nearly natural, slightly moderated, heavily moderated, extreme degradation. Experts are required to define the thresholds between classes and to assign the current class and possible future class as a result of trends/basin developments. These classes can help discussing the status of the basin with stakeholders, who can indicate the desired status of each river reach. It is conceivable that for some reaches further degradation may be accepted, while for other zone restoration is desired.

When the desired status is clear, the results of Task 3 can be applied as part of the activities of Task 4 and 5, to define jointly with stakeholders a set of recommendations for the practical implementation of environmental flows. This will include: i) the most suitable temporal schedule for flow releases (concerning minimum, maximum and flood flows); ii) the procedure for controlling environmental flows; iii) the procedure for monitoring the effectiveness of environmental flows, and iv) the procedure for incorporating lessons derived from practice to the implemented environmental flow regimes (adaptive management).

The above steps are visualized in the Figure 5-3.

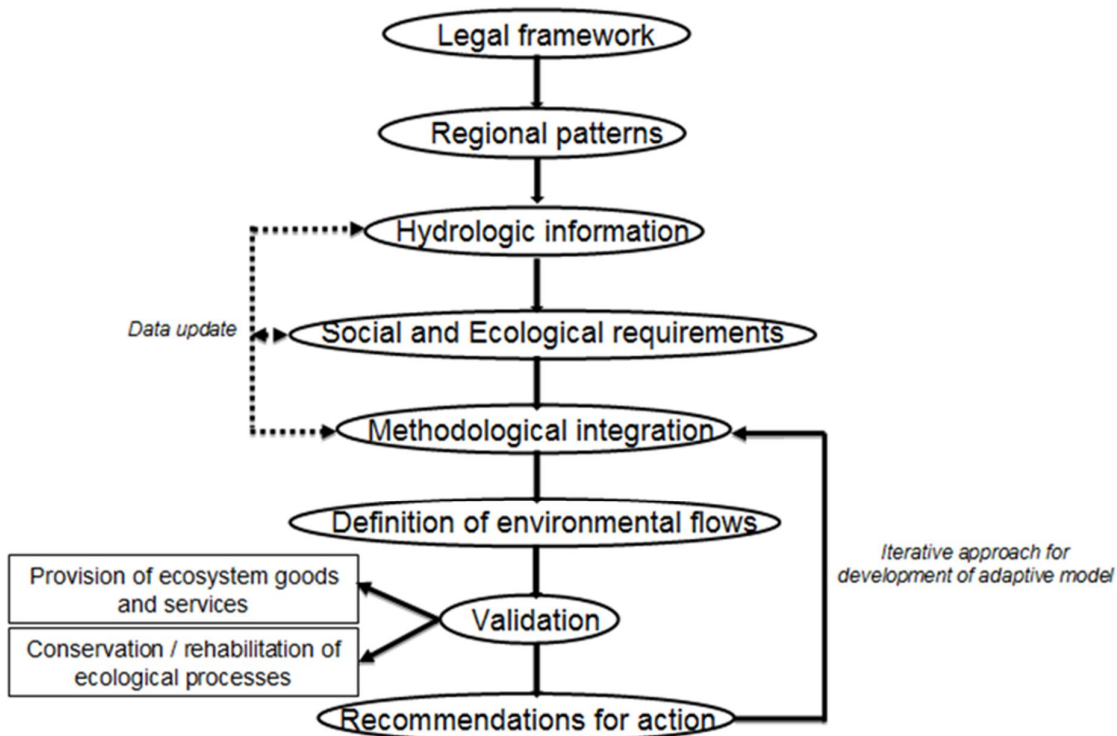


Figure 5-3: Scheme for the implementation and adaptive management of environmental flows in Ganga Basin.

5.3 Data requirements and data collected

Main data requirements and main data to be collected for developing Task 3 are the following:

- Flow data: daily/weekly/monthly non-regulated recorded or simulated flow series and present flow records in the stream gauging stations. Series length should be large enough to include dry/wet cycles and some relevant droughts and floods.
- Water quality: physico-chemical parameters (general and specific ruling core ecological/social processes), available data on sediment transport.
- Biological data: distribution of main habitats and species (aquatic and riparian), status of communities, preferences and requirements of target species.
- Hydraulic-geomorphic data: cross sections, distribution of main mesohabitats, geomorphic processes, location of hydraulic singularities (natural/artificial).
- Social data: livelihood objectives, social needs and uses, distribution of human pressures.
- Cultural data: religious preferences, ancestral costumes, and recreation activities linked to Ganga waters.

Those data will allow the adequate understanding of the river structure and dynamics, its present status as part of its short, medium and long term evolution and the relationships between the main variables and agents involved in its functioning and management.

Annex 1 presents a more detailed note on the data collection required for all tasks.

5.4 Capacity building

Capacity building of stakeholders is a truly important and central step for the successful implementation of the Environmental Flow Assessment. Capacity building for this Task 3 will be aimed to providing abilities to adequately incorporate environmental flow requirements to water planning and management in the Ganga basin. In consultation with Task 5, stakeholders to be involved in EFA and decision-making will be identified and invited to be part of this discussion and training.

Capacity building in EFA aims at employees of central, basin and state agencies dealing with water management and nature/biodiversity conservation. The aim is to teach them the fundamentals of the concept, avoid common misunderstandings, and make them aware of the data and modelling requirements to provide functional environmental flows. Another major issue of capacity building will be improving their knowledge and closeness to the creation and interpretation of ecology-flow-ecosystem services responses and interactions. Size and complexity of the river basin suggests the interest of making stakeholders protagonist of present and future data collection, preparation and incorporation in those interactions. Number and variety of variables and processes intervening in the ecohydrological and sociohydrological functioning of the Ganga River also recommends incorporating as many stakeholders as possible with responsibilities or relationship with water and environment management in Ganga River. Capacity building will be most effective if employees are available for on-the-job training by international and Indian experts during the whole project. Training will also include the participatory definition of social and ecological flow requirements, and the final discussions for delivering environmental flow regimes and models during the final phase of the project.

Capacity building activities will therefore consist of two activities:

- Presenting and discussing the importance of environmental flows and the balancing of these interests with other types of use as part of the stakeholder workshops

- Involving local experts in the data collection and analysis to train them to assess environmental flow requirements in relation to ecosystem objectives

5.5 Links with other tasks

Task 1 provides the River Basin Model, which will be used by Task 3 to analyse impact of different flow regimes on the ecology and on ecosystem services. Low flow requirements and reservoir operation rules can be modified in RIBASIM. The RB Explorer can then calculate the impacts, if suitable knowledge rules have been made available. Task 3 will provide the input for these rules.

Task 3 will make use of the hydrological modelling provided by Task 2 to collect hydrological data which is needed for the characterization of flow patterns in the different river zones and to assess hydrologic alteration. Also this information will be used to construct the hydrologic foundation which will be the basic block for the proposed methodology to fulfil the EFA.

Environmental flow requirements and models derived from Task 3 will be used in the scenario modelling of Task 4, and to feed the environmental-based flow requirements in the Ganga Water Information System (Task 6)

Finally, the collaborative modelling facilitated by Task 5 will provide input on model schematization and knowledge rules for ecology and ecosystems services. Task 5 will help to identify those parties that are to play a role in future environmental flow assessments and decision-making, and who will be the target audience for the

5.6 Contributions to project results

Task 3 will contribute to the progress reports, the scenario modelling report and the final project report as well as to each of the three cycles of basin-wide and state workshops in the framework of the collaborative modelling approach. Contributions to the workshops will take the form of presentations and facilitating group model building sessions. Task 3 will prepare the following deliverables:

Report describing conceptualization, river zonation and data collection.

Report defining application of holistic approach, hydrologic foundation and additional flow blocks to be integrated in the EFR for different river reaches and sections. Development of complementary ecology-flow-ecosystem services responses.

Report determining final environmental flow proposals for each river zone, Delivery of all model software developed and associated data files.

5.7 Detailed work plan

Figure 5-4 presents the detailed workplan for Task 3, including task and activities, staff input and deliverables and reports.

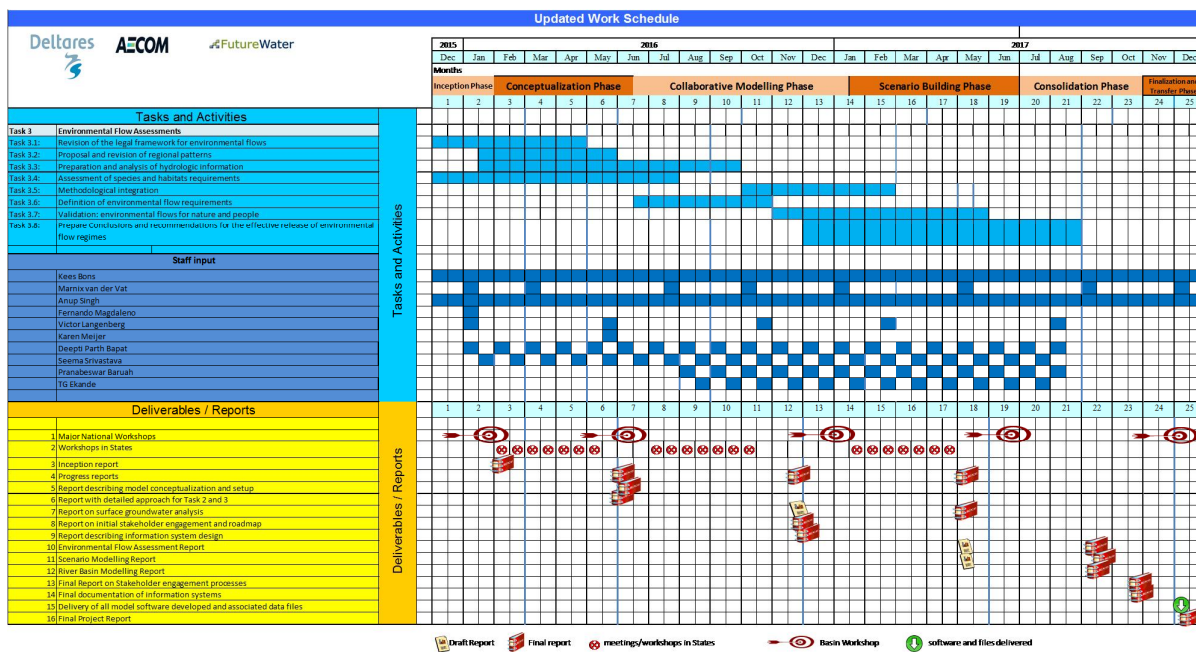


Figure 5-4: Detailed work plan for Task 3 Environmental Flow Assessments

6 Task 4: Scenario Modelling

6.1 Objectives

Task 4 will focus on the use of the river basin models to explore pathways for sustainable river management under pressure and uncertainty. Water management in the Ganga Basin faces major challenges to cope with present pressures and potential global change impacts, and the inherent uncertainties surrounding future developments. Without robust management strategies and adaptation paths, human and natural services in the basin will suffer severe damage and we may be forced into sudden unplanned actions which are far more costly and less appreciated.

Successful water management involves defining strategies that are not very sensitive to unanticipated changes in pressures (i.e. robust) and do not a-priori exclude alternative strategies (i.e. flexible). Many recent scenario studies on water management, including in the Netherlands, were mainly 'What-if' assessments, based on comparing the state of socio-economic and ecological functions of the water systems in one or two future situations with the current situation.

6.2 Methods

The interaction between man and environment is regulated by the administrative and institutional setting. Institutions comprise both formal (laws and regulations) and informal (habits, power relations) rules for the interaction and behaviour of people. This is depicted in the figure below. Integrated management will require an understanding of all three domains of the land and water system.

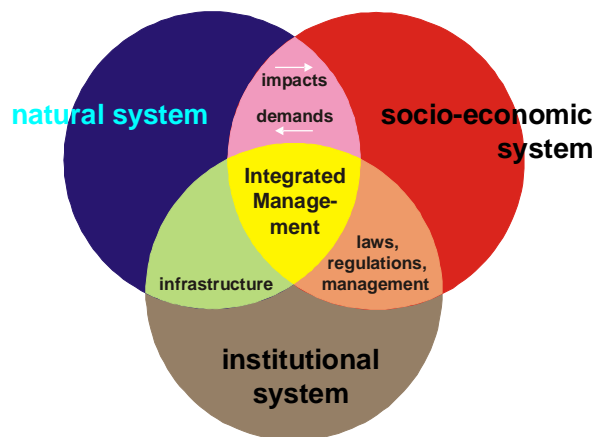


Figure 6-1: Integrated management as a combination of three domains

man-made elements: the network or infrastructure layer. This brings us to the Spatial Layer approach .

On top is the Occupation layer (zoning of land use functions) and below the Base layer is found (consisting of water, soil and ecosystems). The approach indicates a physical hierarchy in the sense that the Base layer influences the other layers through both enabling and constraining factors (figure below).

Taking the man-environment interaction concept a little further, we can expand each of the boxes into more detailed descriptions, such as the different environment or ecosystem compartments (water, soil, river basins, coasts) and societal components (such as economic sectors and institutions). In fact, what we call the environment is most often not pristine nature anymore. It has been changed by many interventions for the (immediate) benefits of man. Therefore, it is better to insert a middle layer, which is a mixture of natural and

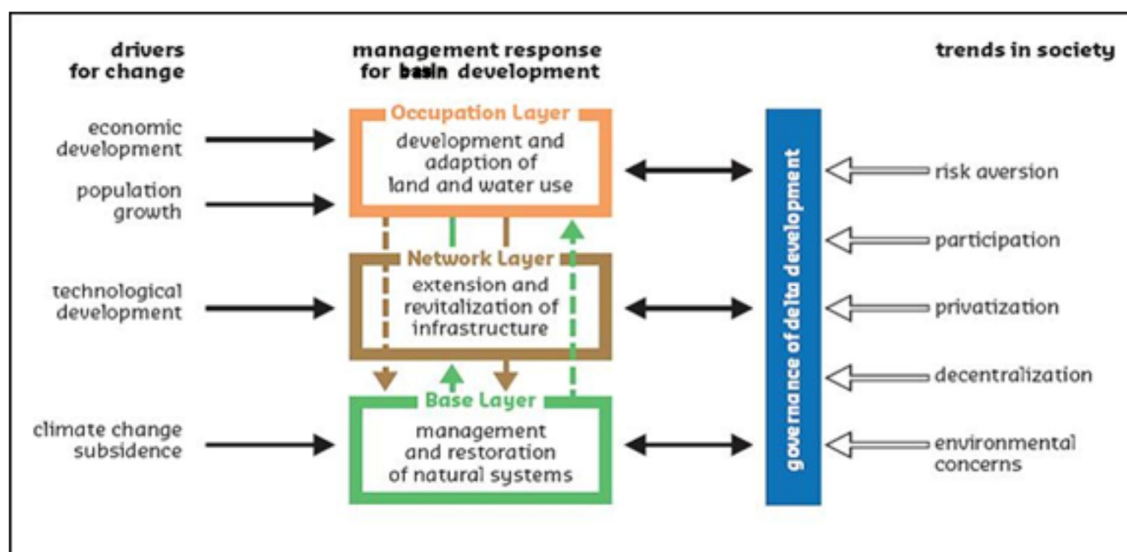


Figure 6-2 The Basin Management Model

Using the Layer approach as a starting point, it becomes clear that there are three main response themes on which basin management could focus, i.e. the development and adaptation of land and water use (Occupation layer), the extension and revitalization of infrastructure (Network layer) and the management and restoration of natural systems (Base layer).

6.2.1 Modeling the present situation

Scenario Modeling in our approach is part of a collaborative approach. In Tasks 1 and 2 the models have been developed with active input from partners and stakeholders which ensures that aspects of the basin and society that are important to these groups are represented in the models and also that output is generated at locations and in formats that are meaningful. In this way these groups feel a sense of ownership to the modeling framework which enhances trust and acceptance.

A very important first step is to reproduce the present situation, and preferably a longer period already past. This will indicate to what extent the available data and models can simulate the processes in the basin and indeed reflect changes as a result of human or natural interventions. Once the model has been calibrated and found credible, it can be used for analysing the behaviour of the system under different conditions. It is important for the success of the analysis that all stakeholders have sufficient faith in the model. Model output needs to be communicated such that stakeholders can easily understand them.

6.2.2 External Scenarios: possible futures

First an ensemble of possible futures are envisioned, based on expert judgment existing information and data on e.g. climate change and climate variability, population growth and economic development scenarios. These potential future developments can create boundary conditions to the water management in the basin. Climate variation could increase periods of droughts and/or frequency of extreme floods. Economic development will influence demands for water for water supply, food and energy production and will also have impact on waste generation. Partners and stakeholders should feel confident that the future as they see, hope or fear is represented in the options developed.

The main drivers identified so far for the scenarios are demographic and economic developments and climate change. The input of partners and stakeholders in the selection of the relevant drivers will take place through the collaborative modelling process (Chapter 8). An assessment will be made of the range of possible future developments for each of the selected drivers. This will be presented to the partners and stakeholders as a basis for the preparation of a limited set of scenarios that combine different development paths for the different drivers.

With respect to socio-economic and demographic developments the assessment will be based on projections available from the relevant authorities. To evaluate the impact of climate changes, time series are required that have been modified to represent the climate of the future. For some of the climate change scenarios of IPPC's 4th Assessment these are available in the WATCH dataset (see Chapter 3). Furthermore, the Indian Institute of Tropical Meteorology has been working on modified time series for climate change for India. The climate change scenarios to be evaluated in this project will be selected from the time series available from these and possible additional sources. Two climate change scenarios will be defined in such a way that they cover the largest part of the variation with respect to the development of water supply and demand, i.e. one wet and one dry scenario.

6.2.3 Selection of indicators - Scorecards

Based on the values and priorities of the partners and stakeholders, indicators are identified that will allow the assessment of the possible combination of measures and strategies and to compare their robustness under the different conditions. Different indicators may be important to different groups and the indicators are selected inclusively. The indicators are represented in Scorecards that represent comparative impacts of each of the chosen Scenarios.

6.2.4 Development Scenario's and Strategies

The combination of possible measures is almost endless. Ideally groups would be able to suggest strategies or individual measures and assess their suitability with the modeling framework by measuring the success against the selected indicators.

In this way the scenario assessments will both inform and be informed by the stakeholders. Whether any of the scenarios or strategies explored lead to the agreement on a basin plan for the Ganga is a matter for the collective governments (central and state) managing the water and related resources of the basin. The process we follow will create an enabling environment for this. At a minimum the scenarios will enable a fuller and more evidence exploration of options for river development and rejuvenation, increase the collective understanding of the river basin and reduce the likelihood of wasted investments in river clean-up.

6.2.5 Sustainability, resilience and adaptation

Resilient strategies are often seen as a means to promote sustainability. River basins are complex and dynamic socio-ecological systems, the behaviour of which is difficult to predict. Drivers of change, including both climate change and socioeconomic development autonomously shape the future. Policy measures are intended to steer away from undesirable towards a more prosperous, healthy and equitable future. Preferably such measures would enhance the resilience of the entire system so that it can adapt to changes and maintain its functions. Knowledge on tipping points where a system may experience a regime shift makes a valuable contribution to the formulation of

strategic alternatives. Such resilience thresholds could be both ecological (e.g. the point when a clear lake turns into a eutrophic lake) and socio-economic (e.g. the amount of debt borrowed without getting bankrupt). Knowing such thresholds can be used for policies at the appropriate level to assure that these are not surpassed. Adaptive basin or water management is being developed by us as a flexible approach using best available knowledge while learning from the results of management actions and adjusting accordingly.

Our team will enhance and support the process, including through reports rich with graphics, through computer visualizations shared online and during consultation workshops. It is foreseen the process of scenario definition and assessment will be iterative through the process of consultation and may well continue long after the end of the project.

6.3 Data requirements and data collected

The scope and detail of the strategies/scenarios to be assessed will be determined during the course of the project, informed by the analysis as it proceeds and by the consultation processes. Nonetheless, the scenarios we will consider will cover at least the following issues:

- (i) options for reducing point source pollution,
- (ii) options for reducing non-point source pollution, and
- (iii) options for alternative environmental flow regimes (including through increased irrigation water use efficiency).

Other scenarios that may be explored include new hydropower dams, the environmental implications of developing parts of the river for inland waterway transport, increased water demand and pollution load by large industrial plants, such as power plants and fertilizer plants, interlinking of rivers, dredging, flood moderation and the potential impacts of future climate change across the water management scenarios. A key aspect is that groups within the basin will be sharing in the scenario development and assessments of their implications creating mutual trust, understanding and collaboration in finding the optimal strategy for the river.

6.4 Capacity building

On-the-job capacity building of stakeholders is aimed to provide them an accurate understanding and feeling for the possibilities strategy and scenario development bring to integrated basin planning and policy preparation. This aspect of capacity building will form part of the basin and state workshops building on the collaborative modelling process.

6.5 Links with other tasks

Task 4 will use the River Basin Model developed in Task 1,2 and 3 for the scenario analysis. The different scenarios will be incorporated as modifications to the input of the models.

The collaborative modelling facilitated by Task 5 will provide input on the most relevant strategies and scenarios and the indicators that should be developed.

The Ganga WIS, dashboard and scorecards developed in Task 6 form part of our computational framework (see Figure 3-1) to store data, model input and output and to present results of scenario analyses in a meaningful way to the stakeholders.

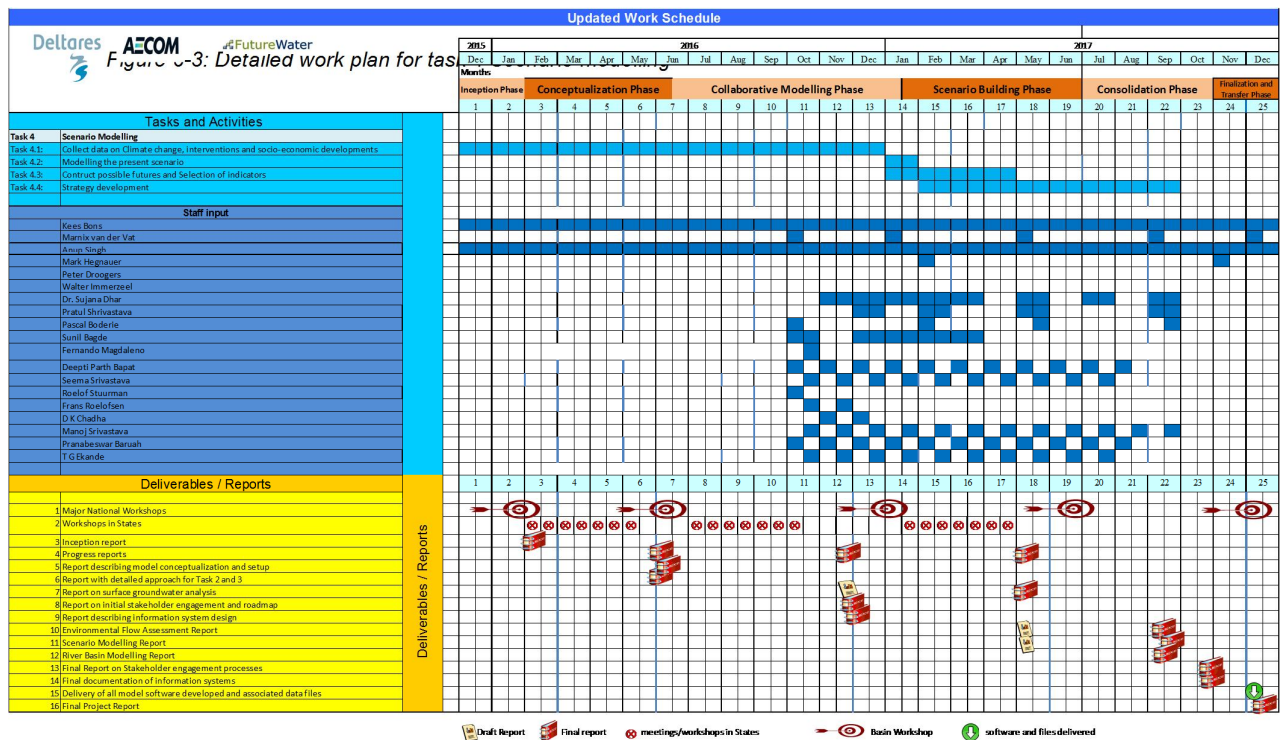
6.6 Contributions to project results

Task 4 will contribute to the progress reports, the scenario modelling report and the final project report as well as to each of the three cycles of basin-wide and state workshops in the framework of the collaborative modelling approach. Contributions to the workshops will take the form of presentations and facilitating group model building sessions. Task 3 will prepare the following deliverables:

- Scenario Modelling report.

6.7 Detailed work plan

Figure 6-3 presents the detailed workplan for Task 4, including task and activities, staff input and deliverables and reports. Note that it is not always possible to separate scenario development from other modelling activities.



7 Task 5: Consultation and Engagement

7.1 Objectives

In line with key objective 4 of the project, the overall objective of task 5 is to establish on-going multi-stakeholder engagement processes in the basin to support strategic basin planning.

This is obtained by the close involvement of stakeholders in developing, modeling and disseminating a series of plausible scenarios that explore alternative options for improving water management including improving river health: collaborative modelling.

7.2 Methods

The way the project intends to reach this objective is through engaging the stakeholders. In the other key-objectives, interaction with the relevant stakeholders as early as possible in the modelling activities: collaborative modelling.

Collaborative Modeling involves interactive and adaptive planning in which stakeholder participation and the development of computer-based models and communication tools go hand in hand. Collaborative Modeling refers to the integration of four distinct approaches for decision support: i) water resources planning; ii) the use of scientific knowledge by means of computer-based models; iii) stakeholder participation; and iv) collaboration in the sense of negotiation. We consider these four linked pillars the basis for effective and sustainable Water Resources Management. Through frequent and interactive involvement, Collaborative Modeling enhances the exchange of perceptions and consensus building and plays a central role in balancing of interests for sustainable water management.

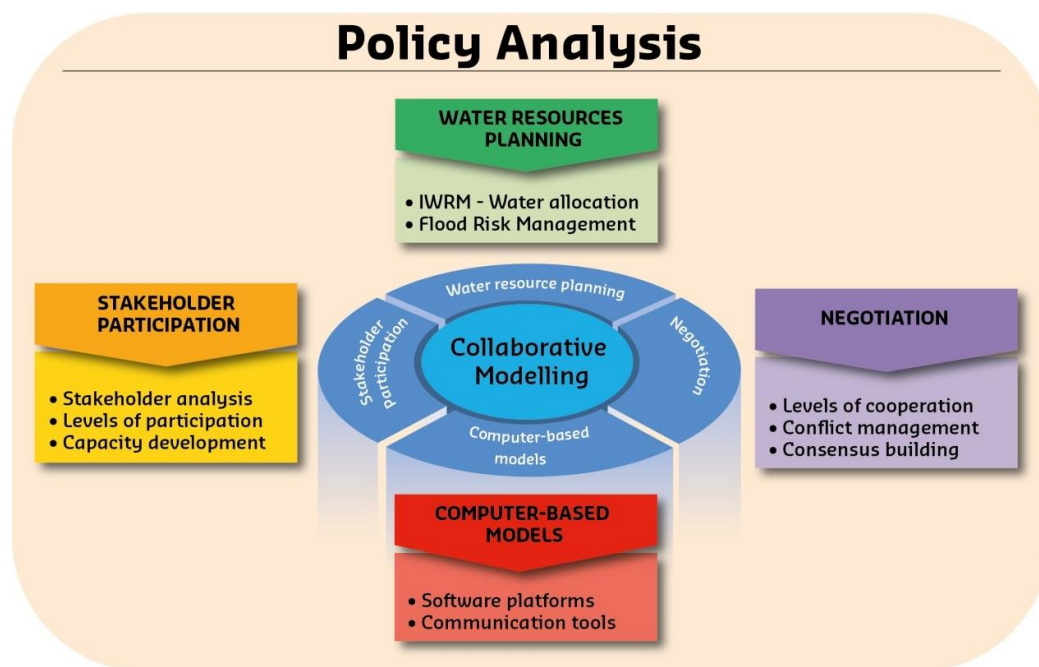


Figure 7-1: Collaborative Modeling as key principle

To engage stakeholders, we will apply different types of tools/methods. First of all, in national level and state level workshops, *Group Model Building (GMB)* will be applied: a participatory

technique to constructively explore perceptions of interactions in the river system with stakeholder groups. GMB will be used particularly for problem identification and scenario definition, and results will inform the development and application of the computational framework. Second, an *Online Discussion Portal* could be developed and used to inform the wider audience and collect their input.

For an effective application of the Collaborative Modeling approach, a content-related analytical framework and an adapted participatory process of involving stakeholders are key. Its application depends on the local context, type of problem(s), level of participation of decision makers and stakeholders, communication tools available, level of cooperation, timing, as well as cross-cutting aspects such as gender equality and existing partnerships among institutions. The Collaborative Modeling approach will be adapted to the conditions of the Ganga River Basin during the different Phases and will consist of a series of interactive and ‘nested’ workshops at State and basin level.

In order to design an effective engagement process (which stakeholders to engage in which manner and which intensity), a stakeholder analysis is carried out in the first phase of the project and will be updated as the project progresses.

7.3 Initial Stakeholder analysis

During the Inception Phase, by use of desk study and the meetings with stakeholders referred to in chapter 1, a list of stakeholders was drawn up, especially for the basin level, see the report “Initial Stakeholder Identification and road map.”

Also, the stakeholders were assessed as to what category of involvement they would best fit, according to the categories of collaborative modelling:

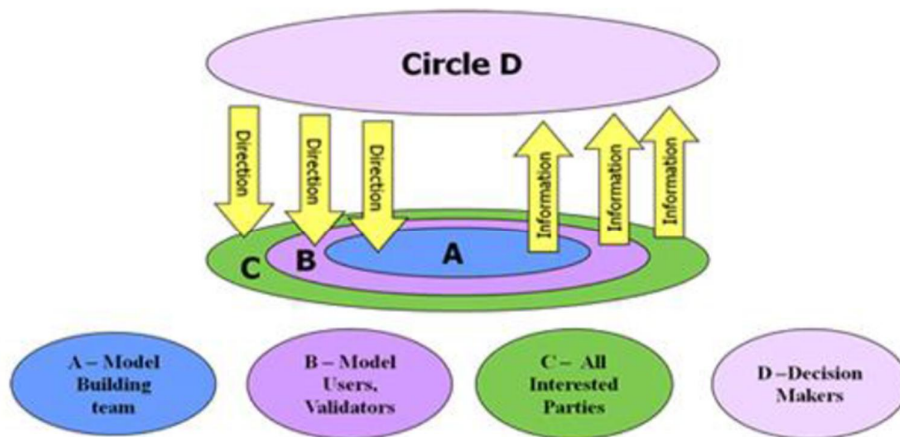


Figure 7-2: Stakeholder categories based on level of involvement

The lists will still have to be adapted while more information of the stakeholders’ interests will be obtained.

In a practical sense, group D, decision makers, are involved in the project through the Project Progress Monitoring Committee, see 1.5. For groups A, model building team, and B, model users/validators, there is no clear distinction yet, but group A will likely come from the people in the Technical Working Group and group B partly from that same group and partly from

other stakeholders. Group C, especially for those from the states, is still being determined. At present, all the Ganga states are being visited and a questionnaire is being administered to get a clearer picture of the different stakeholders, their stakes and their potential role in the project.

7.4 Next steps, the roadmap

In close cooperation with the other tasks, the different steps in the collaborative modelling process and the desired degree of their involvement, a rough schedule has been drafted in December with the staff from the Ministry, see table 5.1. Based on the information coming from the meetings with stakeholders in the states and further discussions with the team members from the other tasks, this table is now being revised.

7.5 Data requirements and data collected

Data requirements for this task should be interpreted as the identification of stakeholders at the different levels and the assessment of the role as actors or influencer and their stake or interest in the matter.

7.6 Capacity building

For the different workshops, especially for the series of workshops that are foreseen in June – August of 2016, we need well-trained facilitators in Group Model Building. Partly because of enhanced communication, but also to sustainably facilitate the stakeholder engagement process, the project will employ national facilitators.

These will be preferably be identified from among those already involved in the project and trained by international specialists before, during and after the workshops.

Team members of task 5 are available to advise and assist the members of the other tasks teams in developing an effective curriculum for the capacity building needs in the respective tasks.

7.7 Links with other tasks

Task 5 coordinates and organizes the interaction of the project with the stakeholders, especially with regard to the larger activities like workshops. At these workshops, input is obtained from the stakeholders to be used in the different tasks of the projects and the preliminary results of the different tasks is shared with and validated by the stakeholders. Clearly, the link with the other tasks is strong.

7.8 Contributions to project results

Task 5 will deliver an initial stakeholder analysis and engagement report in the first year of the project and a final stakeholder engagement report at the end of the project.

As written above, it will facilitate the interaction between the different project experts and the stakeholders.

Table 7-1: Preliminary planning of stakeholder (groups) involvement

Steps in the development of the tool	Involvement of s.h. groups				Type of involvement
	A	B	C	D	
1. Inception/Kick-off meetings	+	+	+	+	Meeting 18/12/15: Roorkee Meeting 21/12/15: specialists Meeting 15/1/2016: nodal officers
2. Involving the States	+	+	+	+	Basin wide Workshop 29 January 2016
3. Determining assessment framework (objectives, ref.sit., indicators, time horizon, etc.)- input dashboard. Determining problems, potential measures		+	+	+	February-May '16: 1st Series of workshops and meetings: national/basin and sub-basin/states in all 11 states.;
4. Intermediate reporting of progress 1			+	+	Basin wide Workshop Mid June 2016
5. Model definition (datasets to be used, units)	+	+			Larger working group meetings per task
6. validation of data	+				Small working group meetings per task
7. Model set-up (schematization, assumptions)	+	+	+		June-September '16: second series of workshops at central level and in all states
8. Model running – 2 nd version dashboard	+				Small working group meetings per task
9. User check	+	+			Larger working group meetings per task
10. Model adaptation	+				Small working group meetings per task
11. Intermediate reporting of progress 2			+	+	Meeting with decision-makers: presentation
12. Check intermediate result with stakeholders	+	+	+		Bilateral “thermometer” meetings with key-stakeholders
13. Repeat 7-9	+	(+)			Small and/or larger working group meetings per task
14. Reporting and discussion of model development		+	+	+	Basin wide Workshop Mid January 2017
15. Determining packages of measures developing scenarios-> final version dashboard	+	+	+	+	January - April 2017 Third series of workshops at central level and in all states
16. Presentation of realistic scenarios and strategies, Hand-over dashboard/project to Gol	+	+	+	+	Basin wide Workshop end of 2017

(Shaded cells indicate major workshop interaction with stakeholders)

7.9 Detailed work plan

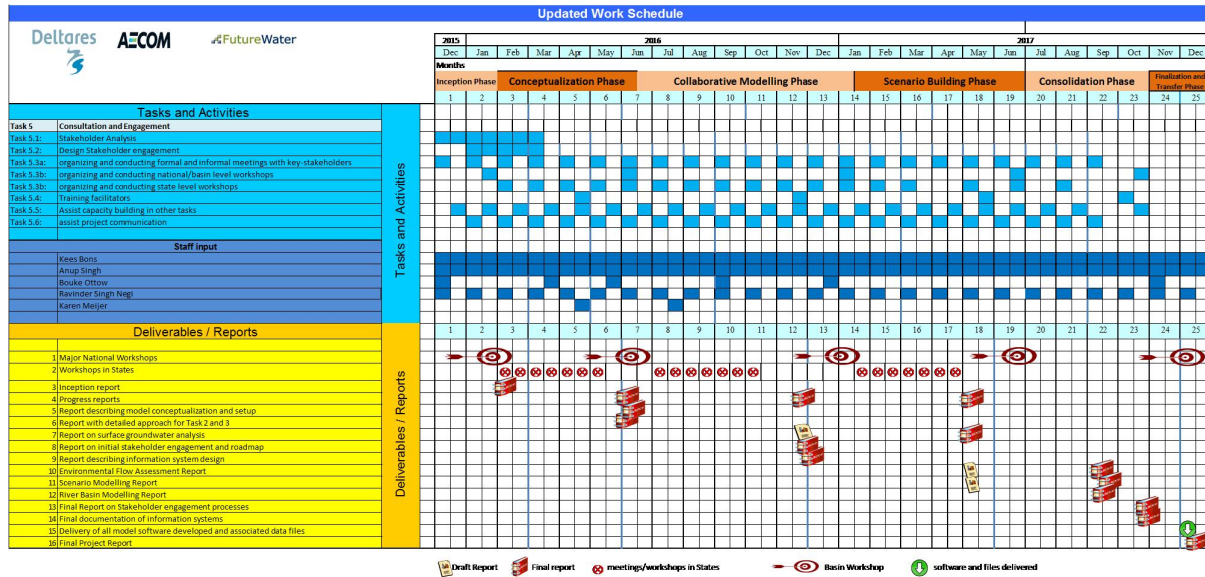


Figure 7-3: Detailed Work plan for task 5: Consultation and engagement

8 Task 6: Information Systems and Documentation

8.1 Objectives

The main aim of Task 6 is to store, manage and present the data and documents collected by the project and the results from the River Basin Model. The working title of this information system is GangaWIS: Ganga Water Information System. The system will facilitate central storage of documents and data (both model input and output). Data comprises static data as well as (semi) dynamic data like time series from meteorological stations and gauges.

The WIS as central storage will be organised using open source building blocks, according to OpenEarth methodologies. OpenEarth is a community that promotes the use of OpenSource solutions to gain, store and disseminate data used in a scientific setting. One of the pillars is to disseminate knowledge about data, processes and software used to achieve general insight in water systems. OpenEarth Methodologies involve working in transparent way via versioning of data and model, as well as working as much as possible via knowledge transfer. More information on OpenEarth can be found on <http://openearth.eu>.

8.2 Methods

8.2.1 Set-up of the GangaWIS

Integrated water management projects are characterised by a huge amount of very diverse data from sources ranging from global dataset to rain gauges that have been observed by hand during the last few decades. All this information is of importance to describe the water system in full detail to gain understanding of the system. Generic and open data management is a key issue in this type of projects.

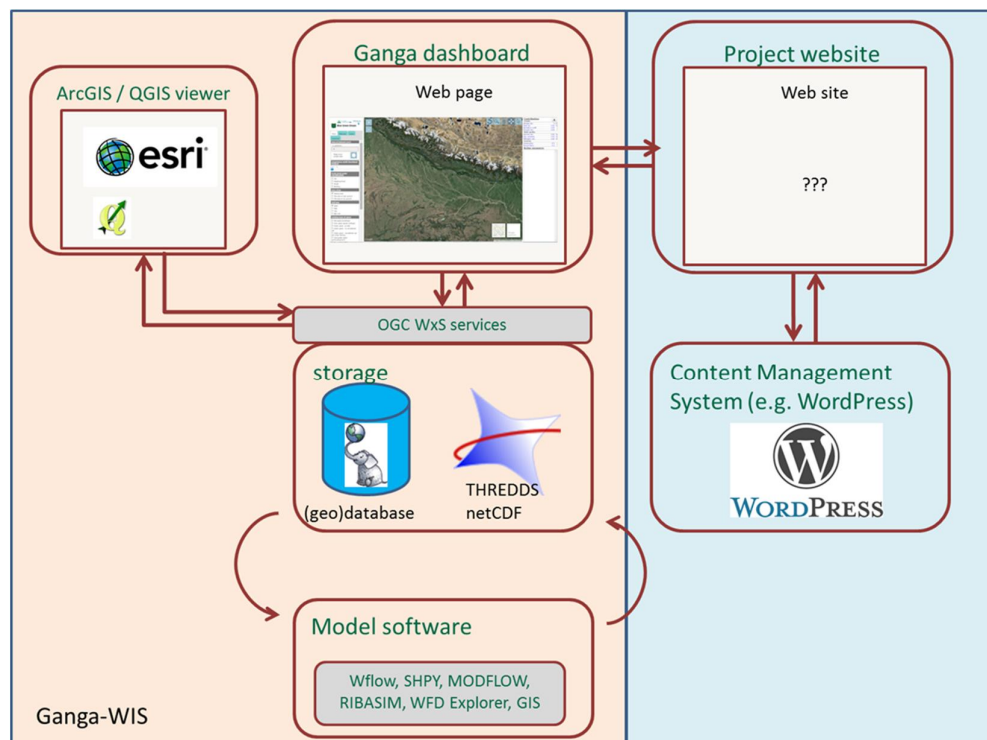


Figure 8-1 Schematic representation of GangaWIS

For this purpose a preliminary setup of the GangaWIS has been prepared during the inception phase (see Figure 8-1). All developments will be done in close consultation with the Indian Water Resources Information System (WRIS) so that they will be integrated as much as possible.

In this figure data plays the central role in the processes of data gathering, preparation of model input, storage of model results and dissemination of data and model results. Data is stored in databases (file based as well as relational database systems) in such a way that the data can be used by multiple actors via standardized open protocols.

So called static maps, like geological maps and land use maps, will be stored manually in the database and extended with proper metadata. Large quantities of data will be retrieved from satellite images and time series from historical sources or from existing monitoring networks.

Some of the parts of the picture above are already in place on Deltares servers. These are:

- database (PostgreSQL²/PostGIS³)
- THREDDS⁴/OPeNDAP⁵ server
- Geoserver⁶ (implements internationally accepted standards for data exchange, the so called OGC services⁷)
- Geonetwork⁸ (OGC catalogue service to make data discoverable)

These open source software solutions form the basis of the GangaWIS. Connections with the models will be carried out by Delft-FEWS (see Chapter 2.2.3) During project executions collected data will be stored in GangaWIS in the form of maps and data tables.

DDS stands for the Data Dissemination Sub-system and serves as the information provider for the end users. Data, model output and information (time series graphs) will be made available in a clear way using OGC services. These OGC services are commonly used for display and dissemination of location based information and has well described features (<http://www.opengeospatial.org>) and can be used in all modern GIS software like ArcGIS and QuantumGIS.

Various techniques will be used to retrieve information available from collected as well as modelled data. One good example is information on observed and calculated information presented in 1 graph. Figure 8-2 gives an example of a comparison between observed and modelled Ortho-Phosphate for a particular location.

² <http://www.postgresql.org>

³ <http://postgis.net>

⁴ <http://www.unidata.ucar.edu/software/thredds/current/tds/TDS.html>

⁵ <http://www.opendap.org/>

⁶ <http://geoserver.org>

⁷ Full OGC documentation can be found on <http://www.opengeospatial.org/>

⁸ <http://geonetwork-opensource.org>

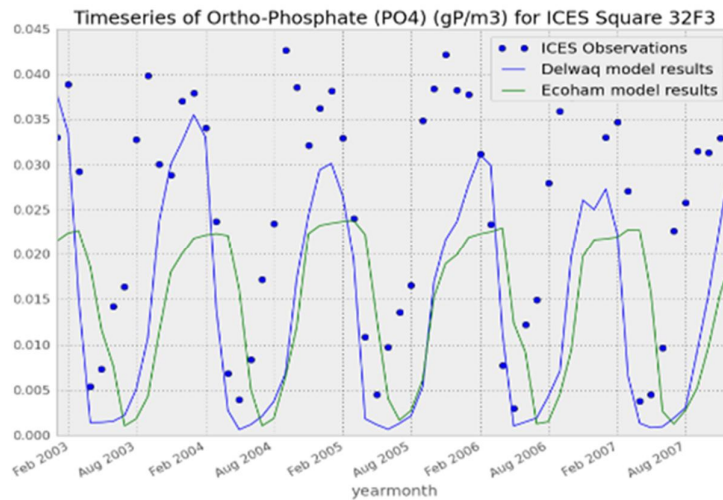


Figure 8-2: Example of presentation of comparison between simulated and measured values as will be made available in GangaWIS

8.2.2 GangaWIS dashboard

The Ganga dashboard will provide an interactive interface to a broader group of stakeholders to the data and information relevant for decision-making. The dashboard typically contains scorecards, graphs and/or charts related to water system state indicators and decision support indicators informed by the different mathematical model output. If needed, more qualitative indicators based on expert judgement may also be included. The performance of measures and strategies under different scenarios for key indicators can be explored and jointly assessed by the stakeholders.

The exact definition of the content of the GangaWIS dashboard will be an iterative process during the project and specifics (which indicators, which representation, units, level of detail, measures, scenarios etc.) will be established via rapid prototyping and verification by stakeholders in one or more workshops organized in Task 5 and is further closely related with the content developed in all the other tasks. It is important to state that the dashboard may also provide a feedback loop towards the simulations the models need to make in order to provide useful values. We should continuously carefully assess whether a defined indicator can be realistically modelled with the then current-state-of-the-art in modelling and data availability.

The GangaWIS dashboard will directly extract the model output data and information from the central data storage as part of the GangaWIS.

An example dashboard is shown in Figure 8-3.



Figure 8-3: Example dashboard configuration

8.2.3 Accessibility and data security

GangaWIS will be built using open source OpenEarth building blocks. By default all data within these systems is open except for the database. This does not mean that there are no outstanding authentication protocols to safely protect the data. During the project Deltares and partners will focus on security of data and will discuss this with all stakeholders. It is essential to understand that authorisation of data can essentially be carried out for each record of data in the database or file on the secured OPeNDAP server. In practice this is mostly done at certain levels of data in a database. This level of authentication will be discussed in detail with stakeholders and data owners. Essentially for every ‘compartment’ (called schema) of a database, data can be authenticated differently. Of course, the Client and the Counterpart have to take the ultimate decisions regarding who gets access to which data and information.

During the start-up phase, data in the database is only accessible via the Deltares Intranet for Deltares employees. As a next step, the database will also be made available to our partners AECOM and FutureWater and to counterpart staff.

8.3 Data requirements and data collected

In the inception phase a preliminary choice has been made regarding some important technical characteristics of the geodata in the GangaWIS such as the extent of the area of interest (Figure 8-4), minimum cell size for raster data and the spatial reference for maps to be used in the project.

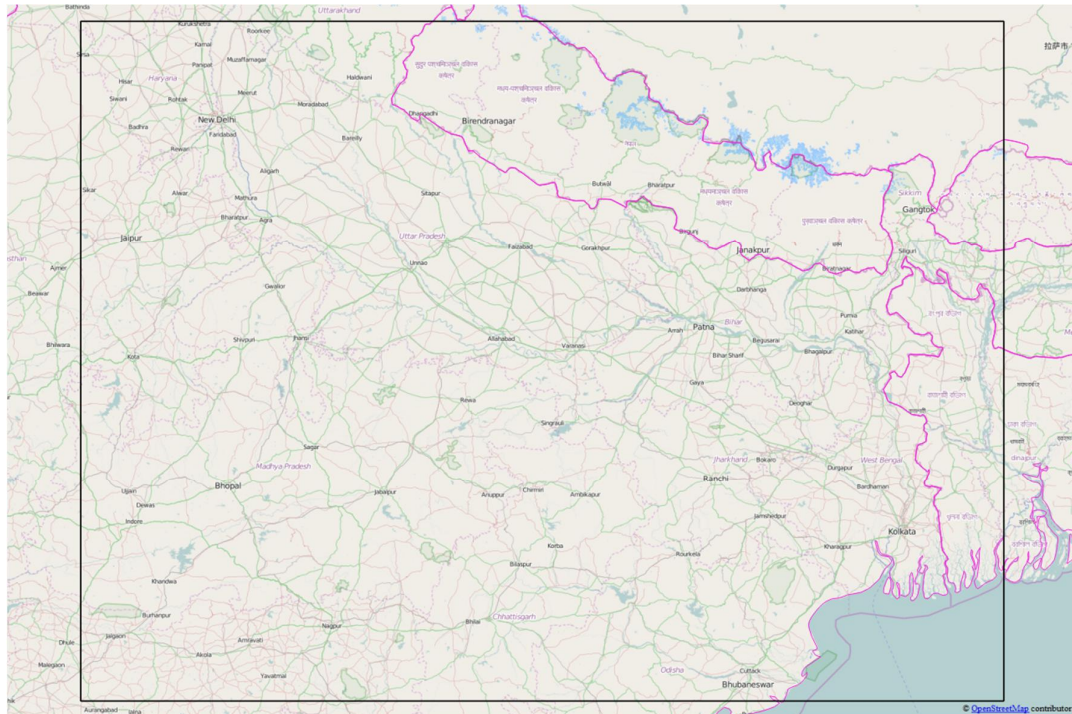


Figure 8-4 Extent of maps in the GangaWIS

The default spatial reference projection has preliminarily been chosen to be Asia South Lambert Conformal Conic ([ESRI:102030](#)), this is preferred over normal latitude-longitude (such as UTM-WGS84, EPSG:4326) because modelling requires measurement units in the metric system that are constant in size over the whole domain. Every layer used will be transformed to the finally spatial reference system. This Lambert projection is also prescribed by the National Natural Resources Management System (NNRMS) for larger scale state databases.

As mentioned before vector data will be stored in the database. Because of the sheer variety in topics several database compartments (in database terms called schemas) have been created which store the base layers of GangaWIS. There is no defined data model for these base layers, because of the variety of information.

With respect to time series this is different. This type of information can be structured to a high abstraction level which is called a data model. A data model describes relations between various tables in a database schema (compartment). The datamodel of FEWS (Figure 8-5) will be used as the starting point for the data model of the GangaWIS. If desired, extensions can be made.

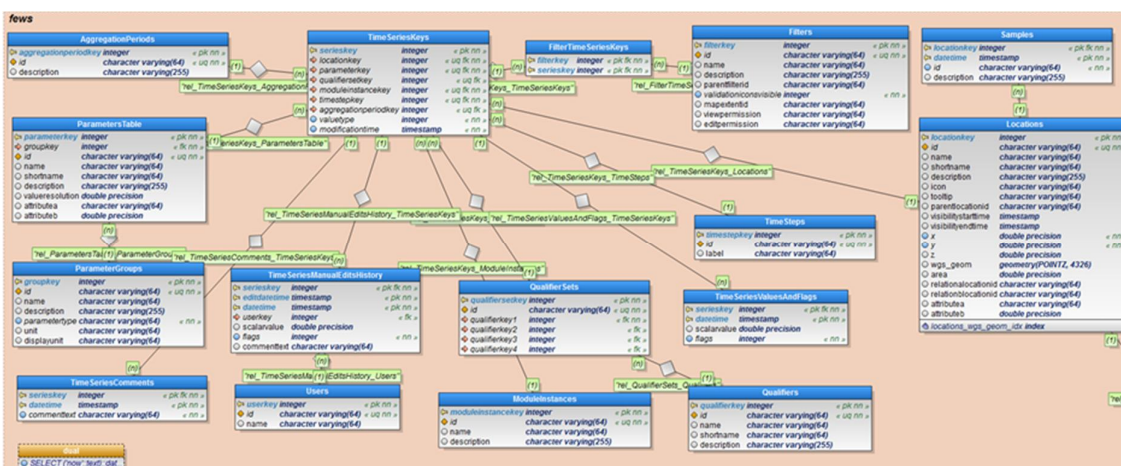


Figure 8-5 FEWS Datamodel

8.4 Capacity building

Counterpart staff will be trained in using and managing the GangaWIS, so that they can add new data, update model input, make new model simulations, retrieve model results, add new model results to the dashboard and operate the dashboard. Specific staff has to be identified for specific tasks, since it is not necessary that everyone can perform all tasks. Stakeholders will be trained in the use of the dashboard, if the dashboard will become available to them.

Training will be concentrated around the end of the collaborative modelling and start of the scenario building phase, to allow counterpart staff and stakeholders to use GangaWIS for their active participation in the project.

If counterpart becomes available that has enough time and skills in data management, they will be trained on the job in setting up and maintaining the GangaWIS. This would be very favourable for the sustainability of the GangaWIS as platform for collaboration and exchange of data and knowledge after project completion.

8.5 Links with other tasks

All Tasks will use the GangaWIS as their source of data and information. However, the data and information will also have to be provided through these Tasks. What data will be stored in the GangaWIS is determined by the other Tasks as described in the paragraphs on data requirement in the previous five chapters.

The collaborative modelling process of Task 5 will define the data and information that will be made available through the dashboard of the GangaWIS. Prototypes will be developed of the dashboard for communication during the workshops and to invite feedback.

8.6 Contributions to project results

Task 6 will contribute to the progress reports, delivery of all model software developed and associated data files and the final project report as well as to each of the three cycles of basin-wide and state workshops in the framework of the collaborative modelling approach. Contributions to the workshops will take the form of presentations and discussions regarding the development of the GangaWIS dashboard.

Task 6 will prepare the following deliverables:

- Report describing information system design; and
- Final documentation of information systems.

8.7 Detailed work plan

With respect to knowledge transfer on the GangaWIS a mission to India is scheduled for December 2015.

Figure 8-6 Schedule and work plan task 6 presents the detailed workplan for Task 6, including tasks and activities, timing of staff input and deliverables.

Mr. Harendra Tiwari, the GIS specialist of AECOM will be asked to carry out work for other tasks as well.

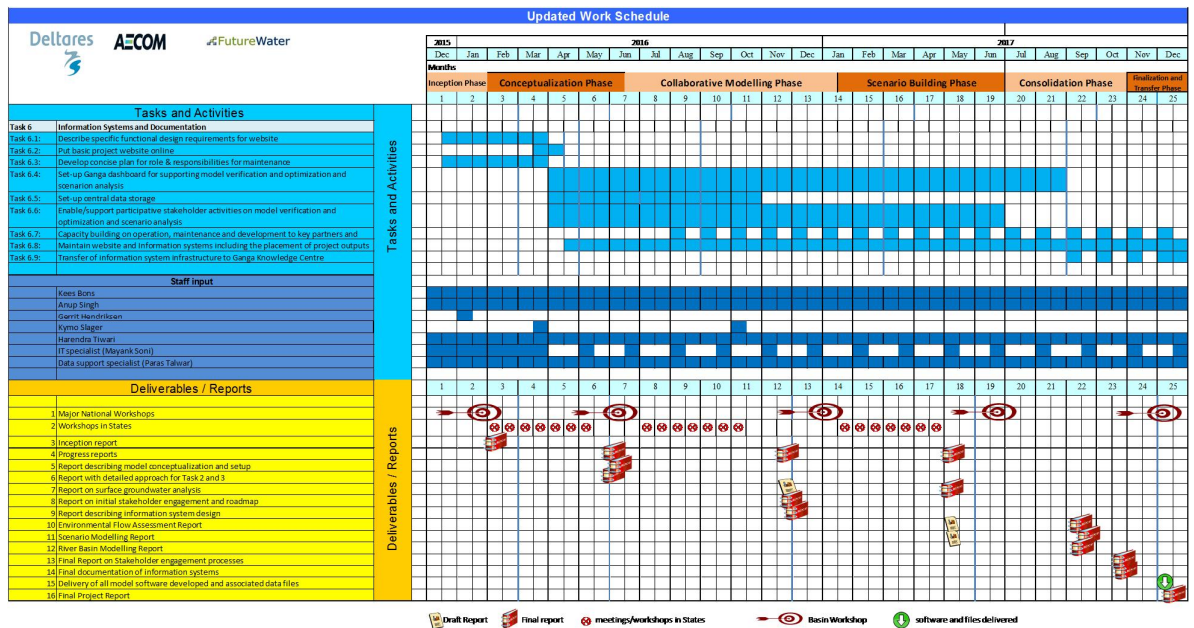
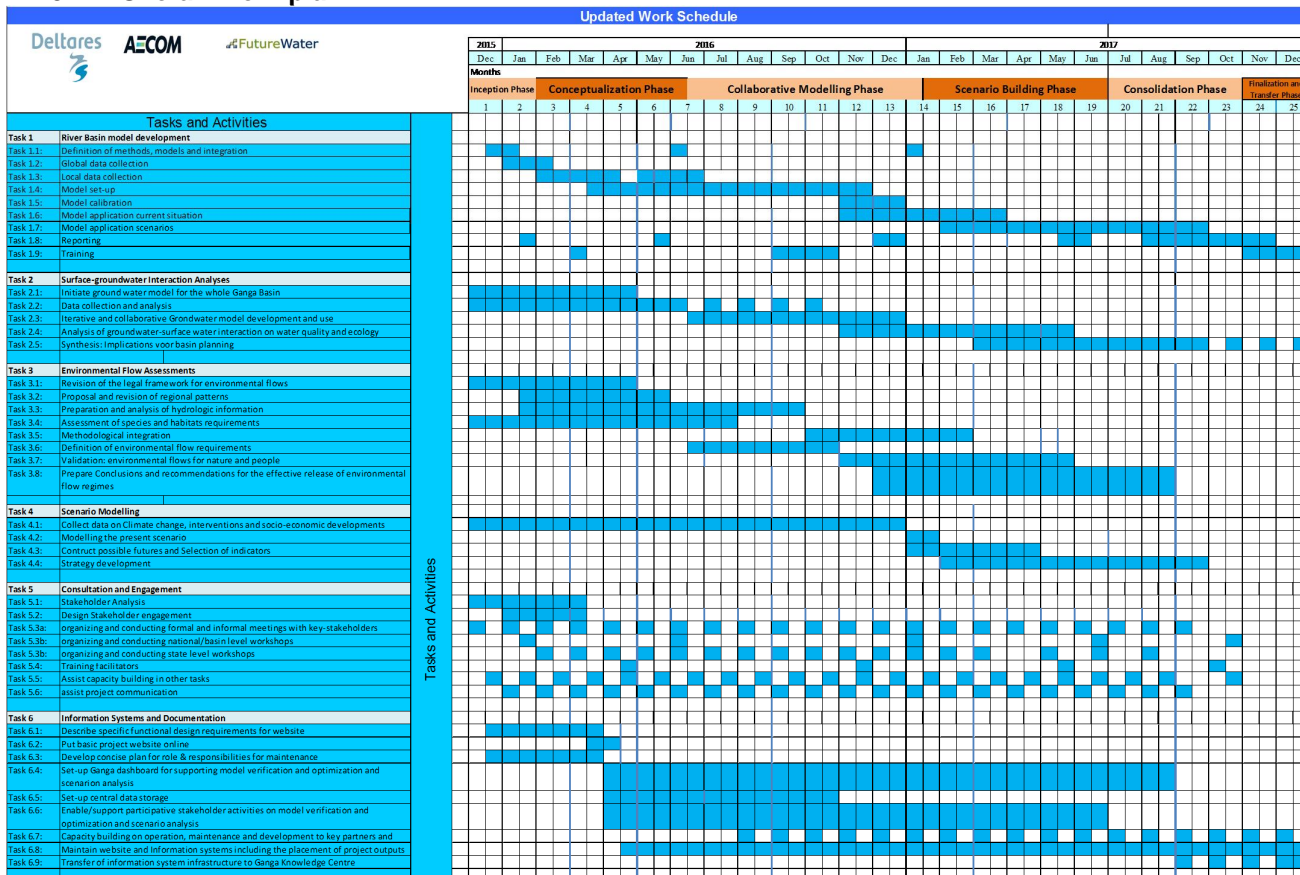


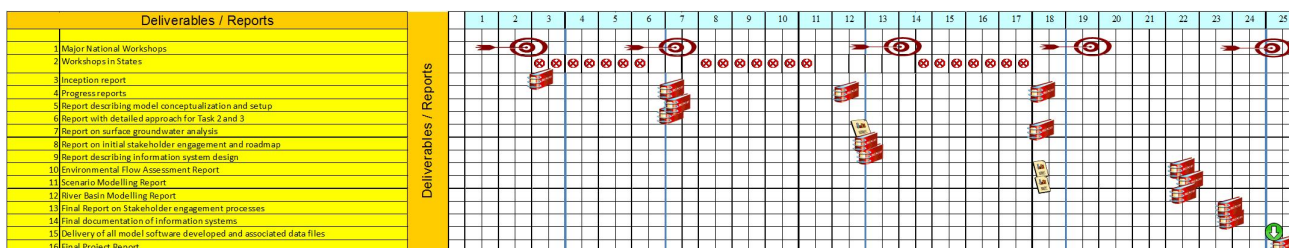
Figure 8-6 Schedule and work plan task 6

9 Adapted work plan and project deliverables

9.1 Overall Work plan



9.2 Deliverables



9.3 Detailed Work plan till June 2016

The activities in the conceptualization phase can be grouped into three types:

1. Stakeholder consultations
2. Data identification and collection
3. System preparation
4. Training

The activities will be elaborated on below.

Stakeholder Consultations

The initial stakeholder assessment/identification will be continually adapted and enriched as the project continues. The stakeholder consultations in this phase have the following objectives:

- Introduction of Project Assignments with Stakeholders
- Requesting for the Nodal Department/ and nominating the contact persons
- Seeking appropriately representative Working Group of relevant Stakeholders for the Project Assignment
- Understanding the Problems/ Issues concerned of the relevant Stakeholders in the Ganga River Basin
- Seeking Responses of the Stakeholders on the project Assignment (circulated the Stakeholders Questionnaires)
- Inform the stakeholders on the next steps in project implementation that need their involvement: collaborative modelling and scenario development.

At the Central level meetings will be held with CGWB, CWC, IMD, WWF, CPCB, (NIH was already visited in December). These meetings starting at the Chairman level will be followed up with more technical meetings with identified nodal persons.

Additional Stakeholders identified during workshops or meetings will also be met and requested to fill in the questionnaire.

Table 9-1: The detailed program for state visits

Detailed Program for State Visits	
States	Dates and Duration
Himachal Pradesh	18 th – 19 th February 2016
Uttar Pradesh	23 rd – 24 th February 2016
Madhya Pradesh	25 th – 26 th February 2016
Bihar	29 th February – 1 st March 2016
West Bengal	2 nd – 3 rd March 2016
Jharkhand	28 th – 29 th March 2016
Chhattisgarh	31 st March – 1 st April 2016
Uttarkhand	11 th – 12 th April 2016
Rajasthan	21 st – 22 nd April 2016
Delhi	5 May 2016
Haryana	Early May 2016

At the state level two day visits are held (see Table 9-1) also starting at the highest possible level. Preferably it is started with a meeting chaired by the Chief Secretary, with secretaries of all relevant departments present. This group meeting is followed up with bilateral meetings with departments. Every department is then requested to fill in the questionnaire (Annex 3).

Data identification and collection

When meeting stakeholders it will also be identified which data the stakeholder needs to address the issues raised, and which data are already available with that stakeholder. After the meetings follow up meetings or communications will be held to collect the data.

CWC, IMD and CGWB will be the main contributors to the data needed in the modelling, so special attention is given to collection of that data.

Parallely global datasets will be assessed on useful data to complement the data from the stakeholders.

Regarding E-flows in this phase the legal framework for environmental flows, species and habitats requirements will be assessed and regional patterns identified.

A start is made with the collection of data on Climate change, interventions and socio-economic developments to prepare for the scenario building phase.

System preparation

In preparation for the collaborative modelling phase a number of activities take place in this phase:

- A tentative general setup of the models will be prepared as a basis for the collaborative modelling workshops
- A website design will be prepared to be discussed with client and a first version will be put online.
- A design of the Ganga dashboard for supporting model result presentation and scenario analysis will be made
- The central data storage will be set-up, initially on the project server.

Training

In March a training is held to acquaint the participants with the different models and tools which are used within the project. This training will focus on the Surface and Groundwater models used. Participants are invited from CWC, CGWB, IMD and NIH.

Annex 1: Data Collection Note

Introduction

This note describes the plan for data collection for the project *Analytical Work and Technical Assistance to support strategic basin planning for Ganga River Basin in India* for Task 1 – River Basin Model Development; Task 2 – Surface – Groundwater Interaction; and Task 3 – Environmental Flow Assessment. The note describes as accurately as currently possible the data to be collected, the sources of the data and the method of collection. This is a first draft version based on discussions with the Ministry of Water Resources, the Central Water Commission (CWC) and the Central Ground Water Board (CGWB) and is meant for discussion only.

With both CWC and CGWB, it has been agreed to have regular meetings with senior staff to present and discuss progress in data collection and modeling. Furthermore, 2 to 3 staff members of CWC and CGWB will be trained in application of the different components of the river basin model. This training will consist of general introductions and tutorials, followed by on-the-job training in data validation, model set-up and calibration.

Coordinators and Nodal Points:

The Chief Engineer, Basin Planning & Management Organisation will be Coordinator for CWC and the Director River data Directorate will function as Nodal Officer.

Dr. Nandakumar P i, Regional Director for the CGWB is coordinator for CGWB, with Shri Upendra Srivastava, Scientist-D as Nodal officer.

Basically, four different routes for data collection can be distinguished:

- 1 Collection of publicly available data mainly from internet and statistical yearbooks by the team of national and international experts;
- 2 Direct data collection by the team of experts from national institutions, such as CWC, CGWB, Central Pollution Control Board (CPCB) and India Meteorological Department (IMD);
- 3 Data collection at State level by the expert team supported by national institutions; and
- 4 Collection of information from participants in the stakeholder engagement process.

Additionally, besides collection of data, the team of national and international experts also collects aggregated information on the characteristics of the Ganga water system. Both national institutes and literature will be the source.

The last route will not be used for direct data collection. Participants in the stakeholder process can provide input and feedback on preliminary results during workshops at national and state level. In this way, their information is incorporated in the river basin model.

Data collection will be carried out by the expert team (and especially the national experts) supported by the staff of national institutions. Supporting letters for data collection through routes 2 and 3 will be sent by the Ministry on behalf of the project. Lists of data will be attached as annexes to these letters (see Annexes).

Data collection for the following topics is covered in this note:

- Maps of the basin (e.g. DEM, landuse);
- Meteorological data to be used as forcing for the hydrological model;
- Hydrological data to be used for calibration and validation of the hydrological model;
- Geohydrological data to be used for calibration and validation of the geohydrological model;

Annex 1: Data Collection Note

- Data on water demand and return flows for drinking water, industry and irrigation, and their sources (groundwater / surface water);
- Data on hydraulic infrastructure and its operation;
- Data on aquifer characteristics;
- Data on water quality and pollutant loads;
- Data on water quality and quantity requirements and ecological relations supporting ecosystem services provided by the river system

It is important to realize that the river basin model will be used for strategic planning with respect to water resources, water quality and ecology. The model should be able to describe sufficiently the overall spatial and temporal patterns of water availability and water demand. Drought damage typically occurs over a period of weeks to months. Therefore, the required accuracy of the models is less than for flood modeling, where damage occurs over a period of hours to days.

The period 1995 to 2005 is proposed for calibration of the models and 2006 to 2015 for validation of the models. The calibration period includes one major El Niño Southern Oscillation (ENSO) event (1997-98) and the validation period another one (2015). ENSO events are for India associated with relatively little precipitation in the monsoon period.

For water demand the year 2015 is proposed to be used as reference year. The timestep of the models will be one month. Therefore, calibration and validation will use average monthly values. The water resources analysis will cover the whole period for which meteorological forcing functions can be obtained: 1901-2015.

All data are required in digital format. Time series should be in a format that can be automatically inserted into the database that will be used in the Ganga Water Information System. Tables have been prepared in Excel for list of data per institution (see Annexes).

Maps

The following maps are required in digital format, preferably in GIS ready format (e.g. shapefiles or GTiff raster files):

- Administrative boundaries of countries, states and districts
- Network of rivers, (irrigation) canals and drainage system including data on bottom level;
- Digital Terrain Model;
- Land use and land cover;
- Soils;
- Hydro-meteorological monitoring network;
- monitoring network for surface / ground water quantity and quality;
- Hydraulic infrastructure such as reservoirs, pumping stations, barrages, weirs and other important structures;
- Extent of glaciers (preferably for different moments between 1900 and 2015);
- Estimation of irrigation source; groundwater or surface water;
- Aquifer characteristics;

Maps will be initially collected through route 1 from internet and updated based on data from national institutes (route 2) and States (route 3). Maps on soils, land use and land cover will be collected from NBSS & LUS in Nagpur.

For the digital maps the ESRI ArcGIS Shape format will be used. Each map should include a .prj file describing the projection. The Indian national standard projection will be used: South Asia Lambert Conformal Conic (EPSG: 102030).

Meteorology

The meteorological data required consist of the following parameters:

- Monthly (or if available daily) time series for precipitation, potential evapotranspiration and temperature; and
- Maps of snow depth, preferably also at a monthly (or daily) interval.

Data in the form of grid maps for the whole period of analysis of 1900-2015 will be obtained from the WATCH and WFDEI data sets, available from the internet and from the Indian Meteorological Department (IMD) through its website imdpune.gov.in. Additional station data will be obtained from IMD. The station data will be used to verify the data in grid maps. If necessary and possible, a correction function will be derived from this verification, for example to correct for altitude.

Hydrology

The hydrological data required consist of the following parameters:

- Monthly (or if available daily) time series of average discharge at a selected number of locations on the Ganges River, its main tributaries, major canals and the inflow and outflow of major reservoirs and barages for the calibration/validation period of 2000-2015. It is currently estimated that the models can be calibrated sufficiently for strategic basin planning using not more than 50 stations;
- Monthly (or if available daily) time series of water level for the major reservoirs and upstream at major barrages and pump stations ; and
- Monthly (or if available daily) time series of water level and rating curves for stretches of the Ganges where flooding forms an essential part of the ecosystem and its services to society.

Discharge data for the Ganga Basin are classified. It appears they can be used for model calibration under a secrecy statement. Most of the required data appear to be available at CWC. For additional relevant locations and reservoirs, data will to be collected from the States.

Geohydrology

The first step is to understand the groundwater system. For the description of this Conceptual Groundwater Model the following maps in GIS format (preferably) are necessary:

- Water loss and water gain Map of the Ganges river and the distributaries (based on existing studies)
- Basin width hydraulic head map (based on studies, models etc. incl. drawdown map)
- Simple hydrogeological map (determine homogenous areas based on hydrogeological sequences)
- Depth to brackish – salt groundwater map (mapping the existing fresh groundwater body)
- Initial groundwater quality assessment (basin wide map and/or strategic transects)
- Develop a basin wide groundwater extraction map (based on: (1) existing pumping well locations and extraction rates, (2) irrigated land use (type, number of harvests), estimated on evapotranspiration demand, (3) (estimated) urban groundwater extractions)
- Data on groundwater extraction rates and locations: (1) Drinking water, (2) industry, (3) agriculture
- Subsidence map or information

Maps contain a lot of information. Additional information is found in recent studies in the Ganga Basin. Please provide us with the right references.

For the development of the numerical groundwater model data requirements are shared with other activities like the hydrology modeling. It applies e.g. for the Digital Elevation Model, land

use, precipitation and evaporation, surface water system (river, canal, drainage) including its characteristics (bed level / width / depth),

Specific for geohydrology the data requirements are:

- Characteristics of the aquifer system (depth, hydraulic conductivity, yield);
- Information on Faults (map or information about horizontal hydraulic resistivity);
- Groundwater extraction: spatially distributed data on rates over time, well depth and user group;
- Time series of hydraulic heads (a selection of available time series)

The process of data gathering starts with the easy available data in order to develop an initial groundwater model. During the project data requirements might be detailed both in time and space. This approach prevents for overfocussing on data gathering.

Water demand and return flows

Data on water demand will initially be derived from publicly available data (route 1) by combining information from statistical yearbooks on population, industrial production and irrigation / agriculture per administrative unit with maps of administrative units. This will yield first estimates of water demand per district. This will be compared and completed with information from the States.

Population data appear to be available from CWC (route 2).

For industrial water use and irrigation from surface and groundwater, States will be asked to supply data per district, command area or project area (route 3), as follows:

- Industrial water use, location of intake and outflow, return flow and type of industry;
- Irrigated area per crop for both Kharif⁹ and Rabi¹⁰, cropping calendar and fraction dependence on surface and groundwater (per month of the year); and
- Location of intake and return flow, irrigation efficiency, loss fraction of canals and return flow.

Hydraulic infrastructure

Hydraulic infrastructure is used to store or divert water. For the major reservoirs and barrages , the following data are required:

- Location;
- Volume-area-level relation and maximum level;
- Level and capacity of different outlets;
- Installed capacity and demand for hydropower, efficiency of turbines and monthly time series of electricity generated;
- Irrigation area served per outlet;
- Domestic and industrial water demand served per outlet;
- Flood storage required (if any); and
- Operation rules, preferably as monthly outflow as a function of level.

For the pumping stations, the following data are required:

- Location;
- Level and capacity of pumps (including the relation between pump capacity and river level);
- Irrigation area served;
- Domestic and industrial water demand served; and
- Operation rules, preferably as monthly outflow as a function of river flow and/or level.

⁹ Kharif is the rainy (monsoon) season in the South Asia, which lasts between April and October depending on the area

¹⁰ The rabi season starts with the onset of the north-east [monsoon](#) in October.

Annex 1: Data Collection Note

It is expected that limited data on hydraulic infrastructure will be available publicly (route 1). Some data appear to be available with CWC (route 2), but most data will have to be collected from the States (route 3).

Water quality and pollutant loads

Water quality data are required to calibrate the water quality model. Monthly or quarterly time series are required, preferably at the same locations where discharges are available and at the main reservoirs. The following parameters are proposed to be included in the water quality analysis:

- Faecal coliform bacteria;
- Biological oxygen demand after 5 days;
- Dissolved oxygen;
- Total nitrogen (and its division over Kjeldahl-nitrogen, nitrate and ammonium; and
- Total phosphorus (and its division over dissolved and particulate and organic and inorganic phosphorus).
- Heavy metals such as cadmium, sink, copper, tin, chromium and lead originating from among others tanneries (and their division over dissolved and particulate matter).

The water quality data appear to be available from the Central Pollution Control Board (CPCB) through route 2. For additional relevant locations and reservoirs, data will to be collected from the States.

It is proposed to include seven types of load sources in the Ganga model framework:

- 1 Domestic sources (through sewers and open drains, Nullah¹¹, as point sources, with or without treatment);
- 2 Domestic sources (as non-point sources);
- 3 Industrial sources (end of pipe, with or without pre-treatment);
- 4 Agricultural sources (farms);
- 5 Non-agricultural land-use loads – waste loads associated with non-productive land use types in the catchment (wetlands, forestry and residential/commercial);
- 6 Septic tanks – loads derived from household septic tanks located in the catchments;
- 7 Other sources, such as bank erosion.

Domestic sources will be calculated from the population data (route 2 from CWC). Additional data are required from the States (route 3) per district, project area or command area:

- Location, capacity and type of sewage treatment plant;
- Location, type, amount of waste water and concentration of pollutants for industrial sources;
- Number per type of cattle;
- Area per crop for both Kharif and Rabi; and
- Location, type, amount of waste water and concentration of pollutants for other sources.

Requirements for ecosystem services

MAPPING

GIS maps with location of hydraulic facilities (water regulation/abstraction)

GIS maps with location of gauge and water quality stations

River geomorphological mapping

GIS maps of abundance and distribution of selected species (aquatic & riparian)

¹¹ A [watercourse](#) or a steep narrow [valley](#), characteristic of mountainous or hilly country where there is little rainfall.

Annex 1: Data Collection Note

GIS maps of habitat characteristics (extent, distribution, composition) for selected species
GIS maps of protected/conservation areas
GIS maps of sacred/religious areas (cremation, riverine temples, ghats, prayer wheels)
GIS maps of tourism pressure
GIS maps of recreative areas (rafting, river crossing, flying fox)

DATA

Water planning goals (scenarios and calendar)
Land planning and typology
River typology and classification
Conservation goals
E-flow goals
Year of construction, year of initial operation of barrages

Ecological requirements of species and habitats (soil information, primary production, etc.)
Important social and cultural, religious and spiritual requirements
Land use (agricultural, industrial – textile and paper mills, cement, tanneries, distilleries, chemical plants-, mining, dumping sites, forest)
River use by local communities (fishing, sediment and minerals extraction, power, water supply, wood, raw material, biomass, medicinal plants, soil fertilizing, cows drinking and gatherings)
Population densities

Collection of information from **stakeholders** (route 4) is done for some key pressures/areas/drivers determining the ecological status of the river (e.g., both natural and man-made modified issues). Data collected from stakeholders can be quantitative or qualitative, when appropriate. The data can be used to complement and verify information collected through the other routes.

- Information on presence/abundance of services/species over time in relation to (natural or man-made) changes in flow regime
- Information on importance of services/species for local livelihoods and culture

Detailed Annexes of Data collection memo not included in Inception report

Annex 2: Stakeholder Identification and Analysis

In the inception period the project team in consultation with counterparts from the Ministry of Water Resources, River Development and Ganga Rejuvenation compiled a list of stakeholders with short descriptions and indications of their possible involvement at the national/basin level or at a state/sub-basin level. The list was adapted based on group meetings and checked again with the nodal officer.

Below the main stakeholders are mentioned at central and regional/state level and categories according to their circle of influence. The generic Circles of Influence framework includes four circles:

- A. (Circle A) Model Developers,
- B. (Circle B) Model users and validators,
- C. (Circle C) (other) Interested parties and contributors,
- D. (Circle D) Decision Makers.

Stakeholders at national/central level

Circle A

Organizations that seem to fit in category A, model builders, at central level are:

1. Central Ground Water Board (CGWB) (MoWR, RD&GR)
2. Central Water Commission (MoWR, RD&GR)
3. National Institute of Hydrology (NIH) (MoWR, RD&GR)
4. Indian Institute of Technology (IIT)

Circle B

Organizations that seem to fit in category B, model users and validators, at central level are:

1. Ganga Flood Control Commission (MoWR, RD&GR)
2. National Mission for Clean Ganga (NMCG) (MoWR, RD&GR)
3. Central Pollution Control Board
4. Ministry of Environment, Forest and Climate Change (MoEF&CC)
5. National River Conservation Directorate (MoEF&CC)
6. Water Quality Assessment Authority Govt. of India
7. National Biodiversity Authority (NBA) (MoEF&CC)
8. National Institute of Technology (NIT)
9. Forest Research Institute (MoEF&CC)
10. Central Water and Power Research Station (MoWR, RD&GR)
11. National Water Development Agency (MoWR, RD&GR)
12. National Remote Sensing Centre India-WRIS
13. India Meteorological Department (Ministry of Earth Sciences, Govt. of India)
14. National Centre for Medium Range Weather Forecasting (NCMRWF) (Ministry of Earth Sciences, Govt. of India)
15. National Remote Sensing Centre, ISRO, Dept. of Space, Govt. of India, Hyderabad.
16. Geological Survey of India, (GSI) Govt of India
17. National Hydrology Project (NHP)
18. Indian Council of Agriculture Research (ICAR)

Annex 2 - Stakeholder Identification and Analysis

19. Ministry of Power
20. Ministry of Drinking Water and Sanitation, Govt of India
21. Ministry of Agriculture & Farmer Welfare, Govt of India
22. Ministry of Rural Development, Govt of India
23. Ministry of Urban Development, Govt of India

Notes:

- organizations that fit category A, do also fit category B.
- many organizations that fit category B, also fit category C, or D, or both, see Annex 4

Circle C

Organizations that seem to fit in category C, other interested parties and contributors, at central level are:

Government:

1. SRO Indian Institute of Remote Sensing, Indian Space Research Organisation, Dept. of Space, Govt. of India
2. National Disaster Management Authority (NDMA), Govt. of India
3. National Institute of Disaster Management, Govt. of India
4. Ministry of Earth Sciences, Government of India,
5. Indian Institute of Tropical Meteorology (IITM) (An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)
6. National Centre for Medium Range Weather Forecasting (NCMRWF) (Ministry of Earth Sciences, Govt. of India)
7. CIFRI
8. National Biodiversity Board Wildlife
9. India NPIM (India non-profit Participatory Irrigation Management)
10. Water User's Associations (Forum)
11. Participatory Irrigation Management
12. Resource Centre for Water Users' Associations (WUA) Not in UP
13. Inland Waterways Authority of India

NGO's

14. Centre for Environmental Education (CEE)
15. TARU the Leading Edge Pvt. Ltd.
16. International Water Management Institute (IWMI)
17. PRADAN
18. International Rivers
19. South Asia Network on Dams, Rivers & People, India
20. Indian Water Portal
21. Indian Water Resources Society (IWRS)
22. Development Alternatives
23. Basin South Asia
24. Centre for Science and Environment (CSE)
25. The Energy and Resources Institute (TERI)
26. Innovative Hydrology
27. Institute for Social and Environmental Transition (ISET)

Annex 2 - Stakeholder Identification and Analysis

28. Aquadam
29. World Wide Fund (WWF)
30. Wetlands International

Circle D

Organizations that seem to fit in category D, decision makers, at central level are:

1. Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR)
Govt. of India
2. Ministry of Environment, Forest and Climate Change (MoEF&CC)
3. Ministry of Drinking Water and Sanitation, Govt of India
4. Ministry of Agriculture & Farmer Welfare, Govt of India
5. Ministry of Rural Development, Govt of India
6. Ministry of Urban Development, Govt of India
7. NITI AROG
8. Politicians
9. Central Ground Water Board (CGWB) (MoWR, RD&GR)
10. Central Water Commission (MoWR, RD&GR)
11. National Mission for Clean Ganga (NMCG) (MoWR, RD&GR)
12. Central Pollution Control Board
13. National River Conservation Directorate (MoEF&CC)

The categories will continuously need to be checked, as our knowledge of the organizations, their roles and their ambitions will develop.

Stakeholders at regional/subbasin level:

A fuller identification will have to be done at the regional/subbasin level. A preliminary list is as follows:

General

- | | circle/category |
|---|-----------------|
| 1. Ministry of Environment, Forest and Climate Change (MoEF&CC) | B D |
| 2. National River Conservation Directorate (MoEF&CC) | B D |
| 3. State Pollution Control Boards | B D |
| 4. State Water Resources Departments | A B D |
| 5. State irrigation & Drinking Water Departments | B |
| 6. State Hydropower Project owners (Uttarakhand & Himachal Pradesh) | B |
| 7. State Government Departments Industry, Tourism | B |
| 8. Religious groups | C |

Madya Pradesh

- | | |
|------------------------------------|---|
| 1. Betwa River Board (MoWR, RD&GR) | B |
| 2. Manthan Adhyayan Kendra | C |

West Bengal

- | | |
|---|---|
| 1. Farakka Barrage Project Authority (MoWR, RD&GR) | B |
| 2. SEED (Society for Socio-Economic & Ecological Development) | C |

Uttar Pradesh

- | | |
|--|---|
| 1. Shohratgarh Environmental Society (SES) | C |
| 2. Gorakhpur Environmental Action Group | C |

Annex 2 - Stakeholder Identification and Analysis

3. Upper Yamuna River Board Directory (MoWR, RD&GR) B D

Uttarakhand

1. Upper Yamuna River Board Directory (MoWR, RD&GR) B D
2. G. B. Pant Institute of Himalayan Environment and Development (MoEF&CC) C
3. Wadia Institute of Himalayan Geology (Ministry of Science and Technology, Govt. of India) C
4. Climate Himalaya C
5. Pragya C
6. People's Science Institute C

Haryana

1. Upper Yamuna River Board Directory (MoWR, RD&GR) B D

Annex 3: Stakeholder Questionnaire

**Ministry of Water Resources, River Development & Ganga Rejuvenation,
Govt. of India**

Ganga River Basin Planning Project in India

“Analytical Work and Technical Assistance to Support Strategic Planning for Ganga River Basin”

Stakeholder Questionnaire

Govt. of India, Ministry of Water Resources, River Development & Ganga Rejuvenation, (MoWR, RD&GR) executing the World Bank assisted “**Analytical Work and Technical Assistance to Support Strategic Planning for Ganga River Basin**”; and Deltares-AECOM are the Project Consultants for this assignment. The focus of this project assignment is on technical assistance to government through analytical work and collaborative modelling and combined with multistakeholder engagement processes, developing information and knowledge base, capacity building of central and state government agencies.

The stakeholders participation is an integral part of this assignment and following set of questions will be the basis for state and national levels stakeholders’ consultations and engagement process. Your response to these questions will be critical to facilitate the exchange of experiences and expertise, existing resources, capacities, gaps and needs in order to accomplish the intended objectives of the said assignment.

You are kindly requested to complete the prescribed format for your inputs based on the perspective of your organisation’s mandate and any information available in respect to Ganga River Basin. Please e-mail the electronic version of the completed questionnaire to Mr. Kees Bons, (Kees.Bons@deltares.nl) and Mr. Anup Singh (Anup.singh@aecom.com). The printed copy of the completed questionnaire must be sent to the **Secretariat, Strategic Planning for Ganga River Basin Project, 4th Floor, Mohan Singh Place, Baba Kharak Singh Marg, Connaught Place, New Delhi – 110001. Phone# 011- 43518 451; 43518 551**

The representatives of MoWR, RD&GR Govt of India along with Project Consultant Team will be visiting/ meeting to your organisation along with various relevant stakeholders in the basin states. In this regard, your early response to this questionnaire will be highly appreciated as it would facilitate the follow-up meetings/ interactions with you. Kindly let us know for any clarifications in this regard.

Name of Department/ Agency:				
Official’s Name & Designation:				
Contact Address:		Phone:		
Web Site:		E-Mail:		
Geographical Coverage of Your Organisation	Central Level	1	Ganga Basin Level	1
	State Level	2	Ganga Sub-basin Level	2

Ganga River Basin Planning Project in India

Please tick(√) Your Organisation's Ganga Basin Riparian States	1) Himachal Pradesh	2) Uttarakhand	3) Chhattisgarh	4) Bihar
	5) Uttar Pradesh	6) Haryana	7) Jharkhand	8) Delhi
	9) Madhya Pradesh	10) Rajasthan	11) West Bengal	12) All
01.	Please describe your organisation's particular interests/ involvement in Ganga River Basin with emphasis on the roles and responsibilities of your organisation.			
02.	Please tell us about your organisation's mandates which effect or affected, directly or indirectly, the Ganga River Basin resources-land, water and related resources (provide list of activities, describe relationship with Ganga River Basin resources, ecosystem)			
03.	From your organisation's perspective, what are the most urgent issues/ problems/ needs for the Ganga River Basin? Describe the causes and effects of these issues/ problems status and plausible solutions.			
04.	What are any institutional arrangements, legal frameworks, and policies, other issues that you think present opportunities or constraints to Ganga River Basin Integrated Planning and Management?			
05.	Does your organisation have any projects/ programmes/ schemes/ action plans within or related to Ganga River Basin or Sub-basins? Please specify goal/objectives, interventions, coverage, time period, funding source, etc.			

Annex 3 - Stakeholder Questionnaire

Ganga River Basin Planning Project in India

06.	What all basic data/ information your organisation utilizes/ requires for Ganga River Basin/ Sub-basins related activities?, e.g. hydrological, remote sensed data, weather & climate, meteorological short-medium term forecasts, geographical, demographic, socio-economic, environmental, etc.
07.	Please provide a list of data collected by your organisation related Ganga Basin/ Sub-basins activities. (e.g. hydrological, meteorological, surface/ground water level/ discharge, geographical, demographic, socio-economic, environmental, etc.) For each type of collected data describe network for ground data, data collection process, quality control & validation, data dissemination & exchange,
08.	Based on available data, what kind of analysis/ expertise (methodology & tools) is available in your organisation or aspires to utilise in future? (River Basin planning models e.g. meteorological, hydrological, water quality models, decision support system, etc.)
09.	Specify your organisation's needs in terms of building capacities, information and knowledge base for strengthening the planning and implementation of Ganga River Basin/ sub-basins related activities.

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10.	Please, provide if available, a list of organisations that are responsible for Ganga River Basin/ Sub-basins related activities in India/ riparian states. Specify their roles and responsibilities.
11.	Describe the process of Ganga River Basin/ Sub-basins planning and management at national level, state level, and community level with particular emphasis on the working relationships among organisations listed above (no 10).
12.	Does your organisation have cooperation or collaborations with other organisations in Ganga River Basin/ Sub-basins related activities? Kindly list and describe
13.	What do you suggest to promote the Ganga River Basin Integrated Planning and Management in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems?.
14.	How you might see your organisation involvement in the process of strategic planning and management for Ganga River Basin?

Note: Please enclosed additional sheet if space provided is not sufficient