GOVERNMENT OF JAMMU AND KASHMIR, DISASTER MANAGEMENT, RELIEF, REHABILITATION AND RECONSTRUCTION (DMRRR) DEPARTMENT

Jehlum & Tawi
Flood Recovery Project

JEHLUM & TAWI
FLOOD RECOVERY PROJECT

FEASIBILITY AND DETAILED PROJECT REPORT FOR FLOOD MITIGATION AND COMPREHENSIVE RIVER MANAGEMENT MEASURES IN TAWI BASIN

INCEPTION REPORT

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AQUALOGUS
Engenharia e Ambiente

Oiltech ENGINEERING

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Consultancy Services for Preparing Feasibility and Detailed Project Report for Flood Mitigation and Comprehensive River Management Measures for Tawi Basin

INCEPTION REPORT

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FEASIBILITY AND DETAILED PROJECT REPORT FOR FLOOD MITIGATION AND COMPREHENSIVE RIVER MANAGEMENT MEASURES FOR TAWI BASIN

INCEPTION REPORT

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1 INTRODUCTION

The present document is the **Inception Report**, presented as part of the Consultancy Services for preparing *"Feasibility and detailed project report for flood mitigation and comprehensive river management measures for Tawi basin*" under the Contract Agreement established between the Joint Venture (**AQUALOGUS** & **OILTECH**) (the Consultant) and **Project Management Unit (PMU)**, Jhelum & Tawi Flood Recovery Project (JTFRP), Disaster Management, Relief, Rehabilitation and Reconstruction Department, Government of Jammu and Kashmir on the 29th June, 2018.

The contract in question is aimed at preparing feasibility and Detailed Project Reports (DPR) for flood mitigation and river management measures in Tawi River Basin.

According to the ToR of the present Assignment, the Consultant hereby submits the **Inception Report** which was prepared after completion of *Task-1: Review flood and river management options and list potential options* of the Part A.

The **Chapter 2** includes a brief presentation of the work objectives and the methodology to develop the activities in order to obtain the expected deliverables with the required level of detail. This chapter is complemented by the **Appendix A**, wherein the detailed methodology and technical approach is presented.

The **Chapter 3** provides an overview of the key policies, strategies and plans of Government of India and Government of Jammu and Kashmir on disaster management, flood control and integrated water resources management. Current practices of flood risk management are reviewed and potential flood risk management options are also presented.

The **Chapter 4** presents the review of the relevant studies and reports, including national and global studies in similar river systems. Additionally, a review of the relevant national guidelines and handbooks is also included as well as the identification of the pertinent national design codes.

The major findings of the Preliminary Hydrology and Morphology Studies are summarized in the **Chapter 5**.

The **Chapter 6** includes a review of the various options proposed by the I&FC Department for flood mitigation and river management in Tawi River Basin, including the Consultants' analysis on the compliance within the ambit of Indus Water Treaty-1960.

The preliminary assessment of the applicability of innovative and emerging flood management options for the Tawi River Basin is presented in the **Chapter 7**, including a comprehensive review of potential measures and options based on an Integrated Flood Management (IFM) Strategy.

The **Chapter 8** includes the assessment of the data availability, including comments on quality, gaps, inconsistencies and strategies and plans for primary and secondary data collection to support preparation of final hydrology and morphology reports, and conduct feasibility plans and DPRs.

The specification of the additional surveys and investigations required to support project preparation is included in the **Chapter 9**.

The **Chapter 10** includes the short-list of available and relevant hydrology, hydraulic / hydrodynamic and morphological models.

The **Chapter 11** summarizes the most relevant findings obtained during Inception Phase and after successful completion of the *Task-1: Review flood and river management options and list potential options* and includes a summary some of the most important sections of the Inception Report.

Finally, the **Chapter 12** includes the considered bibliography and references.

2 METHODOLOGY AND TECHNICAL APPROACH

Within the scope of the **Inception Report**, the Consultant presents the technical approach, methodology and work plan for carrying out the study and preparing the feasibility reports and detailed project report of flood mitigation and comprehensive river management measures for Tawi Basin, in accordance with the Terms of Reference (ToR) included in the Contract.

The consultancy services require necessarily a careful and thorough planning of the tasks and activities involved, in order to achieve the objectives/outputs with accuracy and within the established deadlines. Therefore, the Consultant prepared an appended document: **Appendix A: Methodology and Technical Approach** which details the project objectives as well as the technical and methodological approach for carrying out the study. These follow, in general, the Consultant's proposal, though some adjustments are already provided based on the information collected and analysed so far.

Specifically, the Appendix is organized according to the following main chapters:

Chapter 2. Project Overview and Objectives

Chapter 3. Technical Approach and Methodology

Chapter 4. Work Plan

Chapter 5. Organization and Staffing

The **Chapter 2** provides an overview of the study site and project importance, objectives and scope. The **Chapter 3** details the methodology to develop the tasks and activities in order to obtain the expected deliverables and outputs with the required level of detail. In the **Chapter 4**, the main tasks and activities to achieve the required objectives are identified as well as their duration and interactions, deliverable's dates and other important events, namely the risk and management strategies. The **Chapter 5** presents the organizational processes and the structure of the team that will be responsible for developing the work, including a staff deployment schedule.

Complementarily, a brief presentation of the work objectives and Consultants' methodology for carrying out the study, feasibility reports and detailed project report is included below.

a) Project importance and objectives

The State of Jammu and Kashmir has a long history of natural disasters. Hazards like earthquakes, floods, fires, droughts, avalanches and landslides often convert into disasters leading to loss of human lives as well as public and private property.

Actually, the Jammu Region encountered many floods in the past but the recent flood of 2014 has been the worst in the history causing colossal damage to the life and property. Tawi and its tributaries were in spate and caused extensive damage in the region. The range of slopes with exceptionally steep gradients on both sides of hills leads to high velocity during high floods. The flood impact is further aggravated by reasons like low banks at many places, accumulation of huge loads of silt at bends and absence of suitable regulation structures.

Following the frequent and severe problems of flooding and inundation in the Tawi River Basin, the Government of Jammu & Kashmir, has proposed the **Project Jhelum & Tawi Flood Recovery Project**.

Accordingly, the present Assignment "*Consultancy services for preparing feasibility and detailed project report for flood mitigation and comprehensive river management measures for Tawi basin*", is included in the scope of the **Project Jhelum & Tawi Flood Recovery Project** and therefore will include the planning and design of innovative and effective measures, aiming to manage flows through river channels works and enhancement of the effective flood risk management to reduce the incidence of severe floods and provide protection to people, houses, public infrastructure, and agricultural land in Tawi river basin.

Specifically, the main objectives of the consultancy service are:

- Conduct feasibility study for definition of flood management issues and opportunities, to evaluate current and proposed flood and river management schemes, review proposed flood management options and identify potential solutions, collect and compile available and freshly data collection appropriate to conduct of feasibility study, conduct feasibility study including preliminary appraisal of cost and benefits, duration, and social and environmental impact assessment and Environmental Management Plan, selection of candidate options, and to prioritize options in consultation with stakeholders.
- Develop Detailed Project Reports (DPRs) for selected and prioritized schemes along with tender documents. The DPR would confirm and optimize candidate plan selected and prioritized in feasibility study, conduct detailed engineering work to proceed directly into preparation of plans and specifications.
- Conduct stakeholder consultation at various critical milestones, and
- Assist I&FC department in obtaining clearance as required from CWC and other central and State agencies.

The outcomes of the consultancy services should provide **the Government of Jammu & Kashmir and public policy-makers** with the necessary information to manage future floods risks as well as strengthen the flood prevention, protection and mitigation in Tawi river basin.

b) Technical Approach and Methodology

The approach and methodology proposed by the Consultant was elaborated on the basis of the ToR, following the objective to increase the resilience against severe flood events and erosion in the Tawi River Basin.

Accordingly, the Consultant will provide consultancy services focused on supporting the Government of Jammu and Kashmir and public policy makers (particularly the Disaster Management, Relief, Rehabilitation and Reconstruction Department – DMRRR and the Irrigation and Flood Control (I&FC) Department) with the necessary information to manage future occurrences, which will include the following main phases:

- Evaluating different flood and river management solutions and conducting feasibility design to develop a comprehensive flood management plan;
- Develop Detailed Project Reports and prepare Tender Documents for selected and prioritized flood management schemes;
- Support to I&FC Department and DMRRR to assure the sustainability for the flood risk management, including transfer of knowledge and capacity building.

The Consultant will mobilize all the efforts and dedication to achieve the work program provided in order to attain the proposed objectives and meet deadlines for the provision of services covered by this Contract. It is the Consultant intent the completion of the assigned work, as well as the accomplishment of all intermediate deadlines, although these can be adjusted in accordance to any request from the Client and, of course, in accordance to the prosecution of the work.

The proposed Work Schedule reflects the real needs, with respect to resources and their use, in view of providing the most adequate services. This can be accomplished by making available a specialized consultancy team with a vast experience in similar consultancy services, in order to achieve the main goals in a proficient and rigours way.

According to the ToR, the Assignment will be developed in the following two (2) main parts:

- **PART A - Evaluating different flood and river management solutions and conducting feasibility study to develop a comprehensive flood management plan (duration of 52 weeks)**
- **PART B - Develop Detailed Project Reports for selected and prioritized flood management projects/schemes (duration of 52 weeks)**

The methodology of the Consultant for carrying out the study, feasibility reports and detailed project report as included in the scope of work is detailed in the **Appendix A: Methodology and Technical Approach**.

3 FLOOD MANAGEMENT IN INDIA. FRAMEWORK AND BASELINE

3.1 INTRODUCTION

Flood Mitigation and Comprehensive River Management Measures for Tawi Basin need to be guided by policy frameworks for disaster risk management and integrated water resources management. This section provides an overview of the key policies, strategies and plans of Government of India and Government of Jammu and Kashmir on disaster management, flood control and integrated water resources management. Current practices of flood risk management are reviewed and potential flood risk management options are presented.

Regarding the framework at national level, the following reference documents were reviewed:

- Indus Waters Treaty, 1960
- National Water Policy, 2012
- National Disaster Management Plan, 2016

At state level (Jammu & Kashmir State), the following documents were reviewed:

- Disaster Management Policy, 2017
- Disaster Management Plan, 2017
- Water Policy and Plan, 2017

Additionally, the following opportunities and programs on flood control and water resources management were reviewed:

- Flood Management Programme 2007-2012
- Jhelum Tawi Flood Recovery Project

3.2 INDIAN POLICIES AND STRATEGIES ON FLOOD CONTROL AND WATER RESOURCES MANAGEMENT

3.2.1 The Indus Waters Treaty, 1960

3.2.1.1 Scope and objectives

The Indus Waters Treaty was established on 19th September, 1960 and was successful in ending a decade-long water dispute, which had been one of the major causes of tension between India and Pakistan since partition. The aim of the treaty was mainly to increase the amount of water availability for both countries and to distribute the water resources of the Indus Basin equitably to them.

The Indus Waters Treaty was signed in Karachi by Prime Minister of India, Jawaharlal Nehru, and President of Pakistan, Muhammad Ayub Khan and senior vice president of the World Bank, W.A.B. Liff. The Treaty was highly appreciated by the international community and was considered worldwide as a positive example of water conflict management. The Indus Waters Treaty was co-signed by the World Bank, which mediated the original dispute and assisted the two parties in reaching an agreement.

Through the Indus Water Treaty, India and Pakistan accepted the rights and obligations of each other on the use of water resources of Indus Basin. Therefore, the immediate outcome of the treaty was that the Indus Basin became politically and economically viable for both countries, promoting the independent development of the water sector.

The Indus Waters Treaty contains twelve (12) Articles and eight (8) annexures as detailed below:

Articles:

- Article I Definitions
- Article II Provisions regarding Eastern Rivers
- Article III Provisions regarding Western Rivers
- Article IV Provisions regarding Easter Rivers and Western Rivers
- Article V Financial Provisions
- Article VI Exchange of Data
- Article VII Future Cooperation
- Article VIII Permanent Indus Commission
- Article IX Settlement of Differences and Disputes
- Article X Emergency Provisions
- Article XI General Provisions
- Article XII Final Provisions

Annexures:

- Annexure A Exchange of Notes between Government of India and Government of Pakistan
- Annexure B Agricultural Use by Pakistan from certain tributaries of the Ravi
- Annexure C Agricultural Use by India from the Western Rivers
- Annexure D Generation of Hydroelectric Power by India on the Western Rivers
- Annexure E Storage of Waters by India on Western Rivers
- Annexure F Neutral Expert

- Annexure G Court of Arbitration
- Annexure H Transitional Arrangements

The treaty designates two groups of trans-boundary watercourses (Figure 3.1), namely the "Eastern Rivers" (comprising the Sutlej, Beas and Ravi rivers) and the "Western Rivers" (comprising the Indus, Jhelum and Chenab rivers).

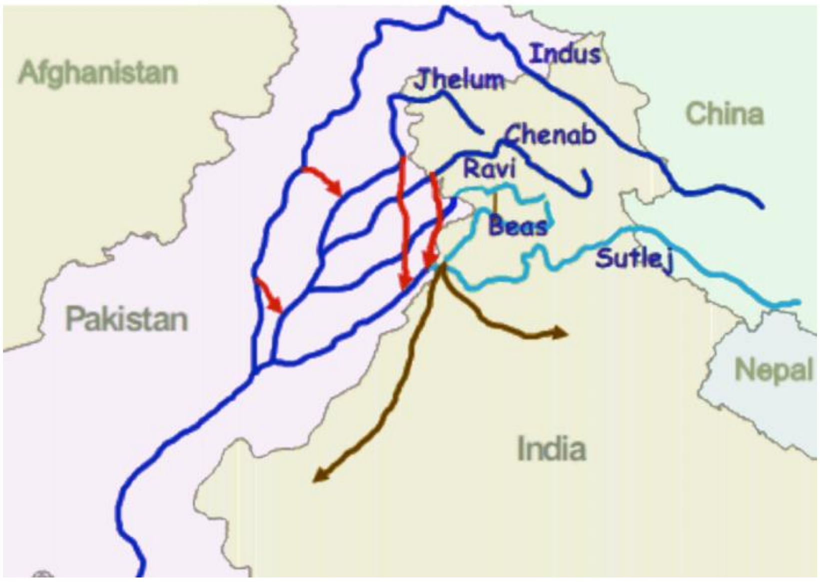


Figure 3.1: Rivers shared between India and Pakistan as per the Indus Waters Treaty. Source: https://iaskracker.com/indus-water-treaty-dispute-india-pakistan/

3.2.1.2 Relevant provisions and obligations according to the scope of the Assignment

Following the scope of the present Assignment, the Indus Waters Treaty was carefully analyzed in order to identify and scrutinize the applicable provisions and obligations that could be relevant for the specification of potential flood mitigation and river management measures for Tawi Basin.

Since the Tawi is a tributary of the Chenab River, particular attention was dedicated to the provisions and obligations of India regarding the Western Rivers, which according to the Treaty (*Article I: Definitions*) comprises the main rivers Indus, Jhelum and Chenab and their tributaries.

Therefore, the provisions and main principles of the treaty regarding the Western Rivers as per *Article III* are following quoted:

Article III - Provisions Regarding Western Rivers

(1) Pakistan shall receive for unrestricted use all those waters of the Western Rivers which India is under obligation to let flow under the provisions of Paragraph (2).

(2) India shall be under an obligation to let flow all the waters of the Western Rivers, and shall not permit any interference with these waters, except for the following uses, restricted (except as provided in item (c) (ii) of Paragraph 5 of Annexure c) 1 in the case of each of the rivers, The Indus, The Jhelum and The Chenab, to the drainage basin thereof:

(a) Domestic Use;

(b) Non-Consumptive Use;

(c) Agricultural Use, as set out in Annexure C; and

(d) Generation of hydroelectric power, as set out in Annexure D

(3) Pakistan shall have the unrestricted use of all waters originating from sources other than the Eastern Rivers which are delivered by Pakistan into The Ravi or The Sutlej, and India shall not make use of these waters. Each Party agrees to establish such discharge observation stations and make such observations as may be considered necessary by the Commission for the determination of the component of water available for the use of Pakistan on account of the aforesaid deliveries by Pakistan.

(4) Except as provided in Annexures D and E, India shall not store any water of, or construct any storage works on, the Western Rivers.

As per *Article III - Paragraph (1) and (2)*, unrestricted use of Western Rivers was appointed to Pakistan and India shall ensure the flow of all the waters of the Western Rivers with some exceptions related with the following purposes: domestic use, non-consumptive use, agricultural use and hydroelectricity generation.

According to the scope of the present Assignment, it is worth mention that flood mitigation and river management measures are considered as a *Non-Consumptive Use* as per Treaty definitions. In fact, a *Non-Consumptive Use* is defined as follows as per *Article I: Definitions*:

The term "Non-Consumptive Use" means any control or use of water for navigation, floating of timber or other property, <u>flood protection or flood control</u>, fishing or fish culture, wild life or other like beneficial purposes, provided that, exclusive of seepage and evaporation of water incidental to the control or use, the water (undiminished in volume within the practical range of measurement) remains in, or is returned to, the same river or its Tributaries ; but the term does not include Agricultural Use or use for the generation of hydro-electric power.

The *Paragraph (3)* of the *Article III* sustain that Pakistan shall have the unrestricted use of all waters originating from sources other than the Eastern Rivers and India shall not use these waters.

The *Paragraph (4)* of the *Article III* anticipates that India shall not store any water or construct any storage works on Western Rivers, except as provided in *Annexures D: Generation of Hydroelectric Power* and *Annexure E: Storage of Waters by India*.

The *Annexure D* is related with water storage for hydropower generation and therefore is not relevant according to the scope of the present Assignment. On contrary, the *Annexure E: Storage of Waters by India* provides some exceptions addressed to flood control and mitigation for Western Rivers. However, most of the exceptions related with storage water are specifically addressed to the flood control in Jhelum River. In addition, the Paragraph (7) of the *Annexure E* specifies that India cannot construct any storage reservoir for flood control purposes in Chenab river and tributaries.

Additionally, some other exceptions are included in *Paragraph (8)* of the *Annexure E* regarding the water storage by India in Western Rivers, worth noting the following:

> *(b) Any natural storage in a Connecting Lake, that is to say, storage not resulting from any man-made works.*
>
> *(c) Waters which, without any man-made channel or works, spill into natural depressions or borrow-pits during floods.*

Both exceptions are related with natural storage, particularly during floods.

Moreover, the Indus Waters Treaty also includes some provisions and obligations in the *Article IV* which are applicable for both Eastern and Western Rivers. The *Article IV* comprises fifteen (15) paragraphs. The relevant and applicable provisions of the *Article VI* according to the scope of the present Assignment are quoted below:

> ***Article IV: Provisions Regarding Eastern and Western Rivers***
>
> *(2) Each Party agrees that any Non-Consumptive Use made by it shall be so made as not to materially change, on account of such use, the flow in any channel to the prejudice of the uses on that channel by the other Party under the provisions of this Treaty. In executing any scheme of flood protection or flood control each Party will avoid, as far as practicable, any material damage to the other Party, and any such scheme carried out by India on the Western Rivers shall not involve any use of water or any storage in addition to that provided under Article III.*

(3) Nothing in this Treaty shall be construed as having the effect of preventing either Party from undertaking schemes of drainage, river training, conservation of soil against erosion and dredging, or from removal of stones, gravel or sand from the beds of the Rivers : Provided that

(a) in executing any of the schemes mentioned above, each Party will avoid, as far as practicable, any material damage to the other Party ;

(b) any such scheme carried out by India on the Western Rivers shall not involve any use of water or any storage in addition to that provided under Article III ;

(6) Each Party will use its best endeavours to maintain the natural channels of the Rivers, as on the Effective Date, in such condition as will avoid, as far as practicable, any obstruction to the flow in these channels likely to cause material damage to the other Party.

(8) The use of the natural channels of the Rivers for the discharge of flood or other excess waters shall be free and not subject to limitation by either Party, and neither Party shall have any claim against the other in respect of any damage caused by such use. Each Party agrees to communicate to the other Party, as far in advance as practicable, any information it may have in regard to such extraordinary discharges of water from reservoirs and flood flows as may affect the other Party.

As per Paragraphs (2), (3), (6) and (8) of the *Article IV*, flood control and river training works in Eastern and Western Rivers could be executed by both parties (India and Pakistan) whereas they (i) avoid any material damages for the other party, (ii) do not use of water or any storage, (iii) maintain the natural channels of the Rivers, (iv) avoid any obstruction to the flow in the rivers and (v) consider the use of the natural channels for discharge of flood.

Therefore, these provisions and obligations shall definitely be considered for the planning and design of flood mitigation and river management measures for Tawi Basin.

Finally, it is also worth noting that the Indus Waters Treaty also recognizes the interest of India and Pakistan in the optimum development of rivers, and accordingly privileges the cooperation and collaboration between the two countries. In this context, the *Articles VI* and *VII* of the Treaty deal with the “exchange of data” and “future cooperation” respectively. Specifically, the *Article VII: Future Co-operation* appeals for the cooperation in undertaking engineering works on the rivers.

3.2.1.3 Summary and comments

As previously described, the main goal of the treaty was to manage the amount of water available in India and Pakistan, trying to distribute the water resources of the Indus Basin equitably. Therefore, most of the provisions and obligations were specified for water resources management in trans-boundary rivers during “normal” flow conditions.

In fact, only a few provisions are specifically addressed to extreme hydrological events (such as floods and droughts) and flood control and mitigation. In this regard, it is worth noting that some exceptions for flood control for Western Rivers were defined, however most of them are exclusively addressed to the Jhelum River.

The provisions and obligations for flood control specified in the Indus Waters Treaty which are pertinent to Tawi River are considered general and broad principles (*e.g.* avoid obstructions, maintain natural channels, avoid damages to downstream).

In conclusion, the flood mitigation and river management measures for Tawi Basin shall be planned and specified taking into consideration the following particular provisions, constrains and obligations as per Indus Waters Treaty:

- river training works for the purposes of flood protection (population and land) and erosion control (dikes, embankments, spurs) are permitted;
- river management solutions such as conservation of soil against erosion, dredging or removal of stones, gravel or sand from the river beds are permitted;
- the construction of works for temporary water storage, even only during the flood period (flood storage dams, weirs, artificial reservoir) is not permitted;
- the flood and river management measures shall be planned and executed aiming at:
  - measures shall avoid significant obstructions to the river flow;
  - maintaining the natural channel as much as technically feasible;
  - consider the use of the natural channels for discharge of flood;
  - consider the use of natural storage, natural depressions, wetlands, etc during floods;
  - not result in any artificial storage works that could permanently storage water;
  - avoid any material damages to downstream streams.

3.2.2 National Water Policy, 2012

The National Water Policy (NWP, 2012) presents the scenario of water resources and their management in India and highlighted the concern on water related disasters as follows:

"There is wide temporal and spatial variation in availability of water, which may increase substantially due to a combination of climate change, causing deepening of water crisis and incidences of water related disasters, i.e., floods, increased erosion and increased frequency of droughts, etc."

The NWP has set certain basic principles in dealing with planning, development and management of water resources, such as, *"All the elements of the water cycle, i.e., evapo-*

transpiration, precipitation, runoff, river, lakes, soil moisture, and ground water, sea, etc., are interdependent and the basic hydrological unit is the river basin, which should be considered as the basic hydrological unit for planning."

For adaptation to climate change, the policy has emphasized to adopt climate resilient technological options. Some of those are as follows:

- The anticipated increase in variability in availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely, soil moisture, ponds, ground water, small and large reservoirs and their combination. States should be incentivized to increase water storage capacity, which inter-alia should include revival of traditional water harvesting structures and water bodies.
- Planning and management of water resources structures, such as, dams, flood embankments, tidal embankments, etc., should incorporate coping strategies for possible climate changes. The acceptability criteria in regard to new water resources projects need to be re-worked in view of the likely climate changes.

The NWP has highlighted the following measures for management of flood and droughts.

- While every effort should be made to avert water related disasters like floods and droughts, through structural and non-structural measures, emphasis should be on preparedness for flood / drought with coping mechanisms as an option. Greater emphasis should be placed on rehabilitation of natural drainage system.
- In order to prevent loss of land eroded by the river, which causes permanent loss, revetments, spurs, embankments, etc., should be planned, executed, monitored and maintained on the basis of morphological studies. This will become increasingly more important, since climate change is likely to increase the rainfall intensity, and hence, soil erosion.
- Flood forecasting is very important for flood preparedness and should be expanded extensively across the country and modernized using real time data acquisition system and linked to forecasting models. Efforts should be towards developing physical models for various basin sections, which should be linked to each other and to medium range weather forecasts to enhance lead time.
- Frequency based flood inundation maps should be prepared to evolve coping strategies, including preparedness to supply safe water during and immediately after flood events. Communities need to be involved in preparing an action plan for dealing with the flood/ drought situations.
- To increase preparedness for sudden and unexpected flood related disasters, dam/ embankment break studies, as also preparation and periodic updating of emergency action plans / disaster management plans should be evolved after involving affected

communities. In hilly reaches, glacial lake outburst flood and landslide dam break floods studies with periodic monitoring along with instrumentation, etc., should be carried out.

3.2.3 National Disaster Management Plan, 2016

Riverine flooding is perhaps the most critical climate-related hazard in India. Flood control is a key element of national policies for water resource management. The occurrence of floods and droughts is closely linked to the summer monsoon activity. Floods occur in almost all river basins of the country. Heavy rainfall, inadequate capacity of rivers to carry the high flood discharge, inadequate drainage to carry away the rainwater quickly to streams/rivers are the main causes of floods. Ice jams or landslides blocking streams; and cyclones also cause floods. Out of 40 million hectare of the flood prone area in the country, on an average, floods affect an area of around 7.5 million hectare per year (NDMP, 2016).

The communities settled in river basins are predominantly dependent on agriculture. They are subjected to extremes of rainfall - very high rainfall and very low rainfall. They are therefore most vulnerable to riverine flooding and also to food shocks during droughts. These are two of the main problems i.e. floods and food insecurity. The Himalayan Rivers are fed by the melting snows and glaciers of the great Himalayan range during spring and summer as well as by rains during monsoons. They are often uncertain and capricious in their behaviour.

In 2016, the Government of India formulated 'National Disaster Management Plan' in line with Sendai Framework for Disaster Risk Reduction 2015-2030. The plan has incorporated the four priorities enunciated in the Sendai Framework for Disaster Risk Reduction under the following five Thematic Areas for Action:

1. Understanding Risk
2. Inter-Agency Coordination
3. Investing in DRR – Structural Measures
4. Investing in DRR – Non-structural Measures
5. Capacity Development

The major themes for actions for understanding disaster risk are:

a) Observation Networks, Information Systems, Research, Forecasting,
b) Zoning / Mapping,
c) Monitoring and Warning Systems,
d) Hazard Risk and Vulnerability Assessment (HRVA), and

e) Dissemination of Warnings, Data, and Information

The major themes for actions for inter-agency coordination are:

a) Overall disaster governance,

b) Response,

c) Providing warnings, information, and data and

d) Non-structural measures

Undertaking necessary structural measures is one of the major thematic areas for action for disaster risk reduction and enhancing resilience. These consist of various physical infrastructure and facilities required to help communities cope with disasters.

The non-structural measures comprising of laws, norms, rules, guidelines, and techno-legal regime (e.g., building codes) frameworks empower the authorities to mainstream disaster risk reduction and disaster resilience into development activities.

The capacity development includes training programs, curriculum development, large-scale awareness creation efforts, and carrying out regular mock drills and disaster response exercises. The capability to implement, enforce, and monitor various disaster mitigation measures has to be improved at all levels from the local to the higher levels of governance.

The Government of India (GoI) has designated Central Water Commission (CWC) responsible for national flood early warning system. The relevant State Government and district administration shall disseminate the alerts and warnings on the ground through all possible methods of communications and public announcements. The Ministry of Home Affairs is the central ministry for coordination of response at national level.

3.3 CURRENT FLOOD MANAGEMENT STRATEGIES ON JAMMU AND KASHMIR STATE

3.3.1 Disaster Management Policy, 2017

The Jammu and Kashmir State Disaster Management Policy aims to mainstream disaster risk reduction into all developmental initiatives to ensure sustainability of investments and minimize the losses due to disasters by taking all necessary measures. It takes a holistic and integrated approach based on inter-sectoral coordination, capacity development of all stakeholders at all levels and in all sectors, community participation, and cooperation and coordination with other agencies (SDMP, 2017).

The institutional mechanism for disaster management at state level includes State Disaster Management Authority (SDMA), the State Executive Committee (SEC), Divisional Disaster Management Authority (Div. DMA) and District Disaster Management Authorities (DDMAs).

The State Disaster Response Force (SDRF) has also been established for effective search, rescue and relief during the disaster. The various stakeholders that play key roles in disaster risk reduction and management are the following.

i) All concerned departments of the State Government and Central Government agencies, present in the State
ii) State, Divisional & District Disaster Management Authorities
iii) Local authorities such as ULBs, PRIs
iv) Fire & Emergency Services
v) Health & Medical Education Department
vi) Public sector undertakings, Corporate Sector, Hoteliers & other allied organizations
vii) State Police & Central Para Military Forces
viii) Armed Forces
ix) Indian Air Force
x) Airport Authority of India
xi) Indian Railways
xii) National Disaster Response Force
xiii) State Disaster Response Force
xiv) Civil Defence & Home Guard Volunteers
xv) Voluntary and Civil Society Organizations
xvi) Indian Red Cross Society
xvii) Multilateral aid agencies and UN agencies
xviii) Community
xix) Print & Electronic Media, and
xx) Others

The Department of Disaster Management, Relief, Rehabilitation and Reconstruction (DMRRR) is the nodal department for coordinating all activities related to Disaster Management in the State. The Irrigation & Flood Control (IFC) Department is the nodal department for disasters related to floods and dam bursts, including Glacial Lake Outburst Flood (GLOF).

The policy has highlighted various key activities in pre-disaster, during disaster and post-disaster phase. The key activities in pre-disaster phase are the following:

i) Hazard, Vulnerability and Risk Assessment
ii) Linking disaster risk reduction and development
iii) Preparation of disaster management plans
iv) Disaster Resource Network
v) Strengthening of lifeline infrastructure

vi) Early warning and forecasting system
vii) Incident Response System
viii) Community based disaster management
ix) Funding mechanism

The key activities in disaster response phase are the following:

i) Implementation & operationalisation of Disaster Management Plans
ii) Evacuation, search and rescue
iii) Essential services
iv) Restoration of essential services
v) Maintenance of law and order
vi) Immediate relief
vii) Damage and Needs assessment

The key activities in post-disaster phase are the following:

i) Damage and need assessment and estimation of funds
ii) Socio-economic rehabilitation
iii) Physical reconstruction
iv) Project Management

3.3.2 Disaster Management Plan, 2017

The Government of Jammu & Kashmir has enacted state disaster management plan in 2017. The plan has set a vision of building safe and disaster resilient Jammu and Kashmir. The objectives of the state disaster management plan are the following:

a) To protect the lives of people in Jammu and Kashmir from any kind of natural disasters.
b) To minimize the suffering of vulnerable population and the loss of property/ infrastructure in the State due to disasters.
c) To achieve maximum efficiency in reducing vulnerability of people to disasters in the State.
d) To promote a culture of disaster resilience in the State.
e) To design appropriate prevention and mitigation strategies across various levels of stakeholders in the State.
f) To enhance the capacities of all relevant stakeholders in disaster risk reduction.
g) To mainstream disaster risk reduction as integrated component of development planning in the State.
h) To nurture and establish efficient disaster response/relief mechanism in the State.

i) To provide clarity on roles and responsibilities for all stakeholders concerned with disaster response and recovery.

j) To ensure co-ordination and promoting constructive partnership with all other agencies related to disaster management.

The plan envisages the development and implementation of a **policy framework** on disaster risk reduction from a holistic perspective, which emphasises on prevention, mitigation and preparedness in pre-disaster phase. This requires the

(i) establishment of the **mitigation fund** for the State;
(ii) raising **awareness for disaster risk reduction** at all levels and
(iii) **improving preparedness** amongst all stakeholders using optimized and accessible **Information and Communication Technology** Systems.

The prevention and mitigation strategies should be both structural and non-structural. The plan has recommended the following structural mitigation strategies (SDM Plan, 2017):

- Land use planning
- Infrastructures for disaster management
- Adaptation of new/appropriate technology

The non-structural mitigation strategies are the following:

- Mainstreaming disaster management in development programmes
- Techno-legal regime
- Planning
- Capacity building
- Safety audit

The plan has also recommended hazard specific strategies. The structural mitigation strategies for floods are the following:

- Fortification of weak embankments and vulnerable points
- Construction of emergency flood ways and river diversions
- Improvement of design for irrigation and flood protective structures
- Construction of dams, flood protection wall, flood diverting channels etc.
- Construction of barrages
- Construction of shelters
- Establish infrastructure for flood monitoring and warning
- Channel improvement
- Flood proofing

- Afforestation and watershed management
- Regular clearance of drains from silt and weeds
- Strengthening/ repair of existing roads and bridges and other critical infrastructures
- Restore natural drainage blocked by roads and canals
- Construction of Small reservoirs, Check dams, ponds etc.

However, all the above-mentioned measures should comply with the provisions and obligations of the Indus Water Treaty whenever applicable.

The non-structural mitigation strategies for floods are the following:

- Strengthening and upgrading of existing flood forecasting and warning system
- Enactment and enforcement of laws regulating developmental activities in flood plain
- Regulate construction near / along water way
- Ensure Flood plain zoning
- Enforce building by-laws for flood plains
- Adopt appropriate measures to assess damage/loss
- Regulate development and redevelopment policies in flood prone areas
- Prepare contingency plan
- Prepare flood management plans

The plan has recommended the following immediate, short term and long term measures for flood risk reduction.

Immediate Measures:

- Closing of breaches
- Development of Flood Forecasting and Warning System

Short Term Measures:

- Raising/Strengthening of existing embankments
- Enhancement of carrying capacity of existing Foods Spill Channels
- Dredging of Out Fall Channel to increase its carrying capacity
- Setting up of Rapid Action Dewatering Facilities in urban areas
- Establishment of adequate emergency response measures and rescue areas

Long Term Measures:

- Additional supplementary Flood Spill Channel
- Creation of Storage

- Development and Enhancing the Storage Capacity of Lakes
- Flood Plain Zoning
- Sewage/ Solid waste management
- Afforestation and watershed protection
- Weather and flood forecasting

3.3.3 Water Policy and Plan, 2017

The Jammu and Kashmir State Water Policy and Plan (SWP, 2017) has highlighted that there are challenges of frequent floods and droughts in one or the other part of the state. The objective of the State Water Policy and Plan is to put optimum use of the scarce water resource by taking cognizance of the existing situation. The plan has stated the following policy on flood management.

"Detailed guidelines shall be notified for preparation of a master plan for flood prone areas with a view to indicating the measures to control the floods and providing protection against the floods with flood forecasting to be given timely warnings to the people. Further, measures shall be taken to protect the natural drainage systems by removing artificial barriers/ encroachments in the path of flow of excess drainage water."

3.4 OPPORTUNITIES AND PROGRAMS IN INDIA ON FLOOD CONTROL AND WATER RESOURCES MANAGEMENT

3.4.1 Flood Management Programme 2007-2012

Government of India assisted the flood prone states in flood management and anti-erosion works for critical reaches, by providing financial assistance to the state Governments through a number of Centrally Sponsored Schemes.

In order to provide financial assistance to the State Governments for undertaking Flood Management works in critical areas during the 11th Plan period (2007-2012), a state sector scheme, namely, "Flood Management Programme" (FMP) was launched by Ministry of Water Resources under Central Plan, at a total cost of Rs.8000 crores which was approved by the Cabinet on 01-11-2007 (FMP, 2007).

In Jammu and Kashmir State, the scheme was also launched and, accordingly, in Jammu Division, eight Flood Management Programmes were undertaken by the Department of Irrigation and Flood Control with the objective of providing relief from floods by executing Flood protection works, anti-erosion works and improvement in drainages of the rivers/nallahs.

Two Flood Management Projects namely FMP Project on river Tawi and Chenab were started during 2007-08 and remaining six Flood Management Projects were started during 2008-09. These included flood protection works on river Tawi, river Chenab, river Ujh, flood protection works on major and minor nallah in Rajouri, flood protection works at Banganga, Dibber nallah at Chenani, left/right banks at river Tawi on Sidra Town and River Dera Baba Banda. The following three major activities were undertaken for flood protection in Tawi River of Jammu division.

1. Construction of earth embankments about 21 Km.
2. Construction of Crate revetments about 21 Km.
3. Construction of Studs/Spurs 108 nos.

Some portions of land not covered by this project are the villages namely Chak Desa Singh, Wazirachak, Tope, Lakshampura, Sumb, Sampuranpur Kullian, Indru De kothey and other adjoining villages. The gaps left in embankment/revetment allow the water to enter into the villages thereby causing flood situations.

3.4.2 Jhelum Tawi Flood Recovery Project

Following the frequent and severe problems of flooding and inundation in the Tawi River Basin, the Government of India / Government of Jammu and Kashmir has requested assistance from the World Bank. Consequently, the Government of Jammu and Kashmir has received financing from the International Development Association (IDA) in the form of a credit for the development of an emergency project named **Jhelum Tawi Flood Recovery Project**.

The project aims at restoring critical infrastructure using international best engineering practices on resilient infrastructure. Since the region is highly vulnerable to both floods and earthquakes, the project is focused on ensuring the adequate design of infrastructures with upgraded resilient features, including contingency planning for future disaster events as well. Therefore, the project is focused by one hand to restore essential services disrupted by the floods and the other to improve the design standards and practices to increase resilience.

Specifically, the project involves seven main components, including: 1) Reconstruction and strengthening of critical infrastructure; 2) Reconstruction of roads and bridges; 3) Restoration of urban flood management infrastructure; 4) Restoration and strengthening of livelihoods; 5) Strengthening disaster risk management capacity; 6) Contingent Emergency Response; and 7) Implementation Support.

Accordingly, the present Assignment "*Consultancy services for preparing feasibility and detailed project report for flood mitigation and comprehensive river management measures* *for Tawi basin*", is included in the scope of the *Component 5) Strengthening disaster risk management capacity* and therefore will include the planning and design of innovative and effective measures, aiming to manage flows through river channels works and enhancement of the effective flood risk management to reduce the incidence of severe floods and provide protection to people, houses, public infrastructure, and agricultural land in Tawi river basin. This initiative is consistent with the government's and WB's priorities for enhancing climate resilience, ensuring food security and promoting inclusive economic growth.

As per Financial Agreement between India and IDA for the Jhelum Tawi Flood Recovery Project, the amount of financing allocated was $250.00 M, for the following components:

- Reconstruction and strengthening of critical infrastructure: $60.00 M
- Reconstruction of roads and bridges: $80.00 M
- Restoration of urban flood management infrastructure: $50.00 M
- Restoration and strengthening of livelihoods: $15.00 M
- Strengthening disaster risk management capacity: $25.00 M
- Implementation Support: $20.00 M

4 RELEVANT BASELINE STUDIES, REPORTS AND GUIDELINES

4.1 INTRODUCTION

This chapter presents the review of the relevant studies and reports, including national and global studies in similar river systems. The comprehensive review aimed at perform a preliminary assessment of major findings, existing data, proposed solutions, main risks and constrains, etc, from previous studies, supporting the assessment of potential solutions for flood and erosion mitigation in the Tawi River Basin. Therefore, the following studies were reviewed in detail:

- Prefeasibility report and reconnaissance survey for flood management in Tawi River
- Project “REFORM” (REstoring rivers FOR effective catchment Management)
- Retrospective and Prospective of 2014 Kashmir Floods for Building Flood Resilient Kashmir
- A Satellite Based Rapid Assessment on Floods in Jammu & Kashmir – September, 2014
- Bangladesh: Main River Flood and Bank Erosion Risk Management Program

Additionally, a review of the relevant national guidelines and handbooks was also conducted in order to ensure the effective and accurate feasibility and detailed design of flood mitigation and river management solutions for Tawi River Basin. The review included the following documents:

- National Disaster Management Guidelines - Management of Floods
- National Disaster Management Guidelines – Community Based Disaster Management
- Guidelines for Preparation of DPR for Flood Management Projects
- General Guidelines for Preparing River Morphological Reports
- Handbook for Flood Protection, Anti-Erosion & River Training Works

Finally, the identification of the pertinent national design codes was also carried out and is presented in this Chapter.

4.2 RELEVANT BASELINE STUDIES AND REPORTS

4.2.1 Retrospective and Prospective of 2014 Kashmir Floods for Building Flood Resilient Kashmir

Following the acknowledgement that future flood strategies shall benefit from lessons learned regarding September 2014 floods, a national seminar was held at Srinagar from

15-16 November 2014, organised jointly by the Department of Earth Sciences, Kashmir University and Centre for Dialogue and Reconciliation (CDR).

The Seminar was entitled: "Retrospective and Prospective of 2014 Kashmir Floods for Building Flood Resilient Kashmir".

Several experts from different areas attended the Seminar, worth noting the following participants:

- **Central Agencies**: Central Water Commission (CWC), National Institute of Hydrology, National Geophysical Research Institute, Central Groundwater Board, National Disaster Management Authority, NRSC/ISRO and National Green Tribunal, India Meteorological Department (IMD)
- **State Government Agencies:** Irrigation and Flood Control (I&FC), Public Health Engineering (PHE), Rural Development, LAWDA, Srinagar Development Authority, IMPA, Agriculture Department,
- **Academic institutions:** Kashmir University, Indian Institute of Technology-Roorkee, National Institute of Technology-Srinagar, Jammu University
- **Other segments of the civil society**.

According to the national Seminar **Retrospective and Prospective of 2014 Floods for Building Flood Resilient Kashmir** and respective Report published on April 2015, several recommendations were specifically defined for the Jhelum River, being however in agreement with the solutions proposed by I&FC Department for the Tawi River Basin.

The Report highlights some urgent short and long-term recommendations (some of them specifically addressed to Jhelum River Basin but which are also found necessary for Tawi River Basin), worth noting the following:

Short-term and Urgent Recommendations:

- ***Knowledge driven all-inclusive multidisciplinary flood planning*** *needs to be initiated*
- ***Strengthening the flood infrastructure in the Jhelum Basin*** *to cope up with the probability of next extreme flooding event of the magnitude observed in 2014.*
- *The government, with the help of academia/research institutes, must consider undertaking a* ***scoping study to assess the probability of flooding in immediate future***
- ***Urgently operationalising the Flood Early Warning System (FEWS)*** *for Jhelum and Chenab*
- *The State Government must initiate on priority (with the help of leading academic institutions), to* ***undertake transparent flood zonation and flood vulnerability assessments*** *of people and places at village level so that the flood risk reduction is integrated with developmental planning at village level in all District Development Plans.*

- *Government consider assigning proposals for bringing the **technical ingenuity of the Irrigation & Flood Control in operationalising of FEWS, basin wide IFM and flood scenario mapping**.*

Urgent Long-term Recommendations:

- ***Strengthening of flood control infrastructure***
- *Initiating a massive capacity building program for **building public awareness and soliciting public involvement in flood risk reduction***
- ***Structural and non-structural erosion control measures**.*
- ***Consolidation of the fragmented data and knowledge into a database** so that it is available to everybody for use on understanding the hydrological and meteorological processes and phenomena in the state.*

Long-term Recommended Measures:

- *The government needs to initiate programs aimed at **conversation and restoration of the degraded wetlands***
- ***Improving the drainage system in the urban areas** of the Jhelum Basin including the restoration of natural drainages wherever possible*
- ***Structural and non-structural measures** be initiated under the supervision of I&FC **for erosion control***

The previously mentioned recommendations and measures resulting from the Seminar will be taken into consideration for the planning and design of flood mitigation and river management measures for Tawi Basin.

Actually, most of the recommendations and measures are found completely relevant, being in line with the emerging Integrated Flood Management (IFM) approach as presented in the **Chapter 7**. In fact, some innovative initiatives were suggested by the Experts for the effective flood management during the Seminar, being stated that "*structural measures for flood control are not always the best possible solution"* and therefore "*the State Government must think of utilizing non-structural measures as well"*.

In this context, it was particularly emphasised the need of planning and operationalization of the Flood Early Warning System (FEWS), being asserted that the IMD has already sanctioned Doppler weather system for the Jammu and Kashmir State that would facilitate weather nowcasting system in the state.

4.2.2 A Satellite Based Rapid Assessment on Floods in Jammu & Kashmir – September, 2014

Jammu & Kashmir experienced extreme floods during first week of September 2014, due to unprecedented and intense rains. On 4th September 2014, J&K experienced 30 hour long rainfall. Some parts of the state experienced more than 650 mm of rainfall in 3 days. In Jammu region such huge rainfall was earlier recorded in 1903, 1908, 1926, 1942 and 1988. The Jhelum River, Tawi River and its tributaries were in spate and caused extensive flooding in the region. A number of landslides have also been triggered by this event.

The Decision Support Centre (DSC) of NRSC in collaboration with Department of Environment & Remote Sensing, J&K took necessary action on satellite data acquisition and processing and kept a close watch on the flood situation. All possible data from Indian Remote Sensing (IRS) satellites, as well as foreign satellites, covering Kashmir valley were obtained and analysed. Rapid flood mapping and monitoring was done on almost daily basis and the flood inundation information was prepared. In addition, cumulative flood inundation, flood progression and recession maps were also prepared for Jhelum River in Kashmir valley (Chugh and Farooq, 2014).

The study presented preliminary observations from Post event LISS IV data (9th September, 2014) showing a number of landslides near the north of Rajouri and Mahore areas of Jammu region however the flooding in the Tawi River, in Jammu region was not consider..

Some of the recommendations of the study to minimize the flood risks, which are also valid for flood management in the Tawi River, are as follows:

1. Strengthening of existing bunds and embankments
2. Improvement of river channel by a comprehensive desiltation program
3. Development of a flood risk zonation map
4. Improvement of natural drainage networks
5. Monitoring of sediment loads
6. Monitoring of land use/ land cover of the river basin
7. River monitoring, forecasting and warning system
8. Formulate preparedness plan, required policies
9. Institutional strengthening and capacity building
10. Reconstruction of damaged infrastructure
11. Relocation of vulnerable populations
12. Restoration of wetlands
13. Regulation of future development

The study also highlighted that the rate of these kinds of extreme events is likely to increase in future. Climate change projections for the 2030s indicate that the number of rainy days in the Himalayan region may increase by 5–10 days on an average. They will increase by more than 15 days in Jammu and Kashmir. The intensity of rainfall is likely to increase by 1–2 mm/day. The PRECIS run for 2030's indicate that annual rainfall in the Himalayan region is likely to increase in 2030s with respect to 1970s range from 5% to 13% with some areas of Jammu and Kashmir showing an increase up to 50%.

4.2.3 Prefeasibility report and reconnaissance survey for flood management in Tawi River

The pre-feasibility report and renaissance survey for flood management in Tawi River was prepared by WAPCOS Limited and was submitted to the I&FC Department on 1999.

Besides presenting some relevant findings and analysis, the Report is considered by the I&FC Department incomplete and inconclusive.

The access to the Report is restricted and therefore a letter of authorization has already been prepared and submitted by the Consultant to the PMU/JTFRP Technical Director, in order to obtain an approval from the Chief Engineer of I&FC Department for the propose of document access and share.

The review and analysis of the Report will be conducted after receiving the access and share authorization and will be included in a next version of this Inception Report or in other next reports.

4.2.4 Bangladesh: Main River Flood and Bank Erosion Risk Management Program

Bangladesh lies in the delta of Ganges-Bramhaputra-Meghna river basin and is prone to river flooding during monsoon season. The flooding situation is further exacerbated by riverbank erosion, similarly with the case of Tawi River. The growing population and increasing economic activities have exposed more people and assets to the flood risks.

A feasibility study on “Main River Flood and Bank Erosion Risk Management Program” was conducted by Northwest Hydraulic Consultant in association with Resource Planning & Management Consultants Ltd. under the Asian Development Bank's Project Preparatory Technical Assistance 8054-BAN (ADB, 2013). The study was conducted to formulate an investment program for addressing acute riverbank erosion and related flood issues along the main rivers of central Bangladesh from Bangabandhu Bridge (Jamuna Bridge) to Chandpur to be implemented by Bangladesh Water Development Board (BWDB).

The proposed program is based on an integrated approach combining flood and riverbank erosion risk management. The program includes structural measures, extensive non-structural activities, and institutional strengthening. The principal measures consist of riverbank protection and local planning to reduce flood risk and increase preparedness, supported by flood risk mapping and early warning during flood seasons with information understandable by the rural population.

Existing embankment lines will be protected along critically eroding riverbanks and gaps will be closed where the embankments have been eroded. The proposed rehabilitated or reconstructed embankments will include side roads to permit better monitoring and response to floods, and to improve the connectivity of the local population to market and urban centres. It is proposed that embankment works should be constructed only after the river banks are stabilized.

The proposed program has three main components:

Component 1: Institutions, Knowledge & Plans

Sub-component 1: Institutional Capacity

Sub-component 2: Knowledge Base

Sub-component 3: Planning

Component 2: Implementation of the Works

Sub-component 1: Structural measures

Sub-component 2: Non-structural measures

Sub-component 3: Participatory Operation & Maintenance

Sub-component 4: Social development and safeguards

Component 3: Project Management

A total of 50 km of riverbank protection, 53 km of embankment rehabilitation, and 36 km of embankment reconstruction or new construction are planned. In addition, more than one million people living in flood risk areas along the main rivers are expected to be supported by a community based flood risk management program organized through the Department of Disaster Management (DDM). Institutional strengthening will largely focus on improving the knowledge base and planning tools for managing critical river reaches, particularly within the planned River Management Wing in BWDB.

The feasibility study was based on a broad range of latest available and historic data including socioeconomic data, systematic satellite imagery from 1973 until 2012, the latest infrastructure and digital elevation information, a broad range of field data specifically collected for safeguards related surveys in the priority subproject areas, and cost estimates based on 2013 market rates and BWDB's schedule of rates.

The feasibility study of Main River Flood and Bank Erosion Risk Management Program in Bangladesh is a good reference for preparing feasibility report for flood mitigation and comprehensive river management measures for Tawi basin. The proposed programs of the feasibility study are equally relevant to Tawi basin.

4.2.5 Project "REFORM" (REstoring rivers FOR effective catchment Management)

4.2.5.1 Project overview

The project REFORM (*REstoring rivers FOR effective catchment Management*) was a large-scale integrating project funded by the European Commission within the 7th Framework Programme, which aimed to investigate natural, degradation and restoration processes in large European rivers and consequently generate tools for cost-effective restoration of river ecosystems, and to improve the monitoring of the biological effects of physical.

This R&D project was developed between November, 2011 and October, 2015 and had the participation of several research institutes and partners from 15 European countries, representing a wide range of relevant disciplines such as: hydrology, hydraulics, geomorphology, ecology, socio-economics and water management.

The REFORM project was organized in three modules (natural processes, degradation and restoration) and eight work packages (WP) as presented in the Figure 4.1.

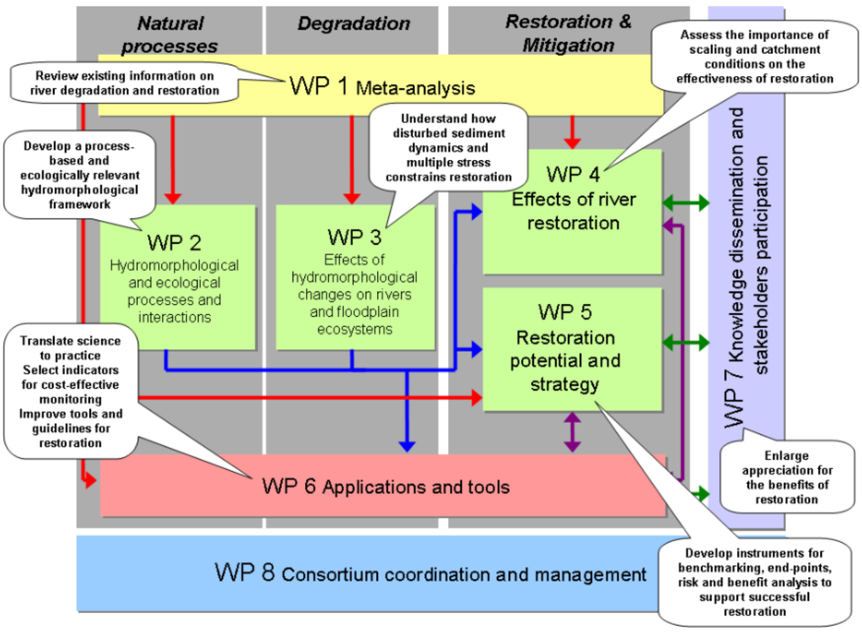


Figure 4.1: REFORM project approach and outcomes

The developed work packages were the following:

- WP1: Meta-analysis
- WP2: Hydromorphological and ecological processes and interactions
- WP3: Effects of hydromorphological changes on river and floodplain ecosystems
- WP4: Effects of river restoration
- WP5: Restoration potential and strategy
- WP6: Applications and tools
- WP7: Knowledge dissemination and stakeholder participation
- WP8: Consortium coordination and management

The project emerged from the acknowledgment of the increasing need of better understand and predict the costs and benefits of future river restoration, particularly following the increasing application of programmes of measures by the EU Member States that have a strong emphasis on restoring river hydrology and morphology.

Actually, recent analysis indicates that a significant number of European rivers are affected by hydromorphological pressures mostly caused by drivers such as urban development, navigation, agriculture, hydropower and flood protection.

Therefore, the REFORM project is particularly addressed to identify cost-effective hydromorphological restoration measures to reach target ecological status in highly modified and human-engineered rivers and systems, wherein severe degradation of water quality and ecosystem functions are observed.

In this context, it is worth nothing that most of the pressures currently identified in European Rivers (*e.g.* hydropower, navigation, longitudinal discontinuity due to dams construction) are not observed in Tawi River. Nevertheless, since river and flood management measures shall definitely consider synergies between river restoration and flood protection, some of the findings and results of the REFORM project are extremely relevant and therefore will be taken into consideration for the present study.

Actually, the current recommendations in the European Floods Directive (2007/60/EC) recommend that decision-makers and planners should consider natural measures or a combination of engineered structures and natural solutions more proactively for flood mitigation and control. Specifically, the EU Floods Directive recommend the application of river restoration measures through improved retention, storage and discharge (*e.g.* retention in tributaries and upstream wetlands, storage in enlarged active floodplains, discharge through side channels) which can have significant effects in reducing flood risks.

Furthermore, REFORM project also highlights that river restoration with green infrastructures are particularly relevant for reducing flood risk, especially in terms of floodplain restoration measures. In this context, the **Chapter 7** presents some commonly applied natural solutions and green infrastructures for flood control and mitigation that can be potentially applied in Tawi River Basin.

4.2.5.2 Objectives

The main objectives of the REFORM project were to provide a framework for improving the technical and economic benefits of hydromorphological restoration measures and to assess more effectively the state of rivers, floodplains and connected groundwater systems.

Particularly, the project aimed at generate tools for cost-effective restoration of river ecosystems, and for improved monitoring of the biological effects of physical change by investigating natural, degradation and restoration processes in a wide range of river types across Europe.

The developed restoration framework addresses the relevance of dynamic processes at various spatial and temporal scales, the need for setting end-points, analysis of risks and benefits, integration with other societal demands (*e.g.* flood protection and water supply), and resilience to climate change.

The REFORM project objectives were grouped into three different categories: application, research and dissemination. Regarding to practical and engineering application purposes, the particular objectives were defined as follows:

- select hydromorphological and biological indicators that comply with the EU Water Framework Directive (WFD)[1] aiming for a cost-effective monitoring that can characterize the consequences of physical degradation and restoration in rivers and their services.
- evaluate and improve practical tools and guidelines for the design of cost-effective hydromorphological restoration and mitigation measures for practitioners and end-users.

[1] The Water Framework Directive (WFD) 2000/60/EC is an EU directive which commits European Union member states to achieve good qualitative and quantitative status of all water bodies, including marine waters up to one nautical mile from shore.

4.2.5.3 Case studies of large river regulation and rehabilitation in Europe

4.2.5.3.1 Presentation of the case studies

According to the objectives of the REFORM project, a synthesis of pressures, restoration experiences and variables suited for monitoring restoration were analyzed and compiled for different types of rivers across Europe. Therefore, six case studies were described, addressing hydrological modifications and restorations. This analysis of large rivers across Europe was used to underpin and illustrate the state-of–the-art regarding the effectiveness and potential of large river rehabilitation.

The selected case studies were found representative of various European conditions with regard to climate, hydromorphological characteristics and catchment size. Therefore, the case studies are located in three different biogeographical regions in Europe and six countries as follows:

- Atlantic region:
  - River Trent (United Kingdom)
  - Delta Rhine (Netherlands)
- Continental region:
  - Middle Vistula River (Poland)
  - Lower Danube and Danube Delta (Romania)
  - Po River (Italy)
- Mediterranean region:
  - Middle Ebro River (Spain)

The Figure 4.2 presents the catchments of the six case studies.

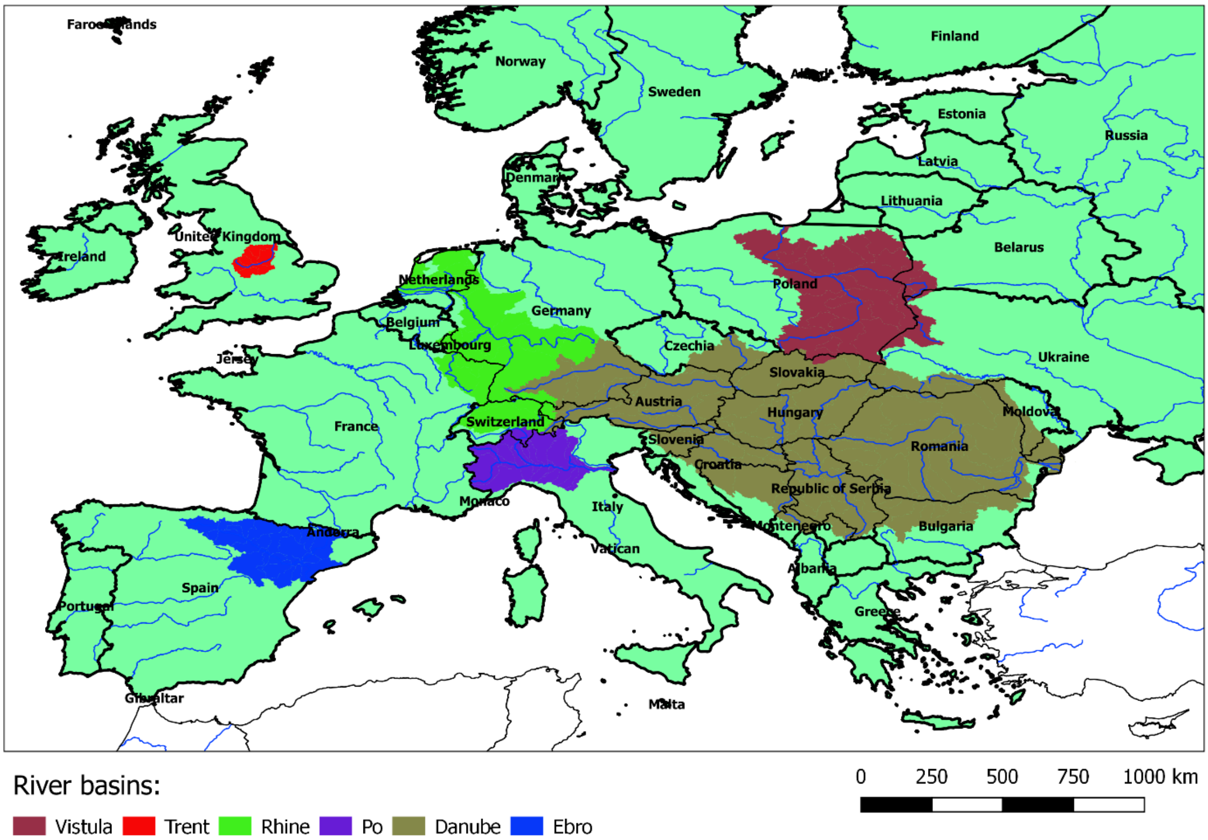


Figure 4.2: River basins case studies of the REFORM project

The cases studies represent large rivers in Europe, with catchment areas higher than 10,000 km^2. However, they differ strongly in climatic zone, river length, catchment size, discharge, slope and river style. For each case study the following information is given:

- General characteristics of the river (stretch);
- Description of historical state or reference condition(s) used in the rehabilitation projects;
- Functions of the river (stretch): for which socio-economic functions is the river used, and what are the resulting pressures for its ecological functioning?
- The effects of identified pressures on hydro-morphology and ecology;
- Mitigation and rehabilitation measures; what measures have been taken or planned to improve the hydromorphological and ecological status of these rivers?
- Ecological effects of measures.

The Figure 4.3 shows the views of the Po and Trent rivers.

a) b)

Figure 4.3: Aerial view of the River Po in its middle course (a) and River Trent in its middle course, near Nottingham city (b). Source: REFORM project

4.2.5.3.2 Drivers and pressures

The rivers are vital resources for humans, wildlife and plants since they configure landscapes, transport water and sediment, support to maintain the natural balance of ecosystems and are used for many purposes. However, their capacity to fulfil these functions is constrained by man-made interventions, generally related with the following drivers: hydropower generation and high-intensity industrial or agricultural use.

Accordingly, the rivers have been affected by major modifications, such as water abstractions, water flow regulations (dams, weirs, sluices, and locks) and morphological alterations, straightening and canalisation, and the disconnection of flood plains. These are commonly called hydromorphological pressures.

The hydromorphological pressures comprise all physical alterations to the structure of a river and natural flow regime, such as modification of discharge regime, bank structures, sediment/habitat composition, gradient, slope, etc. These pressures can result in severe consequences on the aquatic ecological fauna and flora and, consequently henceforth significantly impact the water status.

The REFORM project identified significant differences in drivers and associated pressures between the analyzed case studies. However, the most important drivers (and associated pressures) for hydro-morphology and ecology of the rivers were identified as follows: agriculture (deforestation and embankments), flood protection (embankments, dams), and navigation (channelization, bank protection, dams).

In general, the performed analysis suggests that rivers Trent, Po, Ebro and Delta Rhine have a significant number of drivers and associated pressures for hydro-morphology, while the case studies of the Danube Delta and middle Vistula are less impacted.

In the case study of the Po river, it was identified an evident relation between the deforestation (resulted from agricultural development) and a remarkable increase of the sediment load of the river which, consequently, caused an extension of the Po delta along the Adriatic coastline. Additionally, it was identified that deforestation also had a significant influence on the hydro-morphology of other analyzed rivers, particularly in the Ebro river.

It was concluded that navigation also represented an important driver for an early regulation of large rivers, resulting generally in the execution of significant interventions in river hydro-morphology such as channelization, stabilization of the river bed (groynes, bank protection), re-sectioning, deepening of the main channel, etc.

The conducted analysis also identified that large parts of (formerly active) floodplains were embanked in all case studies, mainly for flood protection and agricultural use of the land. For the case study of the Delta Rhine, the construction of embankments has started in 11th century by the Roman Empire. For the Trent river, the analysis showed different geomorphology phases during the past centuries, changing from braiding to stable anastomosing conditions as a result of increase of forest cover in the floodplains.

Moreover, the performed analysis in the REFORM project also identified the construction of dams in the rivers as a relevant pressure for the hydro-morphology and ecology of the rivers. Actually, the construction of dams usually results in a decrease of longitudinal connectivity in the river, thereby impeding the adequate migratory conditions for fishes and other species. Additionally, it also results in a modification of the hydrological regimes and sediment transport in rivers. In this context, it was found in the REFORM project that rivers Trent, Po, Ebro and Lower Danube *“have been severely impacted by the construction of dams”* regarding to hydro-morphology and ecology of the rivers.

Regarding the ecological impact of dams, the REFORM project highlights that construction of dams could result in notable negative impacts and frequently result in three types of environmental alterations:

- changes in the released flow regime (quantity and quality);
- reduced passage of alluvial materials, in particular suspended solids; and
- fragmentation of the river corridor, resulting in interruptions in downstream and upstream passage of biota.

Regarding to drivers and pressures related with hydro-morphology and ecology, the Tawi can be considered as a relative intact river along most of its extension (such as the case studies of the Vistula and Danube delta) and therefore has a low number of pressures. The major alterations in the naturalness of the Tawi morphology occur in the lower course, near Jammu city.

In fact, the drivers and pressures in the Tawi river result mostly from urban development, in particular in the lower Tawi. In a smaller scale, agriculture and flood protection can also be considered as a driver for the current hydro-morphology condition of the Tawi, however without any significant and evident related pressures. Additionally, deforestation is also considered as a significant pressure in the region nowadays, being locally identified in some areas of the catchment.

4.2.5.3.3 Measures

Besides various floodplain restoration or rehabilitation projects have been planned or realised in recent years along large rivers in Europe, there are several cases wherein technical constraints related with navigation, urban development and flood mitigation that evidently impede some rehabilitation measures of being technical and economic feasible. This aspect was identified in some analyzed case studies in the REFORM project, particularly in the rivers Ebro and Po wherein only a small number of measures are planned so far.

On contrary, a significant number of measures have been considered for the highly regulated rivers Trent and Delta Rhine. The executed (or planed) measures mostly consist of: connecting man-made water bodies, construction fish passages, increase and restore wetlands, opening and relocate embankments, lowering aggraded floodplains and restoring connectivity to tributaries.

Along low gradient lowland rivers, such as the Lower Danube and the Delta Rhine, measures mostly focus on the restoration of the lateral connectivity gradient in floodplains and improve the ecology of the riparian zone.

Along the Lower Danube, large areas of the formerly active floodplains are planned to be reconnected to the river by opening of the embankments. In this context, 95 wetlands/floodplains (covering 612,745 ha) with the potential to be re-connected to the Danube River and its tributaries were identified and 11 wetlands/floodplains (62,300 ha) were prioritized to be reconnected.

In the Delta Rhine, the connectivity between the river and floodplains has already been partly restored by relocating of embankments, removal of minor embankments and lowering of aggraded floodplains.

Regarding to the rivers Trent and Po (and also some extent of the Delta Rhine), the applied river rehabilitation measures were defined aiming to increase variation in width and depth of the main channel, intending to promote the occurrence of natural hydromorphological processes.

The case study of Vistula river was considered as a relative intact river stretch. Nevertheless, different options have been planned to rehabilitate the right bank of the river in Warsaw (Figure 4.4) included the following measures:

- cut off from the bank or lowering the top of the groynes to form the narrow branch of the riverbed along the right bank,
- creation the islands, stabilized by abandoned parts of groynes,
- creation of beaches and recreational areas by the silt removing and maintenance of the vegetation (partial removal of shrubs and invasive species of trees).

Figure 4.4: Conception of reconstruction of goyne's system located on right bank of the Vistula river between two bridges in Warsaw. Source: REFORM project

As previously presented, there are notable differences in the identified pressures between the analyzed case studies in the REFORM project. Consequently, the measures that are taken to eliminate or mitigate the identified pressures also significantly differ. Nevertheless, the river rehabilitation measures which were mostly applied (or planned) in the case studies are the following:

- creation of natural riparian zones;
- increase and restore wetlands;
- groyne adjustments;
- reactivate floodplains;
- creation of side channels.

The analyzed case studies showed that many rivers have changed their morphological characteristics and hydrological regimes over the past, being difficult to identify and select a reference or pristine state. Moreover, since the anthropogenic effects are much more dominant now than ever before, the pristine states are unrealistic targets for river restoration and rehabilitation. Consequently, the REFORM project highlights that is not evident that restoration measures should be planned and executed trying to mimic attributes of previous river ecosystems.

4.2.5.4 Key results, conclusions and recommendations

The REFORM project provided a comprehensive framework to support river managers and decision-makers in exploring the causes of hydromorphological management problems and planning sustainable solutions. The project is particularly addressed to support reaching target ecological status in highly modified and human-engineered rivers and systems, wherein severe degradation of water quality and ecosystem functions are observed.

Therefore, the project provides useful tools to promote the cost-effective restoration of river ecosystems and comprehensive guidance to select hydromorphological and biological indicators, complying with the EU Water Framework Directive (WFD).

The REFORM project highlights that a multi-scale understanding of hydro-morphology is important in order to identify degraded segments and reaches of river and consequently plan adequate restoration approaches.

Specifically, key results, conclusions and recommendations of the REFORM project are the following:

- *Hydromorphological assessment should consider physical processes and appropriate temporal and spatial aspects beyond river restoration project boundaries and project life span.*
- *Vegetation and plants can play a cost-effective and significant role as physical ecosystem engineers for river restoration.*
- *Current biological sampling methods are not appropriate to capture hydro-morphology impacts and generally underestimate their impacts on biota.*
- *Restoration projects should adopt a synergistic approach with other resource users to secure win-win scenarios and have well-defined quantitative success criteria*
- *Cost-benefit analysis can help in prioritizing restoration measures and plans.*
- *Restoration had positive effects even in small restoration projects.*

4.3 RELEVANT GUIDELINES, HANDBOOKS AND CODES

4.3.1 National Disaster Management Guidelines - Management of Floods

The National Disaster Management Authority has formulated guidelines on management of floods in India (NDMA, 2008). According to the guidelines, the following salient activities need to be covered in the Flood Management Plans (FMPs):

- Identification of flood prone areas and preparation flood hazard/vulnerability/risk maps
- Putting in place DSS for flood management including preparedness, rescue, relief, rehabilitation and recovery
- Development, expansion and modernisation of flood forecasting and warning systems
- Structural measures for prevention of flooding and improvement of drainage
- Identification of reservoirs for review and modification of operation manuals and rule curves
- Enactment and enforcement of flood plain zoning regulations
- Making the existing and new buildings and infrastructure such as roads, railway lines, bridges, canals, etc. capable of withstanding the fury of the floods and not enhancing flood vulnerability/risk
- Training of trainers in professional and technical institutions on FM issues
- Training of professionals like engineers and architects for incorporating measures that can sustain the structures and provide shelter to people during floods in flood prone areas
- Flood-proofing
- Public awareness campaigns on flood safety and risk reduction and sensitising all stakeholders to flood problems and mitigation in flood prone areas
- Regular inspections of structural works such as embankments, drainage channels, protection works, etc. and implementation of required restoration/strengthening measures prior to and emergency measures during floods in the flood prone areas
- Developing an inventory of the existing built environment
- Assessing the flood risk and vulnerability
- Developing guidelines for flood-proofing measures and for all existing critical lifeline structures and major public buildings in flood prone areas
- Carrying out mock drills for enhancing preparedness
- Strengthening the EOCs network
- Streamlining the mobilisation of communities, NGOs, civil society partners, police force, CD, the corporate sector and other stakeholders on occurrence of floods
- Preparing district, municipality, community and village level FMPs
- Creating an inventory of resources for effective response to floods in flood prone areas
- Strengthening research capability of various academic and research institutions for taking up development of cost effective FM measures
- Preparing documentation on lessons from previous floods and their wide dissemination

- Preparing an action plan for the upgradation and integration/interlinking of the FM capabilities of the CWC, IMD and the state governments in flood forecasting with clear roadmaps and milestones
- Developing appropriate scheme for insurance of lives, crops and private and public properties in flood prone areas by collaborating with insurance companies and financial institutions
- Operationalizing the NDRF and SDRF battalions
- Allotment for land for the Regional Response Centres
- Strengthening the medical preparedness for effective response to prevent spread of epidemics especially water-borne diseases after floods

The Guidelines for Flood Management can be summarized as follows:

1. Embankments/flood walls/flood levees have to be constructed for prevention of flooding after carrying out detailed hydrological and morphological studies regarding their favourable and adverse effects.
2. The CWC and the state governments have to study the problem of rise in river beds in a scientific manner and explore the techno-economic viability of desilting/dredging as a remedial measure to mitigate the effects of rise in the river beds.
3. Appropriate channel improvement works have to be taken up to increase the velocity and/or the area of flow and reduce the flood level in the river depending upon site-specific conditions.
4. State governments should prohibit the blocking of the natural drainage channels and sluices with an appropriate law and improve their capacity and construct new channels and sluices to ensure flow of excess rainwater in the area.
5. State governments should study the feasibility of implementing schemes for diverting excess water to existing or new channels through by-passing towns and cities to prevent flooding.
6. Watershed management measures such as afforestation, check dams, detention basins etc. have to be implemented in catchments to prevent soil erosion, enhance water conservation and minimise water and sediment runoff.
7. State governments should consider appropriate anti-erosion measures such as revetments, slope pitching, permeable and impermeable spurs using conventional materials and/or geo-synthetics for protection of towns, cities, industrial areas, groups of thickly populated villages, railway lines, roads and embankments from erosion by rivers in a time-bound manner.

8. Sea walls/coastal protection works has to be planned and executed by the respective coastal states/port authorities, keeping in view the complexity of sea behaviour and other environmental aspects.
9. The state governments has to provide adequate number of raised platforms/flood shelters at suitable locations in the flood plains with basic amenities such as drinking water, sanitation, medical treatment, cooking, tents, lantern etc. for the people to take shelter during floods.
10. Basin-wise flood hazard mitigation models have to be developed.
11. A mechanism has to be developed wherein representatives of the CWC, IMD, NRSA and the states cooperate with one another, exchange data on a real-time basis and formulate the flood forecasts and warnings.
12. Hydrological and meteorological data have to be collected on real-time basis.
13. The state governments have to enact and enforce appropriate laws for implementing flood plain zoning regulations.
14. The reclamation of the existing wetlands/natural depressions has to be prohibited by state governments and they must formulate an action plan for using them for flood moderation.
15. Training and capacity building measures have to be taken up for designated authorities dealing with the disaster.
16. A number of organizations, like NGOs, self-help groups, CBOs, youth organizations such as NCC, NYKS, NSS etc., women's groups, volunteer agencies, Civil Defence, Home Guards, etc. must be encouraged to volunteer their services in the aftermath of any disaster.
17. The state governments have to utilise different types of media, especially print, radio, television and Internet, to disseminate timely and accurate information.
18. A team comprising a social worker, a psychologist and a psychiatrist should provide counselling to victims.

4.3.2 National Disaster Management Guidelines – Community Based Disaster Management

When a disaster strikes, the group of people living in a particular disaster prone area suffers directly from the impacts of the disaster and they have to respond immediately. Hence, communities are also called first responders. It may take several days or even weeks to reach the support from government mechanism or outside donors to the affected communities. Being first responder, the community assumes significant roles in disaster response.

One of the objectives of National Disaster Management Plan is *"Capacity development at all levels to effectively respond to multiple hazards and for community-based disaster management"***.** The National Disaster Management Plan has identified capacity development of community-based disaster management as a major theme.

The National Disaster Management Guidelines on Management of Floods have made several provisions for community based disaster preparedness and response coordination among various organizations for flood response. The guidelines suggest institutionalizing the role of community based organizations, non-governmental organizations etc. in Incident Command System (ICS).

The National Disaster Management Guidelines on Community Based Disaster Management (NDMA, 2014) has defined the Community Based Disaster Management (CBDM) as *"a condition whereby a community systematically manages its disaster risk reduction measures towards becoming a safer and resilient community"***.** Community Based Disaster Management (CBDM) initiates a process involving sequential stages that can be operationalized to reduce disaster risk. The different stages in CBDM are disaster/vulnerability risk assessment, risk reduction planning, early warning systems, post disaster relief and participatory monitoring and evaluation.

CBDM programming framework recognizes and values the fact that people at-risk of disasters have capacity and keen interest in using their own capability in reducing disaster risk provided it also addresses the issue of overall wellbeing. The primary outcomes from CBDM programme are:

a) People at-risk of disasters have their own annual DRR plan at community and community institution level.
b) The DRR Plan is in the hands of capable local people to follow it up with duty bearers and others.
c) Government and people come together to implement risk informed development priorities of the people at-risk of disasters.
d) Strengthening of capacities at the local levels.

Guiding Principles:

The guiding principles of CBDM programming and implementation process are the following:

1. Multi-stakeholders' participation
2. Participatory approach with community as lead

3. Involvement of informed facilitators
4. Time and resource budgeting
5. Forum for convergence
6. Inclusive approach

CBDM Processes:

Community Based Disaster Management is a process in which at-risk communities are actively engaged in the **identification, analysis, treatment, monitoring and evaluation of disaster risks** in order to reduce their vulnerabilities and enhance their capacities. It is a step by step process which involves interaction of multiple stakeholders. The interrelated steps of community based process to achieve the goal of resilience are given below:

1. Preparing Communities for DM planning and action
   a. Area Identification
   b. Inception Meeting in village
   c. Community mobilization
2. Formation & Nurturing Village Disaster Management Committee (VDMC)
3. Risk assessment
4. Disaster Risk Reduction planning
5. Mainstreaming Disaster Risk Reduction Plans with Development Plan
6. Monitoring and follow up
7. Addressing underlying risks
8. Preparedness to respond to disasters
   a. Awareness
   b. Response and Recovery
9. Capacity building for CBDM
10. Towards sustainability

Institutional Framework:

Effective community-based disaster risk management can only be implemented if there are local institutions to sustain community initiatives, integrate community actions with government policies and practices. For the effective community level action on disaster risk management measures, community based institutions shall be promoted, developed and nurtured to create a safe society taking full advantage of the capabilities and resources available from the community to the national level among different stakeholders.

The community based disaster management institutional framework is needed for:

i) Bringing clarity about the nature and form of institutions involved at the community level.
ii) The linkage of community based institutions with upward level government and other support institutions for better coordination and action.
iii) Role of government institutions and civil society organisations in facilitating the formation and functioning of community institutions.
iv) Mechanism for monitoring and evaluation of the structure and functioning of community based institutions and processes.

The operational framework of CBDM institutions is provided in the Guidelines. The CBDM Institutions shall be invoked with a special notification or by incorporating in the State Acts. The CBDM institutions shall be termed as Village Disaster Management Committee (VDMC) for the rural areas and Urban Local Body Disaster Management Committee (ULBDMC) for the municipal areas. The VDMC shall be at the Gram Panchayat level having 9 to 11 members. DDMA shall be responsible for setting up VDMC.

The VDMCs must develop a Village Disaster Management Plan (VDMP) in a consultative process with regard to preparedness, response and mitigation measures. While VDMC is an autonomous Institution, it must report to the gram sabha and upper tier authority (DDMA or intermediate level DM Authority) on annual basis on matters of composition of committee, functioning of VDM teams and disaster mitigation plans and its convergence with the development plan and its status.

Funding Mechanism:

The funds available with the DDMAs may be used for the capacity building of the VDMCs, preparation of the VDMPs and implementation of activities for vulnerability reduction in convergence with development programs.

The Local Area Development Scheme of Member of Parliaments can be used to finance the activities of VDMC. Own funds of Panchayats and Urban Local Bodies gained from taxes, duties, tolls, fees and grants-in-aid, donations, investments, interest returns, and other sources can also be used for disaster management purposes.

In addition to government funds, donations and grants from the private sector, such as research institutions, individuals and companies can be used to fund disaster management measures.

Monitoring and Evaluation Mechanism:

The VDMCs may present their report annually in the Gram Sabha and seek feedback in a social audit format. The report of the VDMC may be forwarded to the DDMA or appropriate level of authority. The DDMAs may set up/commission evaluation studies and prepare annual report on the functioning of the VDMCs.

4.3.3 Guidelines for Preparation of DPR for Flood Management Projects

The Central Water Commission of Government of India has prepared "Guidelines for Preparation of DPR for Flood Management Works" (CWC, 2018). The guidelines serve as a handbook for having a comprehensive view of design principles, construction techniques and costing thereof for flood protection, anti-erosion and river training works.

The Guidelines suggest the following outline for a Detailed Project Report (DPR) for Flood Management Works.

1. Foreword by head of the Department
2. Salient features
3. Executive Summary
4. Prioritization of schemes
5. Hydrology
6. Design of works
7. Abstract of Cost
8. B.C. Ratio
9. Construction Plan
10. Index map
11. Drawings
12. Annexure & Certificates

The Hydrological study of the project will provide the following information:

- Estimation of design flood
- Water surface profile

Design of works consists of the design of all river training and drainage structures, such as, embankments, revetments, spurs/groynes, drainage improvement works, and sluices. The structures should be designed as per provision of Bureau of Indian Standard (BIS) codes. Relevant codes are listed in **Section 4.3.6**.

Cost estimate is prepared on the basis of latest schedule of rates of concerned State. Analysis of rates should be worked out considering the cost of materials, carriage-handling-storing, labour and share of machines in execution of works and overhead charges etc. Benefit cost ratio should be calculated by dividing total annual benefits/damages by total annual cost.

Construction planning may involve the following steps.

- Invitation of tenders
- Procurement of construction material
- Storage of construction material at site
- Testing of the material

Model tender documents should be prepared. The DPR should also consist of bar chart showing activities related with execution of the project. Index map, drawings and other relevant information should be appended with the DPR.

4.3.4 General Guidelines for Preparing River Morphological Reports

The Central Water Commission of Government of India has prepared "Guidelines for Preparing River Morphological Reports" (CWC, 2009). The guidelines serve as a handbook for preparing morphological study of river for planning, design and construction of river management works in general and river training and anti-erosion works in particular.

For a scientific and rational approach to different river problems and proper planning and design of water resources projects, an understanding of the morphology and behaviour of the river is a pre-requisite. River Morphology is a field of science which deals with the change of river plan form and cross sections due to sedimentation and erosion. In this field, dynamics of flow and sediment transport are the principal elements. The Morphological Studies, therefore, play an important role in planning, designing and maintaining river engineering structures.

The objectives of river Morphological report are:

i) To identify the problems - location specific and morphological, works taken up and their performance.
ii) Interpretation of factors responsible for different types of problems, causes of failure of the measures taken, and the necessary corrective measures.
iii) Understanding of river mechanics to facilitate mathematical/ hydraulic modelling.
iv) To identify further studies to be carried out.
v) To identify additional data required.
vi) To evolve criteria for planning and design of structures for efficient river management.

Generally, the morphology report consists of the following information:

1. INTRODUCTION

- Terms of reference, if any

- Brief introduction with statement of the problem
- Need for morphological studies
- Specific objective and scope of the studies
- Definitions (as per standard glossary of terms)
- Index map (Topo-sheet 1 cm = 25 km)
- Data used
- Limitations of the data and methodology

2. THE RIVER

- Description of the main river and tributary system (including networks)
- Topography of the catchments, flood plains, deltaic reaches
- Valley slope, bank slopes, bed slope
- Description of flood plain with mention of Khadir limits, significant high and low areas
- Brief description of various river valley projects – existing, under construction and planned with figures of water utilization for different purposes
- Observed ill-effects, if any on the river regime / behaviour during the post project period
- Land use – significant changes from time to time with land use maps.

3. PHYSIOGRAPHY AND CLIMATE

- Physiography with detailed map of stream, hypsometry curves
- Rainfall pattern, intensities, frequencies, duration etc.
- Temperature (maximum, minimum, mean) in different parts of the basin
- Humidity
- Evaporation (observed)

4. SOILS

- Soil types found in different parts of the basin
- Soil characteristics, composition
- Erodability of bank material
- Engineering properties of bank material
- Soil map

5. WATER QUALITY AND UTILIZATION

- Quality of surface water, pH Value, mineral and metal content, BOD, dissolved oxygen.

- Geo-hydrology with water quality
- Different water uses including for navigation

6. GEOLOGY

- Geomorphology with different geo-morphological maps showing flood plain features like point bars, alternate bars, middle bars, valley plugs, oxbow lakes, palaeo channels etc. with their descriptions and their effect on river behaviour.
- Geology with description of various lithofacies, rock types, erosional characters of rocks, influence of factors like fractures, joints, faults, sheared and shattered zones on river shape and pattern. Structure, tectonics, earthquakes, landslides and their effect on sediment load
- Drainage pattern (Horton's classification), drainage density

7. HYDROLOGY

- Temporal and spatial distribution of rainfall, mean monthly and annual isohyets
- Storm movement
- Rainfall intensities for 1,2,3 days
- Isohytal map and maximum intensities observed
- Description of lean season and flood season flows with figures of maximum, minimum, mean and bank full flows, flood flows of different return periods, brief description of historical floods, 50%, 75%, 80%, 90% dependable lean season flows
- Water surface slope
- Sediment transport during lean and flood season with figures of coarse, medium and fine sediments
- Gauge and discharge hydrographs
- Graphs showing typical variation of sediment load with discharge
- Hydrological stations, Inventory of G&D sites with frequency of measurements
- Network analysis of G&D sites
- Sediment size distribution and concentration of suspended load along vertical direction.
- Bed material size distribution (samples to be collected at 4 to 6 locations at every alternate cross-section from a depth of 30 cm. below the bed)

8. PROBLEMS

- Flood damage, threat to cities/villages, agricultural/ irrigation fields, lines of communication, public utilities etc.

- Bank erosion posing threat to important towns and other populated areas, roads, railways; Apparent causes of the problem.
- Significant lateral shifting of the river posing threat of outflanking of important structures like bridges, barrages etc. besides bank erosion. Possibility of avulsion into another river and the possible consequences thereof etc
- Significant shifting of the river away from the important towns/ villages/ river bank industries, etc. causing water shortage for drinking, industrial use and irrigation, cooling water for thermal water stations besides degradation of the city environment
- Earlier studies done by different agencies, remedial measures taken from time to time, performance/ efficiency of the measures and the need for further measures based on morphological studies

9. MORPHOLOGICAL CHARACTERISTICS

- Delineate the courses of rivers and its tributaries with existing major roads, embankments, railway lines, Hydraulic/flood control structures and any other important specific locations with the help of remote sensing data and hydrographic survey data
- Shifting course of river and identify critical locations and rate of shifting
- River flow analysis
- Fluvial geomorphology. It should also contain information in terms of identifying abandoned/ moribandh/ seasonally active spill channels/ meander scrolls/ oxbow lakes etc.
- Channel characteristics. These may include plan form changes if any, braiding characteristics and shoal formations, meandering characteristics and sub-meanders, physical constraints like hills and nodal points, bed forms in low, medium and high stages with sonic soundings.
- Regime formulae applicability for width, depth, velocity, slope etc. Changes in Manning's 'n' values.
- Sediment load analysis including rate of sediment transport with comments on transporting capacity
- Identify all major morphological problems both natural and man-made
- Evaluate performance of major flood control structures executed so far from morphological point of view and their effects on river morphology
- Historical information on aggradation and degradation in different reaches
- Lateral migration from historical data
- Khadir limit

- Multi-purpose reservoir and barrages and other structures with their effect on upstream and downstream
- Low water channel characteristics in the context of navigational development
- Catchment area treatment, if any and its likely effect.
- Diagnosis of the problems of land use pattern, general drainage characteristics, flood inundation, flood-prone/ flood-spread area, bank erosion, deposition/ island formation, identification of palaeo channels etc. Scope and limitations of mathematical and physical models including review of available models and their choice.

10. SUMMARY

- Various parameters having a bearing on the river characteristics, behaviour and problems.
- Basic approach to the problems in general and specific recommendations for a lasting solution to the problems.
- Further studies required, if any.
- Additional data required for such studies.

These general guidelines provide a very good reference to prepare a Morphological Report of the Tawi River. The consultant will prepare a Morphological Report of the Tawi River considering project's requirement, availability of data, time and other constraints.

4.3.5 Handbook for Flood Protection, Anti-Erosion & River Training Works

This Handbook provides the necessary guidance to field engineers to deal primarily with structural measures of flood management like flood protection works, anti-erosion measures and river training works. The handbook containing details of construction materials, guidelines for design embankment, bank revetment, spurs/groynes, RCC porcupines, drainage improvement works, construction methodology, cost estimate and unit rate analysis provides a ready reference to plan, construct and monitor the flood management projects in an integrated manner (CWC, 2012).

Guideline for design of embankments stipulates the following standards.

1. The **topographical data** (Index plan showing area affected, contour survey plan of the area, past river courses, plan and section of earlier executed works), **hydrological data** (discharge, gauge, velocity, carrying capacity, extent of spill of river, cross sections and longitudinal section of river, rainfall data for the basin, sediment flow and river behavior like aggrading or degrading etc) and **history of past floods** indicating duration of floods, flood discharges and corresponding

levels, stage of river at which damage was most pronounced, extent of damage etc. need to be collected and analysed.

2. The design flood for embankment for predominantly agricultural areas can be taken 25 years, for township or industrial areas 100 years for fixation of crest level.
3. The embankments should be aligned on the natural bank of the river, where land is high and soil available for the construction of embankments. The alignment should be such that important township, vital installations, properties, cropped area is well protected by the embankment.
4. The minimum distance of the embankment from the river bank and midstream of the river should be one times Lacey's wetted perimeter and 1.5 times Lacey's wetted perimeter [Lacey's wetted perimeter (P) = 4.75 $(Q_{design})^{½}$] respectively.
5. The length of the embankment directly depends upon the alignment. However, it is to be ensured that both ends of the embankment are tied up to some high ground or existing highway or railway or any other embankment nearby conforming to the design height of the embankment.
6. BIS code 12094: 2000 is used for design of the embankment.

Various methods of bank protection are revetment, vetivers, submerged vanes, RCC Kellener Jettys, Geo-cell etc. BIS code 14262:1995 is used for design of the bank revetment. Spurs/groynes are structures, constructed transverse to the river flow and extended from the bank into the river. Spurs/groynes, protruding into river come under purview of anti-erosion works. These types of works are provided to keep away flow from the erosion prone bank. The spurs are provided along with launching apron to prevent scouring under the water and consequent fall of spurs. IS code 8408:1994 is used for design of the spurs.

Drains are constructed with the objective of relieving excess water from agricultural and other areas and disposing of surplus water which is not required for normal agricultural operations. The proper disposal of surplus rain water is also essential to avoid its percolation down to the water table which may otherwise lead to rise in the water table thereby aggravating or creating the problem of water logging. IS code 8835:1978 is used for design of the drains.

IS Code 8835:1978 stipulates that drains may be designed for 3 days rainfall of 5 year return period. However, in specific cases requiring higher degree of protection, return period of 10 or 15 years may also be adopted. Cross drainage works should be designed for 3 days rainfall of 50 years return period. Cross drainage works are always designed for a higher discharge than the cut sections of the drains. This is due to the fact that damage in structures during flow events resulting from extreme rains can be much more than to the drain.

4.3.6 Design Codes

The following codes and standards are relevant to prepare the DPR for flood management works in Tawi River.

River Training and Diversion Works Sectional Committee:

- IS 4410: Part3: 1998 - Glossary of Terms Relating to River Valley Projects: Part 3 River and River Training
- IS 8408:1994 - Planning and design of groynes in alluvial river – Guidelines
- IS 8835:1978 - Design of Drains
- IS 10751:1994 - Planning and Design of Guide Banks for Alluvial Rivers – Guidelines
- IS 12094:2000 - Guidelines for Planning and Design of River Embankments (Levees)
- IS 11532:1995 - Construction and Maintenance of River Embankments (levees) - Guidelines
- IS 14262:1995 - Planning and design of revetments - Guidelines
- IS 14815:2000 - Design Flood for River Diversion Works - Guidelines
- IS 12926:1995 - Construction and Maintenance of Guide Banks in Alluvial Rivers - Guidelines

Water Resources Planning, Management and Evaluation Committee:

- IS 4008:1985 - Guide for Presentation of Project Report for River Valley Projects
- IS 4186:1985 - Guide for Preparation of Project Report for River Valley Projects
- IS 4410: Part 2:1967 - Glossary of Terms Relating to River Valley Projects: Part 2 Project Planning
- IS 4410: Part 4:1982 - Glossary of Terms Relating to River Valley Projects: Part 4 Drawings
- IS 4410: Part 11: Sec 5:1977 - Glossary of Terms Relating to River Valley Projects: Part 11 Hydrology Section 5 Floods
- IS 4410: Part 21:1987 - Glossary of Terms Relating to River Valley Projects: Part 21 Flood Control
- IS 13739:1993 - Guidelines for Estimation of Flood Damages

Hydrometry Sectional Committee:

- IS 1192:2013 - Hydrometry - Measurement of Liquid Flow in Open Channels Using Current-Meters or Floats
- IS 3912:2013 - Hydrometry - Direct Depth Sounding and Suspension Equipment
- IS 3913:2014 - Hydrometry Functional Requirements and Characteristics of Suspended-Sediment Samplers
- IS 4986:2002 - Installation of Raingauge (Non-Recording Type) and Measurement of Rain - Code of Practice
- IS 4987:1994 - Recommendations for Establishing Net Work of Raingauge Stations
- IS 5542:2003 - Guide for Storm Analysis

- IS 6339:2013 - Hydrometry -Sediment in Streams and Canals - Determination of Concentration, Particle Size Distribution and Relative Density
- IS 8389:2003 - Installation and Use of Raingauges, Recording - Code of Practice
- IS 9116:2002 - Water Stage Recorder (Float Type)
- IS 9922:2010 - Measurement of Liquid Flow in Open Channels - General Guidelines for Selection of Method
- IS 14359:2014 - Hydrometry: Echo Sounders for Water Depth Measurements
- IS 14573:2014 - Hydrometry: Velocity-Area Methods Using Current-Meters - Collection and Processing of Data for Determination of Uncertainties in Flow Measurement
- IS 15117:2002 - Hydrometric Determinations - Cableway Systems for Stream Gauging
- IS 15118:2014 - Hydrometry: Water Level Measuring Devices
- IS 15119: Part 1:2002 - Measurement of Liquid Flow in Open Channels - Part 1: Establishment and Operation of a Gauging Station
- IS 15119: Part 2:2014 - Hydrometry: Measurement of Liquid Flow in Open Channels Part 2 Determination of The Stage-Discharge Relationship
- IS 15362:2003 - Hydrometric Deteremінations - Flow Measurements in Open Channels Using Structures - Compound Gauging Structures
- IS 15454:2004 - Liquid Flow Measurement in Open Channels - Velocity-Area Method Using a Restricted Number of Verticals
- IS 15527:2004 - Measurement of Liquid Flow in Open Channels - Measurement in Meandering Rivers & In Streams with Unstable Boundaries
- IS 15772:2014 - Hydrometry Field Measurement of Discharge in Large Rivers and Rivers in Flood
- IS 15823:2009 - Hydrometry - Computing Stream Flow Using and Unsteady Flow Model
- IS 16138:2013 - Measurement of Liquid Velocity in Open Channels - Design, Selectio and Use of Electromagnetic Current Meters
- IS 16222 :2018 - Hydrometry — Methods of Measurement of Bedload Discharge (First Revision)
- IS 16223 :2014 - Hydrometry: Guidelines for The Application of Acoustic Velocity Meters Using the Doppler and Echo Correlation Methods
- IS 16274 :2018 - Hydrometry - Hydrometric Data Transmission Systems - Specification of System Requirements (First Revision)
- IS 16364 :2017 - Hydrometric Uncertainty-Guidance (HUG)

Environmental Assessment and Management of Water Resources Projects Committee:

- IS 15442:2004 - Parameters for Environmental Impact Assessment of Water Resources Projects
- IS 15832:2008 - Glossary of Technical Terms Related to Environmental Impact

– IS 15845:2009 - Environment Management Plan for Hydropower/irrigation/flood Control/multipurpose River Valley Projects

Indian Standards by the Indian Roads Congress (IRC):

– IRC 089-1997: Guidelines for Design and Construction of River Training and Control Works for Road Bridges

5 RIVER BASIN HYDROLOGY, MORPHOLOGY AND DIAGNOSIS OF CURRENT SITUATION

5.1 HYDROLOGICAL ANALYSIS OF FLOOD RISK

The Consultant has prepared the **Preliminary Hydrology Report** which includes a review and analysis of historic floods, of the river basin hydrology and diagnosis of current situation, including rainfall, water level and discharge records. Additionally, a flood frequency analysis was also conducted.

The State of Jammu and Kashmir lies between the hot plains of the Jammu Province and coldest dry table-land of Ladakh, where the climate is temperate sub-humid type, characterized by two distinct seasons, winter and summer. The winter is from November to February and summer is from March to October.

In the Tawi basin, July and August are generally the wettest months with about 55 % rainfall and November is the least rainy month with about 2-3% of total rainfall. Tawi River experiences heavy flood in July and August. Monsoon starts from 1st July with heavy thunder showers and continues up to mid September. Normal annual rainfall is the basin varies from 1110 to 1500 mm.

The state of Jammu and Kashmir is highly affected by multiple hazards ranging from fires to floods, landslides, cloudbursts and earthquakes. The landslides, flash floods and riverine floods are the major recurring hazards in Jammu and Kashmir. The most part of Jammu and Kashmir fall under high damage seismic risk zone. The low-lying areas of Kashmir valley and Jammu are prone to riverine floods whereas the upper parts are prone to flash floods, landslides, avalanches and snow storms. Historically, the State has witnessed major floods in the years 1900, 1902, 1903, 1905, 1912, 1929, 1948, 1950, 1955, 1957, 1959, 1976, 1987, 1988, 1992, 1993, 1995, 1997 and 2006. Recent major flood disaster event was on 6 September 2014.

As per recorded data, the discharge recorded and affected areas and damages of some historical flood and flash flood events in the Tawi River Basin are presented in the Table 5.1.

Table 5.1 – Maximum Flow Discharge Events Tawi River – Bridge Site (Source: EE Jammu I&FC Division).

Date	Discharge recorded at Bridge Site		Area affected	Damages and Losses
	Cumecs	Cusecs (Lakhs)		
27-Sep-50	6230	2.2	40 villages	50 lives lost
26-Aug-57	6793	2.4		
9-Aug-61	6060	2.14		
22-Sep-62	5266	1.85		
9-Aug-73	6057	2.14		
2-Aug-79	5095	1.8		
25-Sep-88	11020	4.6		
1992	NA	NA		200 lives lost
3-6 Sep 2014	13500	4.78	33 ft water	

The landslides and erosional processes are activated by extreme rainfall (cloudburst) events. These processes significantly contribute to the floods and sedimentation. The main causes of 2014 floods in the state are the following:

i) High intensity continuous rainfall on 4-6 September, 2014
ii) Land degradation, soil erosion, deforestation, unscientific road construction, encroachment on steep hill slopes and unmanaged agricultural practices resulting siltation and rising of river bed
iii) Urbanization leading to increased exposure, decreased infiltration and increased runoff
iv) Obstruction of natural drainage and congestion of urban drainage system resulting overflow of surface runoff

According to the records of India Meteorological Department, the Jammu, Udhampur and Doda districts received 467.3 mm, 582.1 mm and 383.3 mm rainfall respectively in the month of September 2014, which were 339%, 165% and 297% of the normal rainfall (Source: http://hydro.imd.gov.in/hydrometweb/(S(ai1ydf45uwusrh3cpolbhe55))/DistrictRaifall.aspx). The flood peak in Tawi River at Jammu on 6 September, 2014 was 33 ft (478600 cusec), which exceeded the highest recorded flood of 31 ft (427000 cusec) occurred on September 1989. This flood peak was resulted due to the very high intensity of rainfall on 6th September, 2014.

The floods of September 2014, the biggest of those that have ever hit the State of Jammu and Kashmir, have caused immense damage resulting in loss of land, lives, houses, public infrastructure, and business hubs etc. The devastating floods claimed 281 lives (196 in

Jammu and 85 in Kashmir), 29 people were missing, hundreds of houses were destroyed and thousands of people were displaced. About 6000 Km road was damaged and 3000 water supply schemes were affected. About 60 major and minor roads have been cut off and over 30 bridges washed away. Near about 5642 villages were affected by flood and 800 villages which were completely submerged (Bhat, 2016). The floods destroyed rice and apples which were at the harvesting stage. The floods adversely impacted education and tourism sector.

Rapid Damage and Needs Assessment (RDNA) mission of the World Bank estimated the total damages and loss caused by floods at about INR 211,975 million (equivalent US$ 3,550.45 million), most of it to housing, livelihoods, and roads and bridges, which combined represented more than 70 percent of the damages in terms of value. Public service infrastructure and equipment of hospitals and education centers were also severely damaged.

The following lessons can be learned from September 2014 floods in Jammu and Kashmir.

- A resilience approach is needed for flood risk management by mainstreaming DRR into development.
- The preparedness, response, rehabilitation and recovery need to be strengthened.
- The flood forecasting and early warning system needs to be established for Tawi River and Standard Operating Procedures need to be developed for forecast-based flood preparedness.
- A campaign to raise public awareness on flood risks and early warning systems is necessary.
- Local capacities should be built in emergency preparedness and response.
- Resilient livelihoods and risk transfer mechanism should be developed.
- Disaster Risk Governance (policy, legislation, institutions) should be strengthened.

5.2 MORPHOLOGICAL ANALYSIS OF FLOOD RISK

The understanding of the morphology and behavior of the Tawi river is essential for a rational approach to different Tawi river problems and proper planning and design of flood mitigation solutions. Therefore, the Consultant has prepared the **Preliminary Morphology Report** which includes a review and mapping of current morphology, covering river channel, banks, and flood plain of Tawi River and tributaries. Moreover, the Report also includes maps in 1:25,000 scales for entire river system, and 1:10,000 scales for selected reaches.

As detailed in the Preliminary Morphology Report, it can be concluded that the Tawi river shows significant morphological diversity between Udhampur and its confluence point with

Chenab. The morphology in the upper reaches is controlled by hills and mountains manifested narrow channels and relatively stable form. In the alluvial plains, it is relatively wider and dynamic is controlled by alluvial processes along with significant human interventions.

The preliminary morphological mapping has focused on characterising the Tawi river in terms of its basin characteristics and channel morphology in the alluvial reaches. The conducted analysis suggests that the active floodplain of the Tawi river in the alluvial reaches downstream of Udhampur is fairly constricted. Major parts of the active floodplain has been occupied for agriculture and urban settlements. Downstream of Jammu city, the river splits into two branches, called Waddi Tawi and Nikki Tawi, that re-join ~20 km downstream. The area between the two anabranches, the maximum width is ~10 km, is also heavily occupied by agricultural lands and urban settlements. In addition, there are a number of bridges along the river in this stretch and the river is also embanked in stretches. A barrage is also under construction downstream of Jammu city. The barrage is flanked by two bridges, upstream and downstream of the barrage, and the one downstream of the barrage is barely 100 m from the barrage.

The morphometric analysis of the Tawi basin suggests that the hinterland is tectonically active as manifested by drainage anomalies and morphological elements. A major effect of an active hinterland is the high sediment flux from the fragile slopes that affects the channel morphology downstream. The small nallahs seem to contributing significant sediment flux owing to their steep slopes and sharp changes in channel morphology of the Tawi river is noted downstream of their confluences.

Moreover, the preliminary assessment also suggests that channel morphology in the upstream mountainous reaches is fairly stable being confined by narrow valleys. Not many depositional or erosional features are documented and the river is primarily guided by the valley settings. At places, the valley widening results in some morphological complexity.

The alluvial reaches particularly those downstream of Jammu are fairly dynamic and frequent migration of meanders are documented. The thalwegs of the main channel as well as confluence point of Waddi Tawi and Nikki Tawi have also moved through time. A detailed documentation of such dynamic behaviour will be presented in the detailed morphological report.

It is also important to note that the river brings in large amount of sediments from its fragile slopes and significant aggradation is noted in the alluvial reaches that has probably raised the bed level of the river significantly over the years. This is also manifested in frequent bars in most parts of the alluvial reaches and was also documented during the field visit.

Moreover, the preliminary assessment suggests that flood risk in Tawi river can be attributed to the following factors:

1. Several stretches of the river in the alluvial part are highly dynamic and they have been shifting their courses very often. Our preliminary assessment suggests that the most vulnerable stretches are Chumbian-Ahmalpur and downstream stretch of Waddi Tawi ~5 km upstream of its confluence with Nikki Tawi. A detailed analysis of planform dynamics would be able to identify the hotspots more precisely and we will present the results in the detailed report.

2. Several stretches of the river are highly aggrading due to large sediment flux and this has made them vulnerable to avulsion and flooding. The stretch of the Nikki Tawi river near Balole Nallah confluence is a good example where large aggradation on the left bank pushed the river to the right bank and this in turn eroded the spurs and has vulnerable to flooding. Large sediment flux from the Balole nallah could have contributed to this shift. Several other bends show a similar pattern and these vulnerable stretches would be mapped using historical images.

3. The interventions such the barrage in construction and several bridges have also contributed to trapping of sediments upstream. The embankments have further restricted the river flow and have aggravated the siltation. This has resulted in instability of the channel and these reaches have become vulnerable to breaches and flooding.

4. While the construction of embankments may have been necessary in some stretches particularly around the major cities such as Jammu. Apart from restricting the flow and inducing siltation, this also generated a false sense of security amongst the people and as a result, the urban settlements have mushroomed very close to the embankments. This has increased the vulnerability to floods enormously.

6 FLOOD MITIGATION SOLUTIONS PROPOSED BY I&FC DEPARTMENT

6.1 INTRODUCTION

The Irrigation and Flood Control (I&FC) Department - Jammu Division is fully aware of the urgent need for the planning and execution of flood management solutions in Tawi River Basin, to effectively manage 478,600 cusecs or higher discharge at Jammu City Bridge to minimize flood risk at vulnerable reaches through strengthening existing or implementing new river management works with approval from the Central Water Commission (CWC), Govt. of India.

The flood mitigation and river management options proposed by the I&FC Department - Jammu Division are as follows:

- Strengthening / enhancing the discharge capacity of River Tawi at the required locations.
- Identification of low lying areas affected during high floods.
- Creating of Flood storage dams etc. and identifying location for flood water detention basins and assessing their capacities and other broad salient features.
- River Management for flood risk management by bank protection, strengthening of existing or planning new embankments / revetments etc. to save life and property of the public.
- Watershed management for increase flood detention and reduce sediment yield.

6.2 EXECUTED AND PLANNED RIVER TRAINING WORKS IN TAWI RIVER

Following the Flood Management Programme (2007-2012) launched by Ministry of Water Resources, the I&FC Department - Jammu Division has started two Flood Management Projects (FMP) on river Tawi and Chenab during 2007-08 and six other projects during 2008-09. These projects aimed at providing relief from floods by executing Flood protection works, anti-erosion works and improvement in drainages of the rivers/nallahs.

These included flood protection works on river Tawi, river Chenab, river Ujh, flood protection works on major and minor nallah in Rajouri, flood protection works at Banganga, Dibber nallah at Chenani, left/right banks at river Tawi on Sidra Town and River Dera Baba Banda. The following three major activities were undertaken for flood protection in Tawi River of Jammu division.

1. Construction of earth embankments about 21 Km.
2. Construction of Crate revetments about 21 Km.
3. Construction of Studs/Spurs 108 nos.

More recently, additional training works and rehabilitation works were executed in the sequence of the catastrophic flood events of 2014.

The existing river training works in Tawi are located mostly in its lower course, from Sardan Nallah confluence and up to India-Pakistan border. Additionally, the I&FC Department has also planned further river management and training works, in the lower course of the Tawi.

The Figure 6.1 presents the executed and planned training river works in Tawi River, prepared based on *Site Plan showing training river Tawi from Manwal to exit of Indo-Pak Border at Spots* , by the Govt. of Jammu & Kashmir – Irrigation & F.C. Department Jammu. As per indications of the I&FC Department this site plan is not updated and therefore was further reviewed by the Consultant.

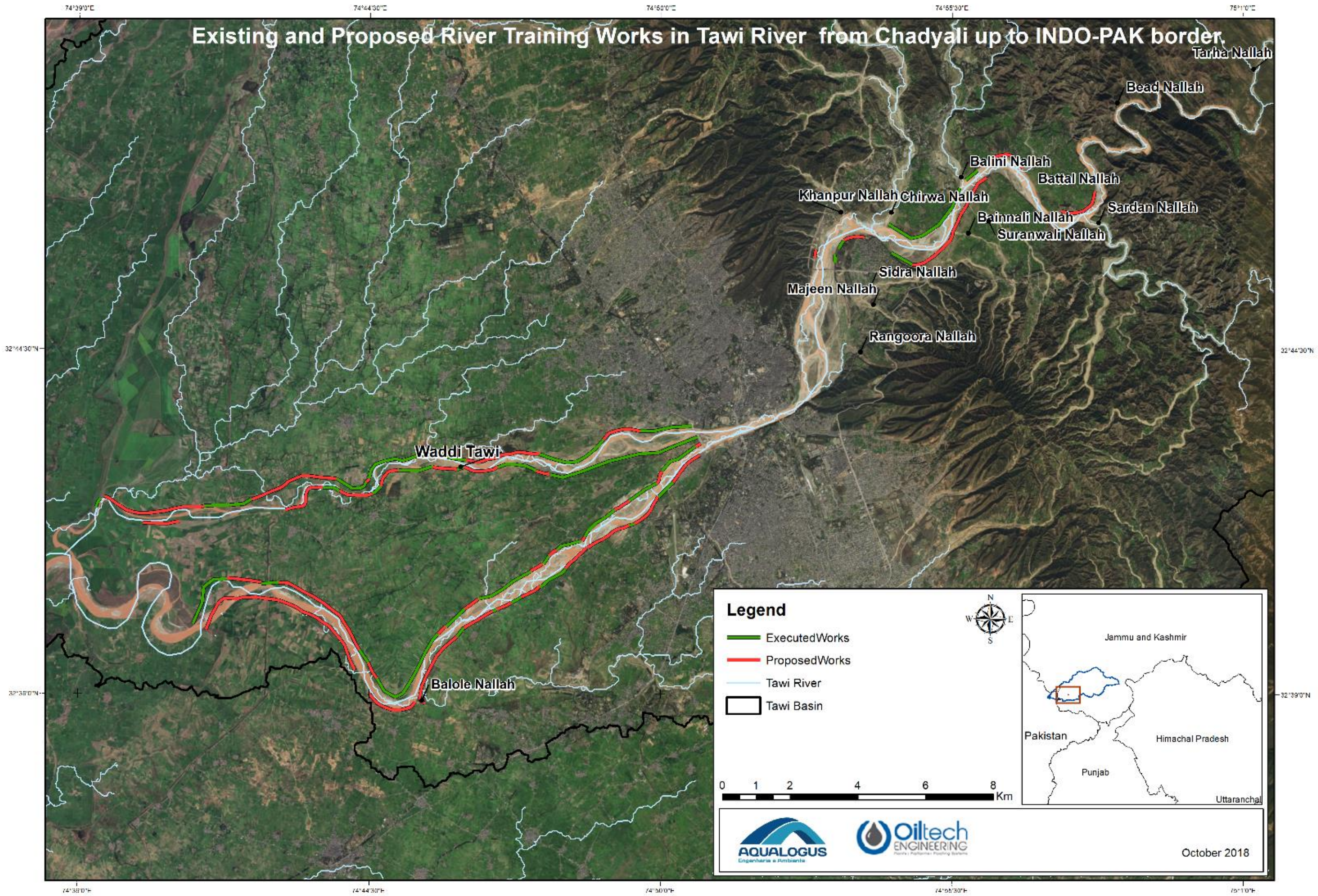


Figure 6.1: Proposed and executed works in the lower course of Tawi River by the I&FC Department – Jammu Division. Source: *Site Plan showing training river Tawi from Manwal to exit of Indo-Pak Border at Spots.*

According to the available base data, the proposed training works by the I&FC Department – Jammu Division in the lower Tawi River are summarized in the Table 6.1.

Table 6.1 – Summary of the proposed training works by the I&FC Depart. – Jammu Division in the lower Tawi River.

	Waddi Tawi		Nikki Tawi		Tawi River (upstream of Jammu City Bridge)		Total		
Training work	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Both Banks
Earth Embankments (m)	8039	2880	4200	3490	1500	3514	**13739**	**9884**	**23623**
Crate Revetments (m)	3120	3500	3250	14324	2590	840	**8960**	**18664**	**27624**
Studs/Spurs (Nos)	82	58	93	120	11	14	**186**	**192**	**378**

As presented in the Table 6.1, the training works proposed by I&FC Department in the lower course of Tawi river include the construction of about 380 spurs/studs, 24 km of earth embankments and 28 km of crate revetments.

The left bank of the Nikki Tawi downstream of the Balole confluence is one of the most critical areas in the lower course of Tawi River in relation with bank erosion and degradation as clearly illustrated in Figure 6.3. In this river reach, the construction of earth embankments and 44 studs in the left bank is proposed by the I&FC Department

Additionally, the I&FC Department proposed the construction of protection works in the Nikki Tawi at various spots between 4th Tawi Bridge and Surya Chak Bridge. In this river reach, the proposed works are summarized as follows:

- Earthen Embankment:
  - left bank: 702 m;
  - right bank: 1462 m.
- Studs:
  - left bank: 4 Nos;
  - right bank: 10 Nos.

In Balole Nallah, the I&FC Department has also proposed the following training works from Sehora to Simbal:

- Crate revetment:
  - left bank: 2288 m;
  - right bank: 1686 m.

- Earthen Embankment with toe crates:
  - left bank: 2590 m;
  - right bank: 2334 m.

The Consultants visited some existing embankments, spurs and bank stabilization works, mostly downstream of the main city bridge. Most of the training works are in good maintenance conditions.

The recurrent solution adopted by the Owner for riverbank protection is by means of embankments, spurs and revetments.

Regarding the spurs, it was adopted a permeable gabion solution (Photo 6.2) which in some locations has already controlled bank erosion effectively as shown in Photo 6.3, inducing the silt deposition due to the local slowdown of the current.

Photo 6.1: Embankment downstream of the gated section in the Waddi Tawi.

Photo 6.2: Spur near Toph Mansa (Nikki Tawi).

Photo 6.3: Nikki Tawi – near Toph Mansa (view to downstream).

Photo 6.4: Spur near India-Pakistan border.

All the executed river training works in the Tawi River have a high geotechnical component. In fact, the Consultant considers that geotechnical engineering expertise will be essential at the next phases of the project, allowing to undertake initial investigation, followed by concept and feasibility designs of the works. The Consultant also envisage the need of geotechnical expertise involved in the asset management of existing training and flood defence works.

Consequently, the Geologist/Geotechnical Specialist of the Consultant team has visited some executed river management and training works.

In respect to geological and geotechnical constraints the study area can divised in two zones:

- Zone I - the area from Udhampur to approximately 5km upstream Jammu, where the Tawi river, intersects mostly the Siwalik Group of Miocene-Pliocene age, and the area downstream, where Quaternary alluvial deposits are present (Figure 6.2).
- Zone II - the area downstream, where Quaternary alluvial deposits are present

Figure 6.2 presents the simplified geological map of Udhampur and Jammu region where the above mentioned zones geological formations are identified.

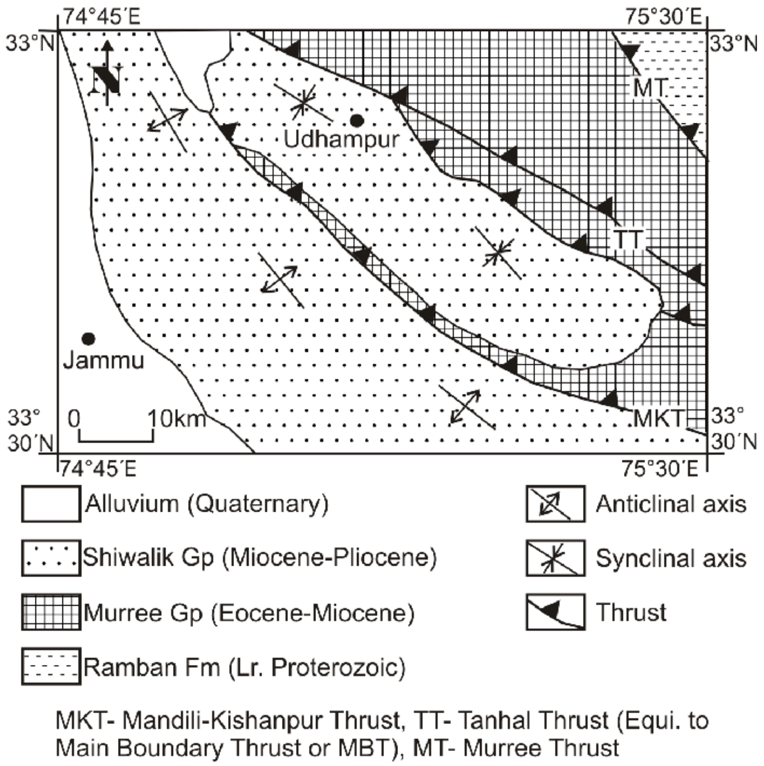


Figure 6.2: Geological map of the Udhampur region, Jammu & Kashmir (Dhang, 2016).

In Photo 6.5 we can observe the Shivalik formation at the intersection between Sardan Nallah and Tawi river and in Photo 6.6 the Quaternary alluvial deposits.

Photo 6.5: Shivalik formation at the intersection between Sardan Nallah and Tawi river (zone upstream Jammu).

Photo 6.6: Alluvial deposits in Jammu.

Based on the available information to present date, zone II where the Quaternary alluvial deposits are present, corresponds to the zone in which the geological and geotechnical constraints are higher. In fact the high thickness of the alluvial deposits may impose foundation restraints to the structures to be designed. Susceptibility of this formation to riverbank erosion/instability, as can be observed in some portions of Tawi river downstream Jammu, is also an important aspect.

The Geological and Geotechnical studies to be performed will identify the most relevant issues in both zones concerning both geological, geotechnical and geomorphological context in the Tawi River Basin.

6.3 ANALYSIS OF FLOOD MITIGATION SOLUTIONS PROPOSED BY I&FC DEPARTMENT

a) Strengthening and enhancing the discharge capacity of River Tawi

One of the proposed measures by the I&FC Department is the strengthening and enhancing of the discharge capacity of the Tawi River. In fact, the flood impacts have been further aggravated by reasons directly related with the insufficient discharge capacity of Tawi River, mostly in its lower course downstream of Nagrota.

Currently, the insufficient discharge capacity of the lower course of Tawi river is mostly associated with the accumulation of huge loads of sediment at river bed and banks, existence of low banks at many places and encroachment of floodplains and wetlands.

Actually, several locations of accumulation of huge loads of sand and silts in the lower Tawi were identified during the site visits as illustrated in the Photo 6.7. Moreover, large scale siltation is also noted around the 3rd and 4th bridge (Photo 6.8 and Photo 6.9) manifested as large gravel bars and channel bifurcation.

Photo 6.7: Tawi River downstream of Jammu City showing huge deposition of sand and gravels on the river bed.

Photo 6.8: 3rd Tawi Bridge (Sidra) near Nagrota.

Photo 6.9: 4th Tawi Bridge.

Generally, the most common reason for carrying out works to rivers is to increase their capacity to carry flood flows. The increase of river flow capacity could be achieved by the combination of the following measures:

- by dike/levee
- by re-sectioning (widening, deepening, etc) the river channel
- by dredging and/or excavation

As per Indus Water Treaty (*Articles III* and *IV*), the flood control and river training works in Tawi could be executed by India whereas they (i) avoid any material damages for the other country, (ii) do not use of water for any storage, (iii) maintain the natural channels of the Rivers, (iv) avoid any obstruction to the flow in the rivers and (v) consider the use of the natural channels for discharge of flood.

Therefore, it is confirmed the compliance within the ambit of *Indus Water Treaty-1960* of the river management works aiming to strength and enhance the discharge capacity of the River Tawi as proposed by the I&FC Department, although some technical aspects and obligations previously enumerated must be ensured.

At a subsequent phase of the Assignment, the Consultant will analyze possible solutions to enhance the discharge capacity of the Tawi River, particularly with the support of the numerical modelling tasks.

b) Low lying areas affected during high floods

Another flood risk management measure proposed by the I&FC Department is to identify the low lying areas affected during high floods.

Actually, the identification of the areas affected during floods is a primary component of flood risk management and land use planning, providing a more reliable measure of flood risk and enable decision-makers to better target land use regulations, avoiding inappropriate development in areas at risk of flooding.

Additionally, the planning and design of comprehensive flood mitigation schemes aiming to reduce the loss of life and property shall be based on an accurate determination of the areas subject to floodwater inundation for different recurrence intervals.

The identification of areas affected during floods relies upon the creation of flood hazard maps, which generally are produced through detailed hydraulic modelling studies, remote sensing or historical data (flood marks, testimonials, etc). Currently, the most reliable and effective method relies on the application of detailed hydraulic modelling studies to identify the flood prone areas. These studies tend to incorporate historical flood event information, hydrological analyses, and hydraulic flow propagation models.

In this context, the introduction of high-resolution digital elevation models (DEMs) has provided the opportunity to map floodplain features with high accuracy over larger spatial scales. DEMs are increasingly being used for visual and numerical analysis of topography, landscapes, and landforms, as well as modeling of surface processes.

Additionally, the application of GIS techniques has been used to easily generate spatial data that could be useful for flood mitigation and planning of the basin. GIS based methods provide a broad range of tools for determining areas affected by floods or for forecasting areas likely to be flooded due to high river water levels.

According to the scope of this Assignment, the Consultant will proceed with the identification of the low lying areas affected during high floods in Tawi River based on detailed hydraulic modelling studies, remote sensing and historical data.

The identification of the low lying areas affected during high floods is generally seen as action to support the landuse planning, regulation and planning of flood control and mitigation schemes. Therefore, this action is within the ambit of related provisions of Indus Waters Treaty.

c) *Flood storage works*

The I&FC Department also proposes the construction and creation of flood storage works, particularly the creation of flood storage dams and identification of locations for flood water detention basins and assessing their capacities and other broad salient features.

Regarding the water storage works for flood control, the Indus Water Treaty (particularly in Article III and Annexure E) anticipates that India must not store any water or construct any storage works on Tawi River. However, some exceptions are included in *Paragraph (8)* of the *Annexure E* regarding the water storage by India in Western Rivers, which are mainly related with water storage resulting from natural processes. These types of natural solutions for water detention (*e.g.* wetlands, natural depressions, ponds) will be analyzed by the Consultant and both technical and economic feasibility analysis will be carried out according to the scope of the present Assignment.

Actually, the lack of natural water detention and retention areas in built-up areas, together with the increased frequency and magnitude of rainfall events due to climate change, is generally one of the main causes of increased risk of surface water flooding.

Therefore, some potential applicable nature-based water detention measures are presented in this document in the **Subchapter 7.2.3.1**.

d) *River management for flood risk management*

River management for flood risk management consists of anti-erosion works for bank protection, strengthening of existing embankments, constructing new embankments, revetments, spurs etc. There are several locations in the Tawi River with gaps in the existing embankments as shown in Figure 6.1. The embankments are eroded in many places and severe bank erosions have also been identified during site visits. Comparison of Google Earth image of 2005 and 2018 for Nikki Tawi near Balole Nallah confluence (Figure 6.3) clearly shows that the river has eroded the left bank significantly. Hence, construction of embankments, revetments and spurs are necessary for flood risk reduction and these measures are in compliance within the ambit of *Indus Water Treaty-1960* of the river management works.

(a)

(b)

Figure 6.3: Nikki Tawi near Balole Nallah confluence. Satellite imagery in 2005 (a) and 2018 (b). Source: Google Earth V 7.3.2.5491. Digital Globe 2012. http://www.earth.google.com

e) Watershed management

Watershed management is the comprehensive process of managing land, water and other natural resources to protect and improve the quality of the water and other natural resources within a watershed. Watershed management carries out number of activities with an integrated approach addressing proper land use, protecting lands from all forms of degradation, conserving water for farm use, proper management of water for drainage, erosion control and sediment reduction. Watershed management processes reduce sediment yield, increase flood detention and hence contribute to flood risk reduction. This option proposed by the Department of I&FC is feasible and will be further explored by the Consultant in the broader framework of Green Infrastructures and Nature-based Solutions for flood risk management.

Additionally, the watershed management measures are generally in compliance within the ambit of Indus Water Treaty-1960, except any kind of measures that involve or result in water storage.

7 PRELIMINARY ASSESSMENT OF APPLICABLE INNOVATIVE FLOOD MANAGEMENT SOLUTIONS

7.1 INTRODUCTION

The Jammu Division of Jammu & Kashmir is prone to flooding from Tawi River caused by annual monsoon rainfall. The river bank erosion further exacerbates the flooding. The bank erosion is also threating the stability of existing embankments. The flooding exposes the population and infrastructures to risk and creates tremendous human misery including death. It causes the loss of fertile land, disrupts communications, and hampers economic and social development.

In the past, the flood management programs have focused too heavily on structural measures and little attention has been given to better adaptation, preparedness and building resilience. A flood resilient society should be able to prepare for, respond to and recover from flood risks. A resilient system should have the following four properties:

- Robustness (ability to withstand a shock)
- Redundancy (functional diversity)
- Resourcefulness (ability to mobilize when threatened)
- Rapidity (ability to contain losses and recover in a timely manner)

Generally, an Integrated Flood Management (IFM) approach is followed for building resilience that works with nature and makes use of eco-system functioning to enhance safety, promote food and freshwater security, protect livelihoods, and adapt to climate change impacts. The World Bank has been actively promoting a resilience approach in flood risk management.

Integrated flood management comprises five key elements (WMO, 2017a):

- Adopting a best mix of measures, both structural and non-structural; to reduce flood risk and mitigate the consequences once a flood occurs;
- Managing the water cycle as a whole while considering all types of possible floods;
- Integrating land and water management, as both have impacts on flood risks;
- IFM should be part of a wider risk-management system, adopting integrated hazard management approaches, taking into consideration all related hazards; and
- Ensuring a participatory approach to develop ownership of the strategy to reduce vulnerability

Accordingly, an **Integrated Flood Management approach** is clearly essential for the Tawi River Basin, considering future risks alongside current trends in order to achieve a flood resilient society, and engaging with a broad range of stakeholders. The flood and river management measures shall be designed using latest and upgraded technology, having the desired resilient features to meet all future contingencies of bigger magnitude well in time and space variables. An effective integrated flood risk management strategy for Tawi basin includes both structural and non-structural measures with the following components:

- **Component 1: Comprehensive Flood Risk Assessment**
- **Component 2: Flood Risk Governance and Capacity Development**
- **Component 3: Structural Measures for Flood Risk Reduction**
- **Component 4: Flood Risk Resilience through Risk Transfer and Insurance**
- **Component 5: Flood Preparedness and Emergency Response**

The comprehensive flood risk assessment provides a foundation for other four pillars of flood resilience as shown in Figure 7.1 below.

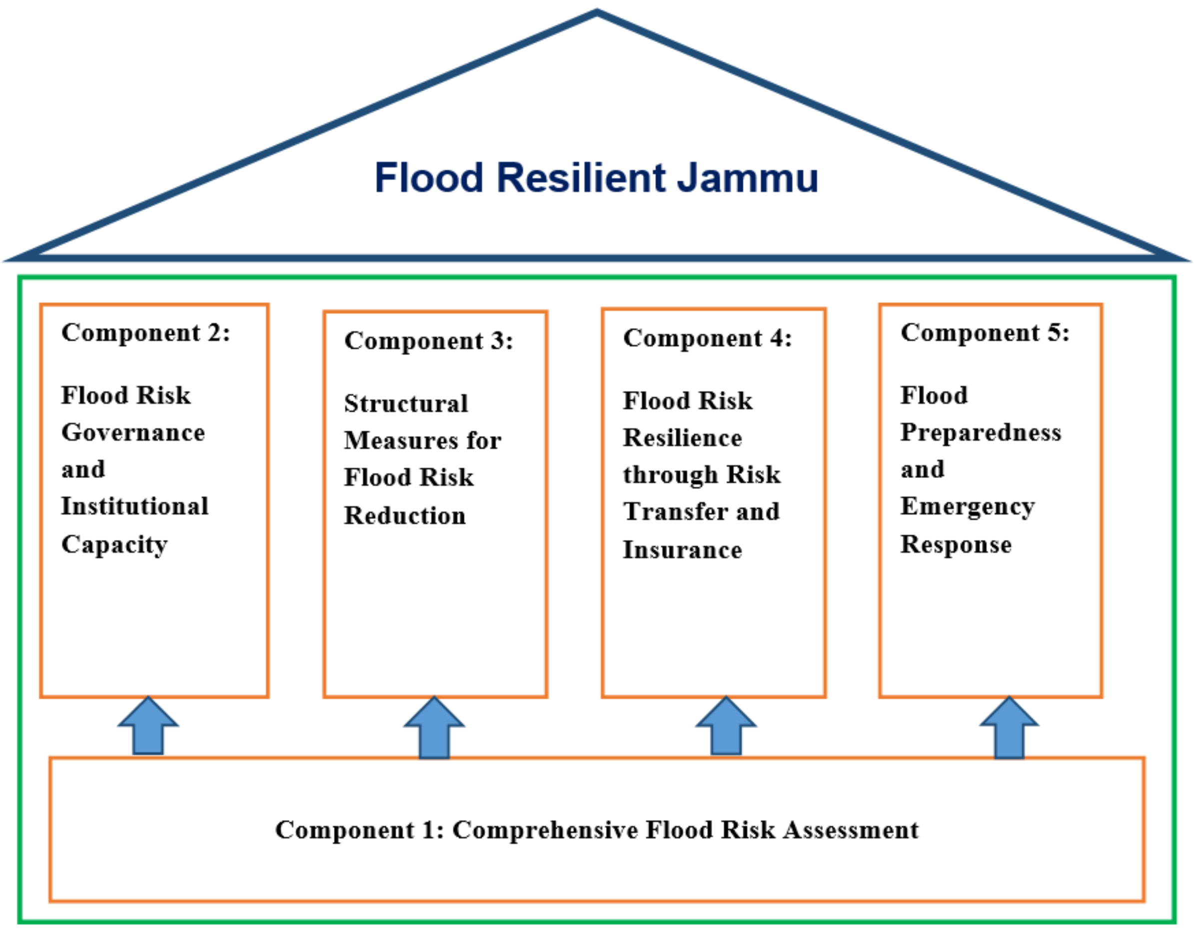


Figure 7.1: Integrated flood management strategy for flood resilient Jammu

7.2 INNOVATIVE AND EMERGING FLOOD MANAGEMENT OPTIONS FOR TAWI BASIN

Based on Integrated Flood Management (IFM) Strategy, the preliminary assessments of the applicability of innovative and emerging flood management options for the Tawi River Basin are presented in the following sections.

7.2.1 Component 1: Comprehensive Flood Risk Assessment

Comprehensive flood risk assessment is the process of flood risk analysis and risk evaluation in a comprehensive manner. A sound understanding of flood risk enables informed decision making for flood risk management. Understanding flood risks requires better information, especially how risks associated with flood hazards interact with communities that are facing rising exposure to these hazards. Flood risk analysis includes hazard assessment, assessment of elements at risk i.e. exposure, vulnerability assessment and risk estimation.

Flood risk assessment is the entry point for any flood management measure. Flood risk assessment provides information on frequency, magnitude and location of flood hazard, population and assets exposed, and the probability and consequences. Understanding flood behaviour and likely impact on the community enables us to examine options to manage the community's exposure to flood risk.

Purpose:

The purpose of comprehensive flood risk assessment is to understand flood behaviour, identify the likely location, type and scale of effects for a range of floods and guide where and what kind of the flood management measures should be taken up.

Since the flood hazard and vulnerabilities are dynamic in nature and change with time, the flood risk assessment should be updated at regular interval of time, preferably every five years or before implementing major flood management measures.

Activities:

- Activity 1: Topographic and Bathymetric Survey Database and Analysis
- Activity 2: Hydrologic Analysis
- Activity 3: Morphologic Analysis
- Activity 4: Flood Inundation Modelling and Mapping
- Activity 5: Flood Vulnerability Assessment
- Activity 6: Flood Risk Assessment

7.2.1.1 Activity 1: Topographic and Bathymetric Survey Database and Analysis

Topographic and Bathymetric surveys of rivers are performed to serve as basis for planning, designing and implementing mitigation strategies to prevent, reduce or control riverine floods. Generally, the topographic survey program employs airborne (Light Detection and Ranging) LIDAR or ground based GPS or ETS technology to generate detailed topography of the river system. If aerial surveys are done, then ground surveys are also performed to capture parameters that cannot be obtained from airborne sensors. The survey activities for assessing river flooding conditions include aerial surveys, control surveys, river cross-sections, profile surveys, bathymetry and hydrometric measurements.

The precise river surveys are necessary for the design and construction of appropriate river training structures and bank protection works. It is noted that the appropriateness of a particular plan/design rely much on the veracity and accuracy of available basic data and information. Large-scale river surveys covering hundreds of kilometers of river channels, as conducted during feasibility study, provide deeper insight into actual river processes. The obtained information supports the prediction of future channel (and erosion) patterns, and also provides the much needed input data for advanced numerical modelling.

All the geometry data coming from different survey modes come together as input data for the flood modeling. The profile and cross section measurements are used to augment the river geometry along the river channel extracted from DEM data. This merged elevation data form the basic geometric input for the flood model.

The topographic and bathymetric survey database developed during feasibility study needs to be further built up to understand the responses of river training structures to river processes. Regular surveys will help to understand how newly built and existing riverbank protection responds to first and repeated river attacks and how the river responds to protected banklines.

7.2.1.2 Activity 2: Hydrologic Analysis

The hydrologic analysis consists of review and analysis of historical flood events, hydrometric data, hydro-geomorphological processes and design peak flows for specified probabilities. Hydrological processes are dynamic and changes in landuse, climate change and flood management measures may influence the hydrology of the river system. For example, deforestation and urbanization may increase the peak flows, interventions to the channel to mitigate flood risk may accelerate erosion or deposition, use of inappropriate bank protection may transfer erosion downstream, straightening or reprofiling the channel may cause the watercourse to attempt to revert back to a more natural state etc. Hence, hydrologic analysis conducted during the feasibility study needs to be continued and further developed in future.

7.2.1.3 Activity 3: Morphologic Analysis

The morphologic analysis consists of assessment of various features and processes of river valley, channel, banks and floodplains. Episodic changes in river course and sediment dynamics that alter the morphology (geometry, form) of the river channel and adjacent floodplain can modify the likelihood of flooding and hence these processes should be considered in flood risk assessment.

The major floodplain features are river channels, bars, meanders, bifurcation, wetlands, natural levees and abandoned channels. Each and every feature developed in the floodplain changes over space with time and controlled mainly by the river. Human interventions such as river management measures may also change river morphology. For example, construction of dams or reservoirs may alter the flow of water and sediments, therefore changing the pattern of erosion and deposition and formation of bars, meanders and bifurcations. Hence, morphologic analysis conducted during the feasibility study needs to be continued and further developed in future.

7.2.1.4 Activity 4: Flood Inundation Modelling and Mapping

The flood inundation or hazard maps basically define the inundation levels at different areas of floodplain of the river. This is important in land use planning and zoning since it identifies decision zones where development and location of communities must be regulated. It also guides investment decisions such as what and where flood and drainage control structures must be put in place, and how will they be designed to withstand future impacts of climate change. The flood inundation model can also guide the integrated flood monitoring and early warning system that the Department of I&FC intends to put in place.

By being able to pinpoint areas that are of highest risk to future flood events, State government will be able to prioritize their programs and projects to address the vulnerability of communities therein, come up with better preparedness programs, and ensure the safety of everyone.

Since the intensity and magnitude of flood hazard may change over time, especially in the context of climate change, the flood inundation mapping conducted during the feasibility study requires to be continued and further refined in future using recent topographic, hydrologic and hydraulic data.

7.2.1.5 Activity 5: Flood Vulnerability Assessment

UNISDR has defined vulnerability as *“the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards”.*

The vulnerability assessment includes the assessment of location, attributes, and value of assets that are important to communities (people, property, infrastructure, agriculture/industry etc) and the likelihood that assets will be damaged or destroyed when exposed to a hazard event, for example, the relationship between the depth of flood and the level of damage for different assets.

Vulnerability is the human dimension of disasters and is the result of the range of economic, social, cultural, institutional, political and psychological factors that shape people’s lives and the environment that they live in. It is influenced by a number of factors at different levels, from the local to the global. It is also dynamic, altering under the pressure of many different forces (Twigg, 2004).

Vulnerability to flooding increases with socio-economic development as more facilities are located on flood plains. It is also the case that with increasing population pressure, the poor often occupy the most flood-prone areas.

Since the flood vulnerability changes over time, the assessment conducted during the feasibility study requires to be continued and further refined in future using recent socio-economic and exposure data.

7.2.1.6 Activity 6: Flood Risk Assessment

Flood risk refers to the combination of the "flood hazard" at a certain frequency with the “exposure” of the population and assets and their “vulnerability” (Figure 7.2). Flood risk could be measured in terms of economic losses (e.g. damage to infrastructure, property, crop losses and transport disruption), or in terms of numbers of people affected and distressed by an event and numbers of people who may have lost their lives.

In risk assessment it is necessary to improve knowledge about flood events, their evolution and extent. It is necessary to simulate different spatial scenarios, identifying the different areas of risk and their degree of severity.

Flood inundation modeling provides the flood extent and depth of different historic floods or floods of different scenarios (e.g. 100-year design flood). Overlaying inundation levels over the terrain constitute flood hazard maps, showing inundated areas and depths for floods of different magnitudes. If the exposure and vulnerability information are added over the flood hazard maps, then flood risk maps are obtained.

Figure 7.2: Components of Risk
Source: http://www.un-spider.org/risks-and-disasters/disaster-risk-management

Information obtained by surveys, hydrologic analysis, morphologic analysis and flood risk mapping provide a comprehensive flood risk assessment. Comprehensive flood risk assessment requires time and resources. The assessment conducted during the feasibility study requires to be continued and further refined in future using more precise topographic, hydrologic and hydraulic data when those data will be available so that more precise flood risk information will be available for better management of flood risks.

In addition to the spatial approach to risk, a risk-based approach to planning for use, emergency and rescue planning is also important. The priority of protective measures should be assessed along the river, analysing areas where the population is most at risk.

Areas that are more susceptible to floods should be identified, including those actions that may be necessary for the protection of specific habitats, rather than sources of drinking water supply. 13 districts in J&K out of 100 in the Country have been identified as Multi Hazard Districts. It is therefore extremely important to take into account the risks related to the frequency and intensity of floods, the increase of water tables, erosion, and sediment trapping, landslides, snowmelt, etc.

Regulating construction in sensitive areas should also be a priority. Exceptions should be restricted to those uses of strict necessity. Adapt the uses to hazards in potential flood zones to minimize potential damage. Accompanying the development of the building in these areas and publishing the results compared to the previous situation should be carried out regularly.

The most sensitive establishments, such as buildings and installations whose operation is essential for civil security, defence or maintenance of public order, or whose failure poses a high risk to humans or presents the same risks due to their socio-economic importance, should be implemented in the least risk prone areas. Only activities that are linked to the water management system or that cannot be implemented elsewhere for reasons of important social interest should be permitted.

Identify and reduce the vulnerability of existing infrastructures and all networks located in flood prone areas (water supply, energy systems, transport and communication networks, public facilities, etc.) and particularly the transport network that can suffer massive disruptions or prevent the evacuation of emergency services.

In potential floodplains, future planning and approval stages of new construction work should take into account new and relative construction methods that incorporate the need to maintain space for water and address water-related problems. Thus, it could eventually lead to establishing mandatory building standards for the flood risk area.

7.2.2 Component 2: Flood Risk Governance and Capacity Development

Effective institutional and legal arrangements support the foundation for proper operation and maintenance of flood risk management system. Good governance is encouraged by robust legal and regulatory frameworks and supported by long-term political commitment and effective institutional arrangements. Effective governance arrangements should encourage local decision-making and participation which are supported by broader administrative and resource capabilities at the national, state and local level.

Purpose:

The purpose of strengthening flood risk governance and capacity development is to clarify the roles and responsibilities of various stakeholders involved in flood prevention, preparedness, response and recovery through legal and regulatory frameworks, to implement flood risk management measures through effective coordination and to build the capacity of institutions and stakeholders involved in flood risk management.

Activities:

The policy and institutional frameworks for disaster risk reduction and flood risk management are already well established in the state of Jammu & Kashmir. However, the following key activities need to be implemented to strengthen flood risk governance and institutional capacity.

- Activity 1: Inter-Agency Coordination
- Activity 2: Landuse Regulation
- Activity 3: Flood Proofing Regulation
- Activity 4: Capacity Development

Within the scope of this Component, the Consultant's responsibility will mostly include the assessment of the feasibility of the previously mentioned activities and suggest in DPR how they can be implemented. Additionally, the Consultant will also carry out some tasks included in the ToR which will support the implementation of the previous mentioned activities (*e.g.* identification of low lying areas, flood risk mapping, training sessions and capacity building).

7.2.2.1 Activity 1: Inter-Agency Coordination

Inter-Agency Coordination is one of the Thematic Areas for Action for disaster risk reduction identified by National Disaster Management Plan, 2016. Flood risk management, covering prevention, preparedness, response and recover, involves multiple agencies. Hence, the inter-agency coordination and collaboration among stakeholders are of utmost importance for successful implementation of flood risk management plans. Inter-agency coordination is a key component of strengthening the flood risk governance.

Guidelines and Standard Operating Procedures (SOPs) need to be developed to define the processes, and roles and responsibilities of all organizations in flood risk reduction, preparedness, response and recovery. They should clearly define data and information sharing mechanism among different organizations and stakeholders. They should also provide guidelines to integrate flood risk assessments into local development plans and programs. The guidelines should ensure inclusive access, representation and meaningful participation of children, women, elderly, people with disability and marginal communities in all processes of flood risk management. They should also promote use of modern information and communication techniques in flood risk reduction and management. The following activities can be taken up for effective inter-agency coordination:

- Formation of inter-ministerial/ inter-departmental technical working groups for flood prevention, preparedness, response and recovery, for example, cluster approach for preparedness and response.
- Formation of State Platform for Disaster Risk Reduction involving government agencies, NGOs, community organizations, civil society organizations, research and academic institutions etc. to share knowledge and best practices on effective approach.
- Development of Guidelines, for example, Disaster Risk Reduction Framework, State Disaster Response Framework etc

The consultant will analyze the feasibility of inter-agency coordination mechanism and processes for flood risk reduction.

7.2.2.2 Activity 2: Land Use Regulation

Historically, floodplains have been attractive areas for human settlement as they offer numerous opportunities in terms of available natural resources. Although living on floodplains has great advantages, their occupants are exposed to flood risks. Land use is recognized as playing an essential role in flood exposure and vulnerability and hence it is necessary to interlink and harmonize land use management and flood risk management (WMO, 2016).

Land use regulation is the process of implementing zoning codes to steer human development away from high-risk areas. Comprehensive flood risk assessment provides the basis for land use regulation. Once the areas with different risk levels (high risk, medium risk, low risk and no risk) are identified, then regulation can be introduced to restrict certain activities that increase the exposure and vulnerabilities. The consultant will analyse the feasibility of landuse regulation to reduce flood risks.

The strategic land use planning at the local level supported by the increased knowledge of flood hazard is helpful to secure resilience to flooding. Thus, the systematic assessment of land and water potential and planning the best land use option in the area is important to reduce the future risk. Water management policies combined with spatial planning should strike a balance between economic and urban development. National Disaster Management Plan, 2016 has recommended the following provisions under non-structural measures for flood risk management.

- Implementing land use regulation for low lying areas as per flood control norms
- Regulation of inhabitation of low lying areas along the rivers, nallahs and drains

J&K State Disaster Management Plan has also made the following provisions under techno-legal regimes for flood risk management:

- Ensure flood plain zoning
- Enactment and enforcement of laws regulating developmental activities in flood prone areas
- Restriction of construction near / along water way
- Introduce necessary amendments in various laws concerned with planning and developments of cities and towns in the state
- Review and revision of Town Planning Acts and Rules/Master Plans taking into account the objectives of disaster resilience

7.2.2.3 Activity 3: Flood Proofing Regulation

Many structures and buildings are located in the floodplains of Tawi river and susceptible to flooding. Flood mitigation measures have partially protected some of these structures and buildings but residual threats to partially protected areas and total threats to unprotected areas remain as major problems. Flood proofing standards applied through building codes and regulations to flood plain structures can help to reduce flood damages. Flood proofing regulation provides the guidelines for structural measures to protect structures and buildings from flood water.

Building standards and codes can play a strategic role in the reduction of potential flood damage. Comprehensive flood risk assessment provides the basis for flood proofing regulation. Based on the delineation of risk zones, this restrictive regulation provides mandatory construction guidance to enhance the flood resilience of infrastructure facilities and buildings. In other words, building codes and standards are adopted and enforced to regulate construction in areas at risk (WMO, 2012).

J&K State Disaster Management Plan has also made the following provisions for flood proofing regulation under techno-legal regimes for flood risk management:

- Review and revision of building laws taking into account the objectives of disaster resilience.
- Enforce building by laws for flood plains.
- Enforcement and strict adherence to building codes and rules in design and implementation.

Flood proofing regulation shall apply to the construction, alteration and repair of any building or parts of a building or structure in flood prone areas. The regulation is generally enforced as part of “Building Codes”. The consultant will analyse the feasibility of including flood proofing regulation in building codes.

7.2.2.4 Activity 4: Capacity Development

Capacity Development is one of the Thematic Areas for Action for disaster risk reduction identified by National Disaster Management Plan, 2016. Capacity development covers strengthening of institutions, mechanisms, and capacities of all stakeholders at all levels. The capacity development includes training programs, curriculum development, large-scale awareness creation efforts, and carrying out regular mock drills and disaster response exercises.

J&K State Disaster Management Plan has also made the following provisions under capacity building for flood risk management:

- Capacity building through Simulation and Mock Drills needs to be carried out both horizontally (across line departments) and vertically (at all levels)
- Develop a cadre of specialized task force in disaster mitigation.

- Strengthen the skills and knowledge of task forces involved in the mitigation of disasters.
- Conduct workshops/training for sensitization of the stakeholders.
- Carry out specific research for instance EIA and SIA.
- Regular updating and documentation of disaster data base.
- Launch awareness campaigns regarding safety measures against potential hazards.
- Develop multi- hazard IEC material for Publication and Distribution.
- Organize exhibitions for public awareness through local institutions.
- Promote communication activities such as awareness, emergency contact numbers, do's and don'ts through posters, volunteers training, and village task force.
- Formulate literature of do's and don'ts for building in local/ vernacular languages.
- Conduct regular drills at all institutions at state, district, village and Tehsil levels.
- Include disaster related topics in schools and colleges curriculum.
- Training medical and non- medical staffs for handling Mass Casualty and providing basic First Aid.
- Ensure that each village has 100 trained individuals in basic first aid for emergency response.
- Ensure that each district has at least 2 divers to deal with drowning related incidents.

The consultant will focus mainly on assessing the feasibility of the capacity development of institutions, particularly, the Department of Irrigation & Flood Control and the Department of Disaster Management, Relief, Rehabilitation and Reconstruction. Capacity building of local stakeholders will be covered under Community Based Flood Risk Management. A broad training needs assessment will be conducted and a tailored training program will be designed.

The capacity development program for institutions may cover the following specialized topics:

1. Flood risk assessment and mapping
2. Riverbank protection
3. Construction techniques and quality
4. Flood risk management
5. Green infrastructures and nature based solutions for flood risk reduction
6. River morphology
7. Flood forecasting and early warning system

7.2.3 Component 3: Structural Measures for Flood Risk Reduction

Structural measures are any physical construction aiming to reduce or avoid possible impacts of flood hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience for life, structures and ecosystems. The structural flood risk management generally involves both engineering interventions (also known as hard engineering options) such as flood embankments and groynes, and ecological interventions (known as soft methods), such as soil conservation and wetland restoration (also known as nature-based methods, detailed in **Subchapter 7.2.3.1**). The soft adaptation options are generally more flexible and cost effective than hard measures.

In India, the main emphasis of the flood management has been on hard structural measures, namely embankments, spurs, river re-sectioning and diversions channels. However, recent approaches on Integrated Flood Management (IFM) recommends that effective flood control and mitigation schemes should not only consider hard and soft measures but also include a careful process of selecting and carrying out the best combination of engineering and nature-based structural and non-structural methods.

In fact, recent guidelines and instructions in flood management (*e.g.* WWF and USAID, 2016; EEA, 2017) recommend that decision-makers should firstly apply non-structural methods for flood mitigation, and then, if needed, include structural measures (both hard and soft engineering solutions) as part of an integrated approach. For the Tawi Basin, it is considered that the adequate combination of methods will optimize the project’s flood risk management, as well as its social and environmental benefits as required by the Indian Governmental Agencies and World Bank safeguards policies.

Taking into consideration the obligation to comply with the provisions of the Indus Waters Treaty-1960, the structural measures for flood control and mitigation which can be potentially applicable in Tawi River Basin are the following:

Hard engineering measures:

- Diversions
- Constructed wetlands
- Levees, embankments, flood walls
- River widening and deepening
- Floodways
- Groynes and revetments

Soft engineering measures:

- Upper watershed restoration
- Soil conservation measures
- Wetlands restoration
- Swales and infiltration devices

- Rainwater harvesting
- Detention basins and retention ponds
- Natural drainage path restoration

All the previously mentioned potential hard and soft structural measures for flood risk reduction in the Tawi Basin will be analysed in subsequent tasks of this Assignment.

Purpose:

The purposes of structural measures are to reduce or avoid possible impacts of flood hazards on people's life, properties, infrastructures and ecosystem.

Activities:

- Activity 1: Green Infrastructure and Nature-Based Solutions
- Activity 2: Grey Infrastructures for Flood Risk Reduction

7.2.3.1 Activity 1: Green Infrastructure and Nature-Based Solutions

Recently, the natural flood management has been gaining recognition as a cost-effective approach to flood risk management. Consequently, the infrastructure works intended to protect areas from flooding has been focused on integrated solutions that combine structural measures (*e.g.* dikes, spurs, diversions, channelization) with green and nature-based measures, especially aiming at recovering and re-naturalising the floodplains and wetlands.

The nature-based flood management is an approach to manage floods which works with natural hydro-morphological processes throughout the river basin to retain flood water temporarily during extreme flood events. This type of solutions also results in additional benefits to biodiversity, water quality and climate change resilience. For that reason, the application of nature-based flood mitigation solutions is considered as a comprehensive approach for landuse management aiming to increase the resilience of communities and landscapes, in particular taking into consideration the imminent challenges of climate change. However, recent studies suggest that nature-based flood management shall be planned and executed in combination with other flood management measures (EEA, 2017, WWF and USAID, 2016).

According to the recent technical Report: *Green Infrastructure and Flood Management* prepared by the European Environment Agency (EEA, 2017), the most effective natural flood management measures are the following:

- floodplain restoration and management;
- wetland restoration and management;
- re-meandering;

– stream bed re-naturalisation.

In fact, the same report highlights that recent investments in Europe for flood control and mitigation were mostly addressed the following nature-base solutions: wetland restoration, floodplain restoration and restoration and reconnection of seasonal streams.

From the previously mentioned nature-based solutions for flood control and mitigation, only the floodplain and wetland restoration and management are potentially applicable in the Tawi River. Actually, the Tawi can be considered as a relative intact river along most of its extension, without any significant executed works of channelization or removal of river's meanders and river bed alterations (*e.g.* concrete lining).

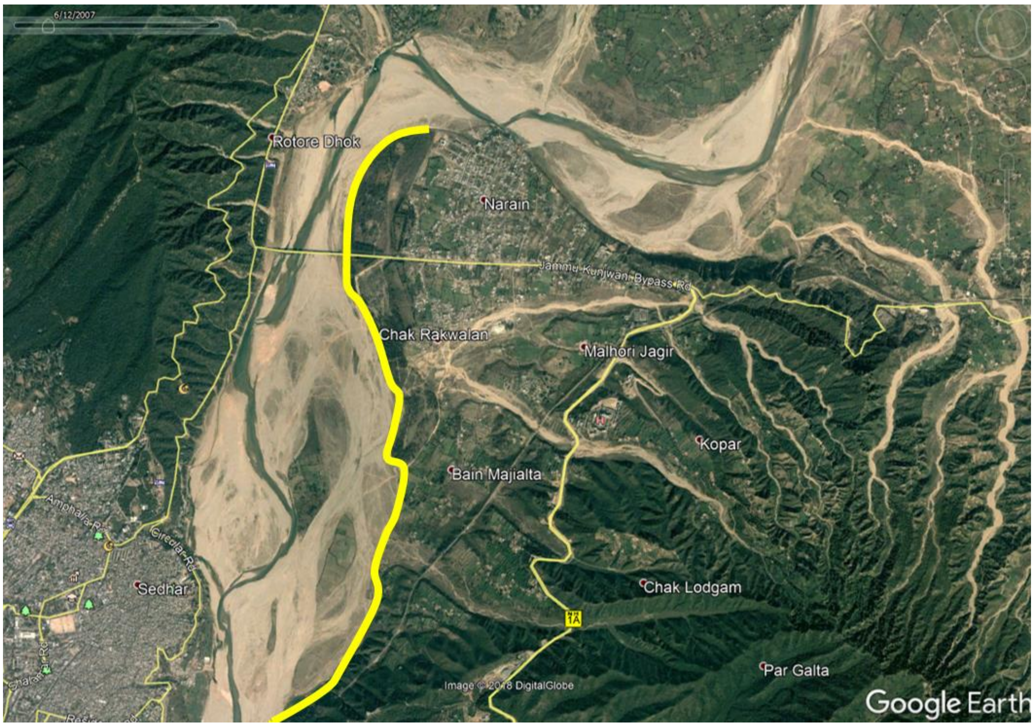
7.2.3.1.1 Floodplain Restoration and Management

A floodplain is defined as the area bordering a river that naturally provides space for the retention of flood and rainwater. Floodplains have been occupied by humans around the world, who in many cases develop and use the areas, modifying significantly the surface. However, this occupation becomes a serious problem when large water flows overtopping the river banks or embankments, flooding its surroundings and particularly those areas that are naturally prone to accommodating this extra discharge. The Figure 7.3 shows a floodplain in flooded and non-flooded situations.

a) **b)**

Figure 7.3: Floodplain in different conditions: (a) non-flooded and (b) flooded. Source: EEA, 2017

Preliminary findings in the lower course of Tawi River suggest that floodplains upstream of Jammu City Bridge has been significantly reduced and are currently inactive. The Figure 7.4 shows the lower course of Tawi River, upstream of the Jammu City Bridge in 2005 before the construction of embankments (a) and in 2018 (b). This hydromorphological alteration in the lower Tawi reduces the natural inundation zones and most probably aggravates the impacts in Jammu City during major floods.



a)

b)

Figure 7.4: Floodplains of Tawi River, upstream of Jammu City Bridge.
Satellite imagery in (a) 2005 and (b) 2018.
Source: Google Earth V 7.3.2.5491. DigitalGlobe 2012. http://www.earth.google.com

The natural measures for floodplain restoration usually consist of enlarging the retention areas, increasing the water storage capacity and consequently preventing water from occupying areas where human activities take place.

The most common natural solutions for the creation or restoration of floodplains include:

- creation of flood bypasses;
- removal or setting-back of embankments;
- connecting isolated water bodies;
- floodplain excavation (lowering/dredging of floodplain surface to provide flood capacity);
- restoration of vegetation;
- change in soil use, promoting retention of water.

Therefore, the Consultant will carefully analyse the feasibility of promoting the creation and rehabilitation of floodplains in Tawi River, since this flood control and mitigation measures is generally a very cost-effective option. In fact, flood mitigation in floodplains occurs through the retention of excessive temporary water and run-off, reducing the peak flows. Additionally, restoring and expanding floodplains liberates space for water to flow, and its roughness generally reduces the speed of stream flow.

Indeed, the floodplain restoration projects could represent high benefits and co-benefits as a nature-based flood management measure, comprising the following direct and indirect effects according to (EEA, 2017):

- storing and slowing run-off and river water (direct effect);
- promote the natural water storage (indirect effect)
- reducing run-off (direct effect);
- groundwater recharge (indirect effect);
- erosion control (indirect effect);
- filtration of pollutants (indirect effect).

By allowing the stream naturally functioning, with controlled flooding, floodplain restoration measures reduce the risk of flooding damages. Buffer zones and storage infrastructures slow the water transfer time between the floodplain and the river, thereby spreading the flow and thus decreasing the flood intensity.

7.2.3.1.2 Wetland Restoration and Management

A wetland is an ecosystem wherein soil is permanently or intermittently saturated with water and which commonly includes dense vegetation. Therefore, wetlands tend to act as a sponge to store floodwaters, absorbing rainfall and promoting that percolation processes occur more slowly into the soil, thereby reducing the velocity and volume of flood runoff reaching the streams and rivers. As a consequence, the water levels in rivers located downstream also rise more slowly and human lives and livelihoods are less likely to be affected by destructive flash flood events.

In cases where the natural wetlands have been destroyed or damaged, decision-makers should plan and create wetlands as a flood management method. In these cases, the design objectives of wetlands are generally to reduce the flood peak and increase the lag time by detaining floodwater.

Specifically, the wetland restoration and management includes the following type of measures:

- installation of ditches for rewetting;
- cutback of dykes to enable flooding;
- changes in land-use;
- agricultural measures, such as adapting cultivation practices in wetland areas.

Most of these measures could be also applied in floodplains restoration as detailed in **Subchapter 7.4.1.1**.

The effectiveness of wetlands for flood control generally vary according to the area, type and condition of vegetation, slope and location of the wetland in the flood path as well as the saturation of wetland soils before flooding. According to (EEA, 2017), the benefits of wetland restoration in terms of flood protection are more moderate in comparison with the floodplain restoration, as wetlands have a relative smaller effect on adjusting the morphological aspects of rivers.

Actually, a typical wetland does not have a very large area and therefore the absorption and storage capacity of river water of the restored wetlands could be significantly limited. As a result of their reduced size and aiming to increase the effectiveness of wetlands for flood control and mitigation, this type of measures is usually combined with other type measures.

Wetland restoration and management can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. They can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. Creating artificial or constructed wetlands in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement.

Therefore, the Consultant will analyse the feasibility of create and/or restore wetlands in the Tawi River Basin as part of an integrated flood management approach, comprising different types of flood mitigation solutions.

Figure 7.5: Inundated wetland. Source: EEA, 2017

7.2.3.1.3 Water-Retention Measures

Concerning the flood mitigation and control measures, recent approaches to flooding have been shifting the emphasis from security infrastructure (*e.g.* embankments, spurs, check-dams, weirs, culverts) to different measures with objectives other than simply containing the water in its “normal” confines. On the contrary, emerging flood mitigation solutions aim at increasing the water retention on wetlands, floodplains, ponds, etc. and promoting the flood diversion in order to reduce the velocity and depth of flood waves.

According to the Alfieri et al. (2016), the flood adaptation measures should aim at reducing peak flow making use of natural retention capacity upstream, while raising flood protection should be considered as a last resort solution, to compensate for the residual risk in areas where other options cannot be implemented.

In fact, natural and green solutions for water retention have been increasingly recommended in recent state of the art studies of river engineering, particularly in the REFORM project.

As per the Indus Water Treaty, the potential applicable water retention measures in Tawi River shall result from natural means and processes of water detention and retention during floods. Therefore, only natural water retention solutions are hereafter analyzed.

There are two freshwater lakes in Tawi basin: Surinsar and Mansar. These lakes are freshwater composite lakes with catchment of sandy conglomeratic soil, boulders and pebbles. Surinsar is rain-fed without permanent discharge, and Mansar is primarily fed by surface run-off and partially by mineralised water through paddy fields, with inflow increasing in rainy season. Both lakes are small up-land lakes of about 50 hectares located nearby the hilly ridgeline. There is no possibility of diverting river flow in these lakes. Hence, they are not technically feasible as a cushion for reducing flood discharge in the Tawi River.

The natural water retention measures are multi-functional measures that aim to protect and manage water resources, particularly during floods, through slowing or reducing the flow of water downstream and leading to a more natural flow regime within a catchment. Therefore, they are generally considered as one of the best environmental options for flood control and mitigation.

Many different measures can act as natural water retention measures, by promoting the retention of water within a catchment. The natural water retention measures which can potentially be applicable in Tawi River Basin in compliance with the provisions of the Indus Water Treaty-1960 are the following:

- Creation of basins and ponds
- Wetland restoration and management
- Floodplain restoration and management
- Restoration and reconnection of seasonal streams
- Re-naturalisation of polder areas (flooding areas)
- Creation of meadows and pastures
- Afforestation in headwater areas
- Targeted planting for “catching” precipitation
- Land use conversion
- Restoration of natural infiltration to groundwater

According to the (EEA, 2017), the natural water retention measures could provide multiple benefits, including reducing risks of flooding and water scarcity, and improving water quality, groundwater recharge and habitats.

Figure 7.6: Flooded meadow
Source: EEA, 2017

Figure 7.7: Basin for flood retention
Source: EEA, 2017

7.2.3.2 Activity 2: Grey Infrastructure for Flood Risk Reduction

Grey infrastructures for flood risk reduction include man-made structures for protecting river banks and floodplains. While green infrastructures are highly preferred, grey infrastructures may also be needed for flood protection as a last resort solution, to compensate for the residual risk in areas where other options cannot be implemented. The potential grey infrastructures for flood risk reduction in Tawi River shall be the following.

1. Embankments, flood walls, levees
2. Channel improvement
3. Desilting/dredging of rivers
4. Drainage improvement
5. Diversion of flood water
6. Anti-erosion works

The locations, types and dimensions of these structures will be identified by comprehensive flood risk assessment as described in **Subchapter 7.2**. The consultant will analyse the feasibility of various flood and erosion control structures for flood risk reduction in Tawi river.

7.2.4 Component 4: Flood Risk Resilience through Risk Transfer and Insurance

Flood risk transfer is the sharing of risk with another party. It is a financial mechanism formulated to reduce vulnerability to flood disasters by employing structured instruments to spread risks in exchange for a premium. These kind of financial mechanisms enable the victims to leverage their initiatives and accelerate the process of rebuilding their lives and livelihoods. Disaster Risk Financing Instrument (DRFI) measures are commonly classified as ex post (e.g. budget re-allocations, loan conversations, borrowing) or ex ante (accumulated reserves, precautionary savings, contingent credit, catastrophe bonds, microfinance, insurance),

Purpose:

The purpose of risk transfer is to compensate or adequately help the victims to be protected against flood hazards and to recover from their losses.

Activities:

- Activity 1: Insurances
- Activity 2: Microfinance

Within the scope of this Component, the Consultant’s responsibility will mostly include the assessment of the feasibility of the previously mentioned activities and suggest in DPR how they can be implemented.

7.2.4.1 Activity 1: Insurances

Insurance can be an important factor in reducing financial risk individually, for companies and even for society, where flood risks are present. Adequate insurance can greatly reduce the effects that extreme events may have on the population. A financial instrument that can both reduce the financial risk for individuals, businesses and even whole societies and raise awareness of being at risk, is flood insurance.

Property owners must defend their properties against the possible damages caused by flood events. A contradictory fact is that, when assured, the population believes that it is less vulnerable to events and therefore less sensitive and concerned. Thus, the insurance must be adequate to not diminish the population's motivation to be prevented.

It is desirable for insurers to offer multi-risk packages, thus combining flooding risk with other risks such as earthquake, landslide, wind storm, hail, subsidence, snow melt, etc. to avoid adverse selection. Cooperation with state and municipal authorities is advisable. Credit institutions should use flood plan mapping or zoning to check their interest rates and reduce rates if buildings are effectively applied against flood damage. Flood risk assessment can be a basis for determining premiums for insurances.

J& K State Disaster Management Plan has also recommended encouraging disaster insurance for crop, building, and health. The flood insurance scheme can cover the following areas:

1. **Life insurance:** Providing insurance on death or disablement of key family members
2. **Business asset insurance:** Providing insurance on certain specific and identifiable business assets e.g., motorcycles, farming/fishing equipment
3. **Crop and livestock insurance:** Providing crop and livestock insurance
4. **Low-cost medical insurance:** Where appropriate working alongside government provision to provide the targeted high value low-cost health care access that the poor most need

7.2.4.2 Activity 2: Microfinance

There is an enormous demand for microfinance by the flood affected poor communities to rapidly begin recovery. Microfinance institutions (MFIs) can develop “Recovery lending” program to support rapid recovery of client’s livelihood (ADB, 2016). Flood risk assessment can be a basis for targeting the high risk communities for microfinance program.

A research conducted by Tata-Dhan Academy in Bangladesh showed that MFIs played the critical roles in addressing vulnerability after the 2005 floods, when a majority of member families took loans to meet their different requirements, including repairing damaged assets, purchasing new income-generating assets, and house repairing. The study found the MFIs to be the single largest stakeholder, followed by the government, NGOs and the local community to provide different short-term support to the disaster victims. The short-term support services included donations for health treatment, purchase of essential household commodities, and humanitarian services. On the other hand, most of the respondents told the researchers that the money that came out of their own savings was the most important component in addressing disaster loss in the long term. They said that, among the external sources, MFIs were important in terms of providing credit for reconstruction and rehabilitation after a disaster (ACEDRR, 2005).

Microfinance can help building flood resilience in the following ways:

1. **Savings:** Encouraging secure cash savings to handle unexpected events
2. **Loans:** Providing small loans to deal with the negative financial effects of short term unexpected financial shocks with the discipline to avoid generating over indebtedness
3. **Enhanced credit for insurances:** Providing credit to cover cost of life insurance, business asset insurance, crop and livestock insurance and low-cost medical insurance
4. **Recovery lending**: MFIs can help their clients with grace periods, loan restructuring and recovery loans that support their recovery from floods.

7.2.5 Component 5: Flood Preparedness and Emergency Response

Purpose:

The purposes of flood preparedness and emergency response are to prepare the communities for effective response before flooding, to reduce adverse impacts during flooding and to assist the affected communities to rebuild itself after flooding.

Activities:

- Activity 1: Community Based Flood Risk Management
- Activity 2: Flood Forecasting and Early Warning System
- Activity 3: Flood Emergency Measures

Within the scope of this Component, the Consultant's responsibility will mostly include the assessment of the feasibility of the previously mentioned activities and suggest in DPR how they can be implemented. Additionally, the Consultant will also carry out some tasks included in the ToR which will support the implementation of the previous mentioned activities (*e.g.*

planning and design of a flood forecasting and early warning system, public awareness campaigns).

7.2.5.1 Activity 1: Community Based Flood Management

The community based flood risk management is the process of engaging the communities living in the flood prone areas for inclusive and participatory flood risk management through their systematic organisation and capacity development. This is a "bottom-up" approach. It is an important step towards enabling communities to help themselves to reduce flood risks. The focus lies on preparedness and building resilience at the grass-root level in line with government's paradigm shift away from response.

Flood risk assessment is the basis for identifying the target-communities which are at-risk. The National Disaster Management Authority – Guidelines for Community Based Disaster Management provides detail processes and components for establishing Community Based Flood Management System in India. The main processes are the Formation of Community Flood Management Committees, Public Awareness and Education, and Capacity Building. This activity will be implemented by the Department of Disaster Management, Relief, Recovery and Reconstruction at the community level in collaboration with NGOs.

7.2.5.1.1 Formation of Community Flood Management Committees

Community Flood Management Committee (CFMC) is a basic organization at the community level for participatory flood risk management. Initially, an ad hoc committee may be formed to facilitate and carry forward the formation process of the fully fledged Community Flood Management Committee (CFMC). The ad hoc committee works with the organization(s) assisting the community in flood management to achieve clarity before the formation of the CFMC and prepares a draft constitution of the CFMC. As part of the preparatory process, and with the assistance of the facilitating organization(s), the ad hoc committee must conduct wider awareness-building discussions and interact with the affected communities, local leaders, youth, veterans, teachers, women and different ethnic groups.

The CFMC that is eventually formed should include local leaders, women, representatives of ethnic groups, representatives of local elite groups, agriculture/health-care officials, teachers, youth and representatives of local NGOs and CBOs. It should be inclusive of all stakeholders in a representative manner. There may be an advisory committee with local-level representatives of concerned ministries, local government, senior citizens, etc., who may provide guidance and facilitate linkages with technical and funding sources as and when required. In many CFMCs, taskforces/committees are formed to facilitate the accomplishment of specific community activities (WMO, 2017b).

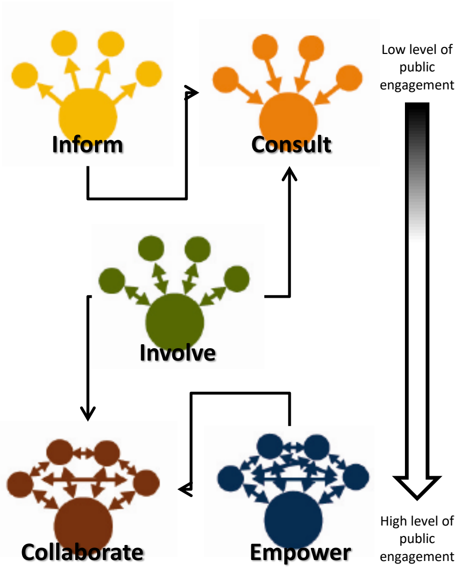
CMFCs perform various functions such as:

- Identification of risks to communities;
- Assessment of needs and capabilities of the community;
- Provision of equipment and supplies for emergency situations;
- Awareness-raising;
- Information dissemination and capacity-building;
- Networking, monitoring and reporting;
- Establishment of institutional building and linkages;
- Planning and interface with government institutions for rescue and evacuation, flood-proofing and flood moderation;
- Conducting simulation exercise/drills to facilitate effective evacuation;
- Development of linkages with other communities and with government and external development partners (including the private sector);
- Monitoring, evaluation and record-keeping;
- Management of information for future reference;
- Resource mobilization.

7.2.5.1.1 Public Awareness, Education and Capacity Building

Raising public awareness in an important aspect of community based flood management. It is necessary to develop Information, Communication and Education (ICE) materials for effective ways of information sharing regarding flood prevention, preparedness, response and recovery which are easily understood and accessible to the public.

The knowledge about the risk can be made through education and maps showing flood risk areas. The flood risk assessment, which identifies the population, the probability, intensity and extent of the impact of flood event, provides the basis for raising awareness of the communities. To alert the population in general, a communication plan must be developed. Involvement and participation at all levels is crucial to their awareness. Public participation in a decision-making process on flood protection and prevention is extremely important to include public concern in the final decisions.



All measures related to public information and awareness are most effective when involving participation at all levels, from the local community, to government, or even regional and international level.

Information on flood prevention and protection plans should be transparent and easily accessible to the public.

The information developed in Geographic Information Systems (GIS) should be widely disseminated and explained to the population. Alert signs should be disseminated to the population, especially to those unfamiliar with GIS information.

The population should be encouraged to take their own measures of flood prevention and be informed about how to act during flood events to protect themselves and their belongings. Practical guides for individuals and municipalities should be published and disseminated on how the population should behave. The population must be aware that there is a need to adapt or even restrict water uses, such as for industrial, agricultural, tourist or private purposes, in risk areas to reduce potential damage. It will be essential to delineate the probability of flooding and the areas with the least reactive population. The communities should be included in training and continuous preparation so that rescue operations are carried out safely and smoothly.

The following activities can be implemented by the relevant J&K state agencies to enhance the awareness of the communities on flood risk:

1. Organize inclusive awareness raising programs on causes and effects of floods and the ways to reduce flood risks using
   a. media (FM Radio, newspaper, social media such as Facebook, Twitter etc.),
   b. school programs (art, essay, poem, song, drama, and quiz competition),
   c. social-cultural programs (songs, street drama),
   d. print materials (poster, calendar, leaflet, hoarding board, wall painting etc.), and
   e. interaction programs (workshops, seminars, field visits etc.)
2. Install flood signs in town centers or floodplains

The Capacity Building of the communities can be achieved through equipping, orientation, knowledge building, skill development and behavioural change. The public awareness and education programs also support capacity building. The capacity building strategy should include:

- Preparing flood risk contingency plan
- Participatory Vulnerability and Capacity Assessment (PVCA)
- Study tour with visit to upstream hydrological and meteorological stations and forecasting centre
- Provision of dissemination and communication equipment
- Training on risk communication and dissemination
- Provision of basic search & rescue equipment

- Formation of various task groups (hazard and vulnerability monitoring, communication & dissemination, search & rescue, first aid, protection, shelter management, food and non-food items, water, sanitation & hygiene, initial rapid assessment etc.) under CFMC
- Mock drills and simulation exercises on search & recue
- Training on early warning system
- Creating a critical mass of trainers and facilitators at all levels

7.2.5.2 Activity 2: Flood Forecasting and Warning Systems

The Central Water Commission (CWC) has established a nationwide flood forecasting and warning system covering major inter-state rivers. The CWC also extends flood forecasting services to other stations strategically important to states at the request of the states concerned. The Irrigation & Flood Control (I&FC) Department of Jammu & Kashmir can establish flood forecasting and warning system in Tawi River basin. With reliable flood forecasting and warning system in Tawi River, loss of life and property can be reduced to a considerable extent. People, livestock and valuable assets can be shifted in advance to safer places. The flood forecasting system could be integrated with the community based flood management system for further dissemination of risk information and immediate response at the community level.

Furthermore, emerging integrated flood management approaches promote measures and instruments to gain a better understanding and preparedness for future flood events and their consequences. Instruments associated with the assessment and management of risk such as **early warning and forecast systems** are extremely effective nowadays to provide the required knowledge for anticipatory interventions concerning the different aspects of flood management.

In order to enhance the resilience of the flood prone areas in the Tawi basin, the consultancy services will be also focused on the **feasibility assessment and design of flood forecasting and early warning systems**. The forecasting and early warning systems should be planned and designed following the four key elements: **risk knowledge**, **monitoring and warning**, **communication and dissemination**, and **response capability**. Figure 7.8 below shows the components of people-centred flood early warning system.

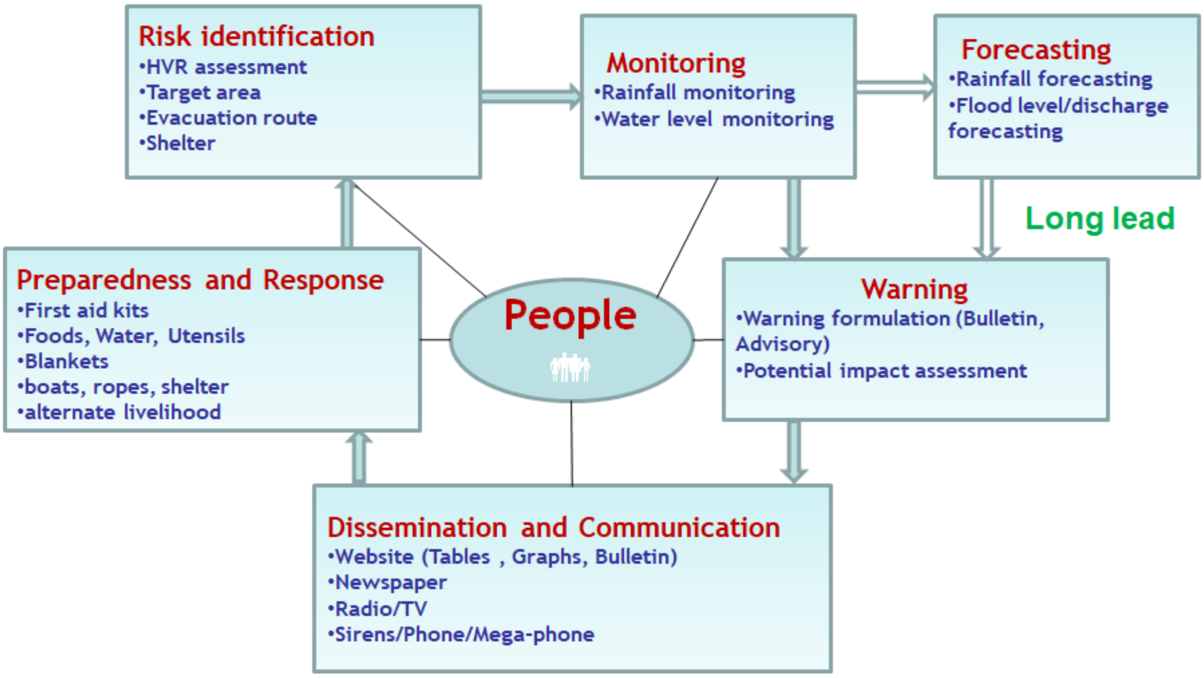


Figure 7.8: People-centred flood early warning system.

Risk identification is achieved through comprehensive flood risk assessment. Real-time monitoring of river level and rainfall is necessary

- to allow staff to monitor the situation in general terms;
- to give warnings against indicator or trigger levels for rainfall intensity and/ or accumulation; and
- to provide inputs to forecast models, particularly for rainfall–runoff models.

The real-time monitoring system consists of the following components:

- Sensors
- Data logger (DCP)
- Communication system
- Accessories (solar panel, battery, cables & connectors)

Modern internet based technology can be employed for collecting the data from sensors placed at different remote parts of the area. These data are transmitted through wireless medium over the internet to a database server where it can be analysed and used in models for the purpose of flood forecasting and warning.

The system uses sensors for detecting water level and rainfall. These data are first stored in a data logger, which supports GPRS data transmission. The data are stored and transmitted at a specified interval of time over the internet that is required for the purpose of flood warning. Figure 7.9 shows the schematic diagram of real-time telemetry system.

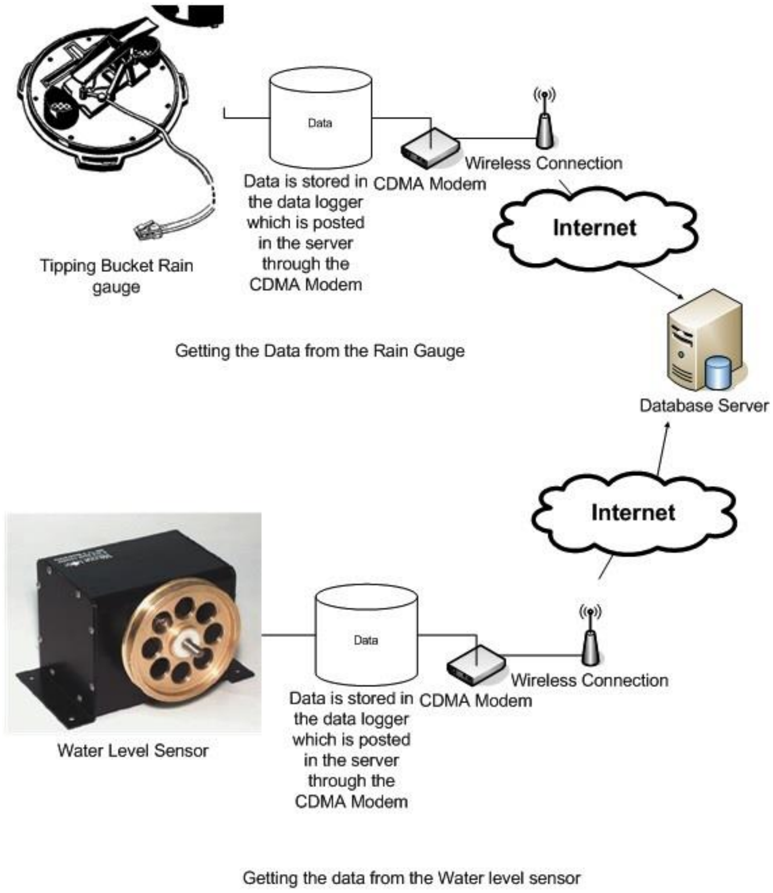


Figure 7.9: Real-time data acquisition system.

The design of flood forecasting and early warning systems should be based on the following foresights:

- It is necessary to develop rainfall based flood forecasting system. Therefore, preliminary findings from the field visits suggest that **station network for water level and rainfall monitoring needs to be modernized and upgraded**.
- The accuracy and lead-time of flood forecasting needs to be **enhanced by integrating the hydrological forecast with Numerical Weather Prediction** (NWP) for Tawi basin.
- The **communication and dissemination system** should be improved for better last-mile communication to the at-risk communities and response capability of the communities should be strengthened. Capacity development at the community level is required to interpret the forecast and translate the early warning into effective preparedness and response. This can be achieved by integrating flood forecasting and warning system with the community based flood management.

These Consultant's recommendations are in line with the National Water Policy, 2012 which highlights that flood forecasting should be expanded and modernized using real time data acquisition system and linked to forecasting models. Moreover, the Jammu and Kashmir State Disaster Management Plan, 2017 also emphasizes the importance of implementing flood early warning systems in the state.

An operational flood forecasting and warning system requires the following:

i) **A real-time data collection and processing system** for receiving and processing the relevant hydrological and meteorological data and information. This will include meteorological data, the water level and discharge data at appropriate gauged sections in Tawi river;

ii) Outputs of a **numerical weather prediction (NWP) model** for meteorological inputs, for example the quantitative precipitation forecast (QPF), for the required lead time of the flood forecasting model;

iii) **A hydrological modeling system**, with a user-friendly interface, to predict the discharge at the catchment outlet and/or discharge at several important locations, at the required time intervals;

iv) **A hydraulic modeling system** comprising a channel routing model to estimate the movement of the flood wave along the channel, the water levels, discharges, and the interaction with the flood plain and flooded areas, giving a flood inundation forecast;

v) **An error correction subsystem** to improve the estimates of discharge based on recent (almost real time) observation of river level;

vi) **Appropriate decision support system**, producing forecast details at various levels and map forecasts showing flood inundation in real time;

vii) **An effective communication and dissemination system** to communicate forecast information with advisory to the public and user agencies;

viii) An effective system for **immediate response**;

ix) An effective **governance and institutional mechanism** to sustain the whole system.

Accordingly, the initial efforts will be focused on **review and diagnosis of current hydrologic and meteorological monitoring network** (in the scope of the *Task-2 - Conduct data collection campaigns*) to provide a basis for planning and design of an effective FEWS for the Tawi River Basin. Nonetheless, a preliminary assessment of the two existing gauging stations in Tawi River (Vikram Chowk Jammu City bridge and Salmay Bridge near Udhampur City) was already conducted. The preliminary findings from the field visits suggest that station network for water level and rainfall monitoring needs to be modernized and upgraded.

Moreover, the Consultant will further conduct the **onsite evaluation of the maintenance state and adequacy of available equipment** (measurement, communication, etc) on the relevant meteorological and gauging stations (*e.g.* existence of adequate record and communication system – data loggers, modems, antennas; remote data access/SCADA; data type/format and frequency acquisition). Following this characterization and diagnosis, the Consultant will be able to plan and design a new Real Time Data Acquisition System (RTDAS) and evaluate the need for new river gauging and rainfall stations and/or rehabilitation and/or modernization of the existing ones.

Following the assessment of available data sources and equipment, the Consultant will carry out under the scope of the *Task-5 - Review various flood and river management options and conduct feasibility study* the **feasibility analysis and the design** of the flood forecasting and early warning system for Tawi River, including the technical specifications, list of necessary equipment's, consulting services and cost estimates of the systems suitable to tender for proposals to purchase and install the systems.

The feasibility analysis and design of the flood forecasting and flood early warning systems (FEWS) will be focused on all the relevant aspects which integrate the following 3 major features as presented in the Figure 7.10: **External Data Sources**, **Integration Platform and Outputs**.

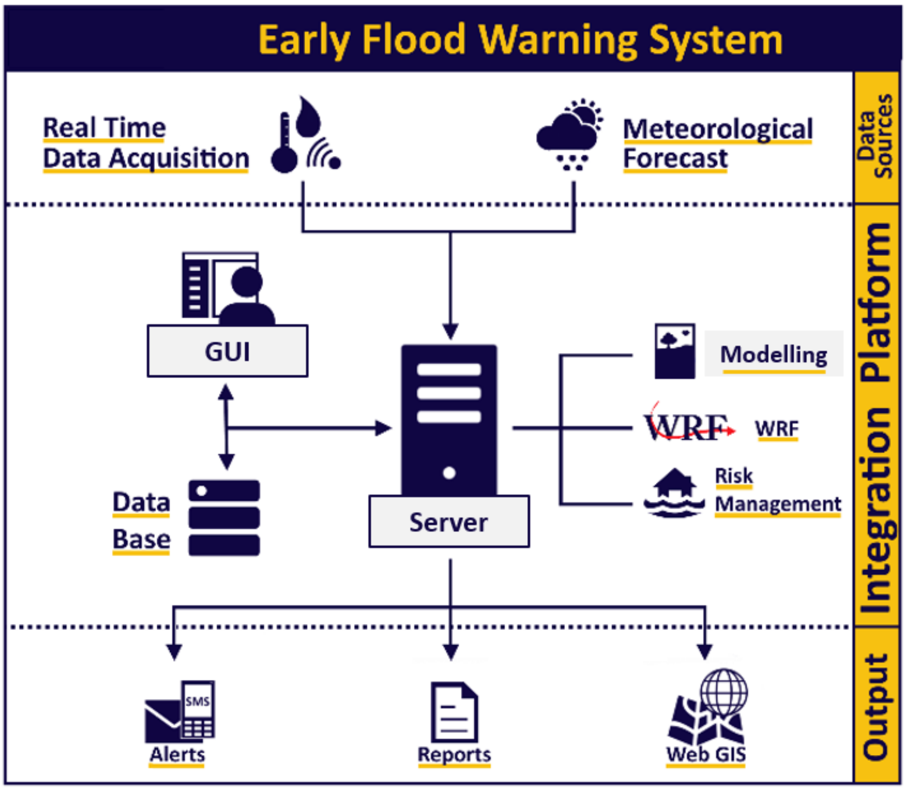


Figure 7.10: Conceptual design of a Flood Forecasting and Early Warning System.

a) External Data Sources

External Data Sources allow to receive data from external sources, like monitoring stations and meteorological forecasts. The design of the flood forecasting and FEWS will comprise the assessment and evaluation of existing external data sources, such as data from monitoring networks (e.g. meteorological stations, gauging stations), real time satellite images, radar images, numerical predictions (e.g. weather forecast) and static layers (e.g. administrative boundaries). All these data shall be integrated into the flood forecasting and early warning system, which are described next:

- **Real Time Data Acquisition**: The flood forecasting and early warning system shall allow downloading and storing data from real time monitoring networks, such as meteorological and gauging stations. Besides giving the end user information about the real-time situation, data can be used to supply boundary conditions for numerical modelling tools and to evaluate the current or forecasted flood hazard and risk. Under the feasibility assessment of installing a flood forecasting system in the Tawi river basin, the Consultant will evaluate the need for river gaging stations, rainfall stations, and other technologies (*e.g.* radar data) and plan and design of a new RTDAS. In this context, it is worth noting that IMD has already sanctioned Doppler weather system for the Jammu and Kashmir State that would facilitate early warning weather system in the State. This data source will be analysed and integrated in the FEWS if possible;

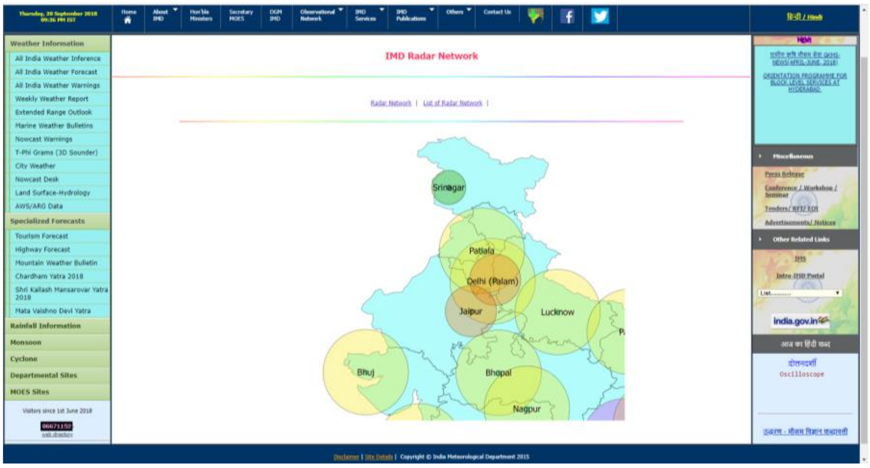


Figure 7.11: IMD Radar Network. Source: http://www.imd.gov.in/pages/services_radar.php

- **Meteorological Forecast**: Numerical weather predictions, like meteorological forecasts, are a key element for effective flood forecasting and generate early warnings. Numerical predictions can be obtained from several data sources, such as global or regional meteorological models and watershed models. These data sources complement the monitoring network, since they have a predictive character.

Accordingly, under the feasibility assessment of installing a flood forecasting system, the Consultant will also evaluate the adequacy of existing data sources for meteorological forecasting (e.g. GFS, NCEP, IMD). The implementation of forecasting models allows to anticipate effectively even further alerts of the FEWS, when compared to feed the FEWS only with real time data.

b) Integration platform and modelling tools:

The Integration platform and modelling tools shall be composed by different software/modules, including a **Server** (the core operating system), a **data base**, a **graphical user interface** (GUI), **numerical modelling tools** (hydrological and/or hydraulic modelling, weather forecasting local/regional modelling (if found necessary)) and a **risk management module**.

Therefore, the Consultant will assess the feasibility of installing/implementing and design all the components of the integrated platform for flood forecasting and early warning system in order to assure and appropriate and effective flood risk management.

Accordingly, the Consultant will define all the aspects related with the system **implementation** (e.g. adequacy of existing data sources, equipment's, hardware and software requirements, capacity and skills among FEWS end-users and staff), **operationalization** (e.g. modelling requirements, outputs and risk assessment frequency) and **maintenance** (e.g. maintenance procedures, upgrades and improvements).

Regarding the integration platform, the numerical modelling tools will be essential to (i) perform hydrological and hydraulic simulations to evaluate the response of the river basins in the upcoming hours / days and to (ii) run operational numerical models locally in order to refine the meteorological predictions obtained from global models (if found necessary).

Accordingly, the Consultant will review and suggest on the technical specifications of the necessary numerical models and modelling requirements in order to obtain accurate outputs. The risk management will be also analysed and evaluated, since it allows configuring different risk levels based on the state variables of the system.

c) Outputs

Regarding the outputs, the Consultant will assess and suggest on the most adequate methods for dissemination and communication of warnings/alerts as well as the types of outputs, following the consultation with I&FC staff.

Accordingly, the Consultant will assess the different forms to communicate flood warnings, like alerts in form of e-mails / SMS, reports, including the feasibility analysis of installing an early warning system that uses a mass communications systems (*e.g.* cellphone SMS) to alert local people. The Consultant will define all the technical aspects and specifications regarding the installation and operationalization of the communication systems for the flood warnings.

7.2.5.3 Activity 3: Flood Emergency Measures

The flood emergency response plan should recognize the timing, staffing, and resources needed to implement an effective response, prior to arrival of the flood event. The plan should consider all shifts, staffing limitations, potential mandatory evacuations in the advance of the hurricane or flooding, lack or resources and supplies, loss of utilities such as electricity and gas in advance of the storm or flooding, and other potential obstacles to adequate completion of the emergency preparations.

Once the flood trigger levels and corresponding time-frame for each level have been identified, the corresponding actions and resources at each level can be defined. Activate the **emergency response** plan in the predefined sequence according to the defined hazard action levels.

Some actions that can be included in the emergency response plans:

- Establish EOCs at State and district level
- Prepare State Disaster Response Framework
- Maintain a detailed registration of events
- Keep stakeholders informed of situation
- Prepare for safe shut-down of operations
- Remove all hazardous substances to a safe location
- Remove portable machinery & equipment to higher levels (groundwater/river flood) or away from the building envelope (wind/rain flood)
- Remove stocks to higher levels or away from building envelope
- Close any manual sewer backflow prevention valves and plug drains and/or sewer lines to prevent sewage backup
- Isolate any low level electrical equipment, shut down machinery & equipment
- Contact storage facility for mobile flood protection systems
- Secure all buildings
- Identify areas and facilities for temporary shelter

Some actions related to recovery plans area following suggested to be undertaken once the pertinent authorities have declared conclusion of the flood event and the site may be safely accessed:

- Post disaster needs assessment
- Post disaster recovery framework
- Contact staff and inform of situation
- Initiate clean-up operations when safe to do so
- Have all utilities checked by qualified personnel before use
- Inform insurance company
- Conduct environmental controls
- Inform disaster recovery company, if one has been contracted for such services
- Inform public sanitation of site damage
- Inform electricity and gas supply company to restore services
- Provision of stockpiling food and NFI

7.3 SUMMARY AND RECOMMENDATIONS

Typically, flood risk management objectives fall into three categories based on the nature of interventions:

- Reduce, retain and detain flood flows
- Improve conveyance and enhance resistance to damage in waterways
- Adapt to floods

River and flood management options for Tawi River Basin will be planned and design as part of an Integrated Flood Management (IFM) approach, comprising interventions in the three above mentioned categories in order to achieve a flood resilient society and ensure the effective disaster risk reduction. Moreover, the proposed measures shall be designed using latest and upgraded technology, having the desired resilient features to meet all future contingencies of bigger magnitude well in time and space variables.

As the understanding of landscape scale hydrological processes has been improving, good practice for managing flood risk has also evolved to incorporate watershed and land use management, aiming to reduce the flow of water through the river reaches and thus reduces flood peak. In addition to natural features such as wetlands and ponds, soft engineering works are also being effectively deployed to reduce the flow velocity on a catchment wide scale and, consequently, reduce the flood risk. Indeed, soft engineering and watershed management measures shall be further explored for the appropriate flood and erosion control in Tawi River Basin.

Furthermore, there is evidence that some flood response programs have focused too heavily on rebuilding infrastructure and not enough on better adaptation and preparedness for the future in complementary investments, such as water and flood management, rural finance, early warning communication systems, etc. Actually, rebuilding damaged buildings and infrastructure as well as hard engineering options (*e.g.* dams, dikes) after these have failed, could be very costly.

Indeed, it is currently undeniable that hard engineering options for flood mitigation are not the only solution. In this context, natural and ecosystem-based water retention measures can be very cost-effective. Not only can multiple benefits for nature and environment be generated, but investment and maintenance costs can also often be lower than those of hard engineering solutions. Therefore, to effectively reduce flood levels in the Tawi River, it will be important to explore nature-based options along the catchment to maximise the retention of water in soils and in wetlands, and to use natural storage areas.

Nonetheless, the nature-based flood mitigation measures are hardly implemented in isolation, since their effectiveness increases whenever multiple measures are combined in a project. Moreover, it is worth noting that generally benefits of nature-based measures tend to increase over time as ecosystems adjust. In contrast, hard engineering solutions often reach their desired benefit level immediately after construction and hence shall be considered in Tawi River Basin, wherein urgent and short-term flood mitigation is required.

Accordingly, the flood management options for Tawi River shall consist of both structural and non-structural measures in the framework of integrated flood management proposed by the Consultant. Specifically, the flood management options will focus on the following issues:

- Reducing the risk of flooding to people and property, quality, diversity, and connectivity of riparian, wetland, floodplain, and riverine aquatic habitats where appropriate.
- Providing a level of protection to urban areas at least higher than floods such as in Sept. 2014 or a 1 percent chance (1 in 100 year event) of occurrence in any one year.
- A rapid morphological analysis considering the fluvial geomorphologic characteristics of the Main River and its tributaries and identification of alternate solutions, which shall be within the ambit of the Indus Water Treaty of 1960.
- An effective SCADA system for monitoring and regulating flow.
- Review of requirements for Tawi barrage lake regulation to maintain specified water levels during lean flow and flood period.
- Analysis of data available with Irrigation and Flood Control Department, other State agencies, India Meteorological Department, Central Water Commission, geological Survey of India, and other central agencies.

- Fresh topographical surveys and investigations, fresh data collection to supplement available data, through bathymetric and river cross-sectional surveys, topographic surveys including from satellite imagery, geotechnical and geological investigations, setting up temporary stations and collection of rainfall / stage / discharge / sediment data, community surveys etc.
- Design of real-time hydro-meteorological network of rain and river gauge sites and sediment sites.

Specifically, the potential flood management options for Tawi River can be the following:

1. Comprehensive flood risk assessment
2. Flood risk governance and capacity development
3. Structural measures for flood risk reduction
   a. Green infrastructure and nature-based solutions
   b. Grey infrastructure for flood risk reduction
4. Flood risk resilience through risk transfer and insurance
5. Flood preparedness and emergency response
   a. Community based flood risk management
   b. Flood forecasting and warning systems
   c. Flood emergency measures

8 DATA AVAILABILITY AND QUALITY ANALYSIS

8.1 INTRODUCTION

During the Inception phase, the Consultant evaluated the availability of base data and carried out a preliminary identification of the main gaps and inconsistencies. The types of data to be collected for the project is identified as follows:

- Topographic data;
- Hydrological and meteorological data;
- Land-use and land-cover data;
- Geotechnical and geophysical data;
- Soil and geological data;
- Main structures located in the study site;
- Institutional and legislative data;
- Economic and financial data;
- Environmental and Social data; etc.

Accordingly, the Consultant contacted and carried out meetings with pertinent stakeholders (*e.g.* I& Department, Jammu's office of the National Institute of Hydrology) in order to assess the data availability and mainly inquire for necessary procedures for data collection to be performed in the subsequent Task Assignment: *Task 2 - Conduct data collection campaigns*.

Others potential organizations, that can be a source of relevant data, were already identified and shall be contacted immediately after issuance of a Recommendation Letter from the PMU/JTFRP Director Technical.

Additionally, the Consultant also carried out a preliminary quality analysis of the available hydrology data which was included in the **Preliminary Hydrology Report**.

Furthermore, the strategies to mitigate the risk associated with poor data quality and/or gaps were also defined, including the acquisition strategies and planning for primary and secondary data collection to support the development of the Project.

The following subchapters present the Consultant's review of the data availability, including comments on quality, gaps, inconsistencies and strategies and plans for primary and secondary data collection to support preparation of final hydrology and morphology reports, and conduct feasibility plans and DPRs.

8.2 HYDROLOGICAL DATA

The existing gauging stations in the Tawi River are established, operated and administered by the Irrigation and Flood Control (I&FC) Department – Divisions of Jammu and Udhampur. Currently, Tawi River is being gauged at Udhampur and Jammu, wherein hourly water levels are continually recorded.

Jammu and Udhampur gauging stations were established in 1988 and 1997 respectively. Table 8.1 shows the location of the gauging stations, catchment area and the period of data availability.

Table 8.1 – Gauging stations and available hydrological data in Tawi River.

Gauging Station	Location[1]		Catchment Area (km²)	Year of data		Source
	Latitude	Longitude		Hourly Discharges	Max. and Min. Discharges	
Jammu	32º 43'E	74º 51'N	2168	1988-todate	1988-todate	I&FC Dep. Jammu Div.
Udhampur	32º 56'E	75º 10'N	627	1997-todate	1997-todate	I&FC Dep. Udhampur Div

1. Coordinate System WGS84

The available data for the Jammu and Udhampur gauging stations is the following:

- Jammu gauging station:
  - Hourly records from 1988 to date.
  - Monthly wise Maximum and Minimum river discharges from 1988 to date.
  - Rating curve established (year to be confirmed).
- Udhampur gauging station:
  - Hourly records from 1997 to date.
  - Monthly wise Maximum and Minimum river discharges from 1997 to date.
  - Rating curve established in (year to be confirmed).

According to the obtained information, data of streamflow measurements (with current meter, ADCP or other method) are not available.

The Jammu gauging station is located upstream of the Tawi Bridge in Bikram Chowk, presenting a controlled drainage area of around 2168 km^2 which corresponds to approximately 75% of the entire Tawi River Basin (*i.e.* up to the confluence with Chenab River in Pakistan). The Jammu Station is currently operational and the water-level observation period is 24 hours and records are taken at an hourly basis.

The Udhampur hydrological station is located about 80 km upstream of the Jammu station and 15 km upstream of the confluence of Duddar Nallah with the Tawi River, presenting a controlled drainage area of around 627 km^2 which corresponds to approximately 22% of the entire Tawi River Basin.

The location of the existing gauging stations in the Tawi River Basin is presented in Figure 8.1.

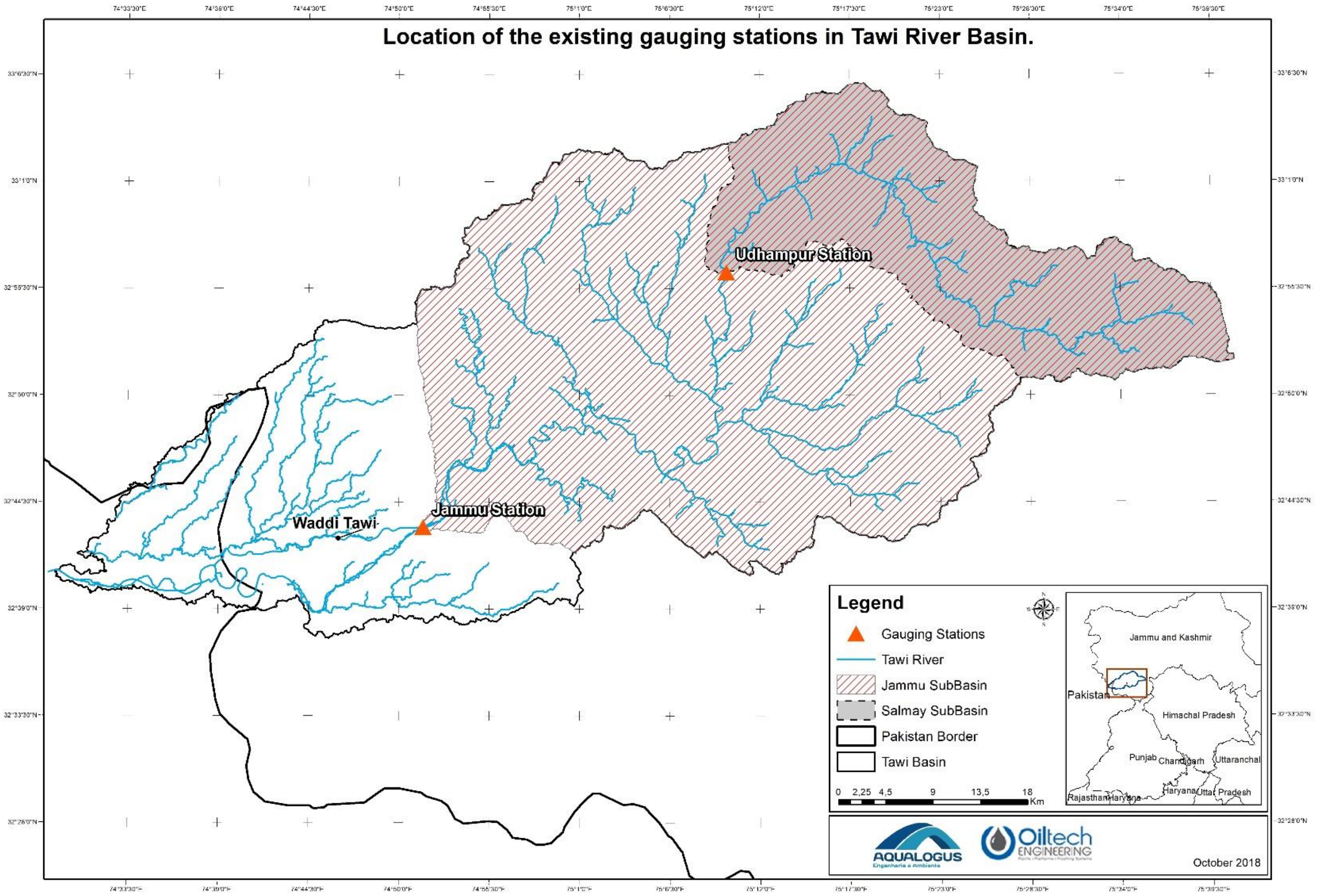


Figure 8.1: Location of the existing gauging stations in Tawi River Basin.

The team visited Flood Control Room at Tawi gauge site and hydrological station on Tawi River at Jammu city bridge on 8th August 2018. The Photo 8.1 below shows the hydrological station at Jammu, upstream of the Tawi Bridge in Bikram Chowk. The water levels are measured in the Jammu station by an inclined gauge constructed at the left bank of the river.

Photo 8.1: Hydrological station on Tawi River at Jammu City Bridge.

The highest flood level of 33 ft with discharge of 478,600 cusec was recorded on 6th September 2014 which was 16 ft higher than the danger level. The Table 8.2 below presents the different threshold levels for flood warning and highest flood levels.

Table 8.2 – Different threshold levels for flood warning and highest flood levels at Jammu city gauging station.

SN	Particulars	Stage (ft)	Discharge (cusec)
1	Alert Level	14	97,400
2	Danger Level	17	142,000
3	Evacuation Level	23	249,300
4	Highest Flood Level on 29-09-1988	31	427,000
5	Highest Flood Level on 6-09-2014	33	478,600

The Flood Control Room maintains phone numbers of different stakeholders and flood warning is communicated by phone when the river level reaches Alert Level.

The rating curve of the Jammu gauging stations is presented in the Figure 8.2.

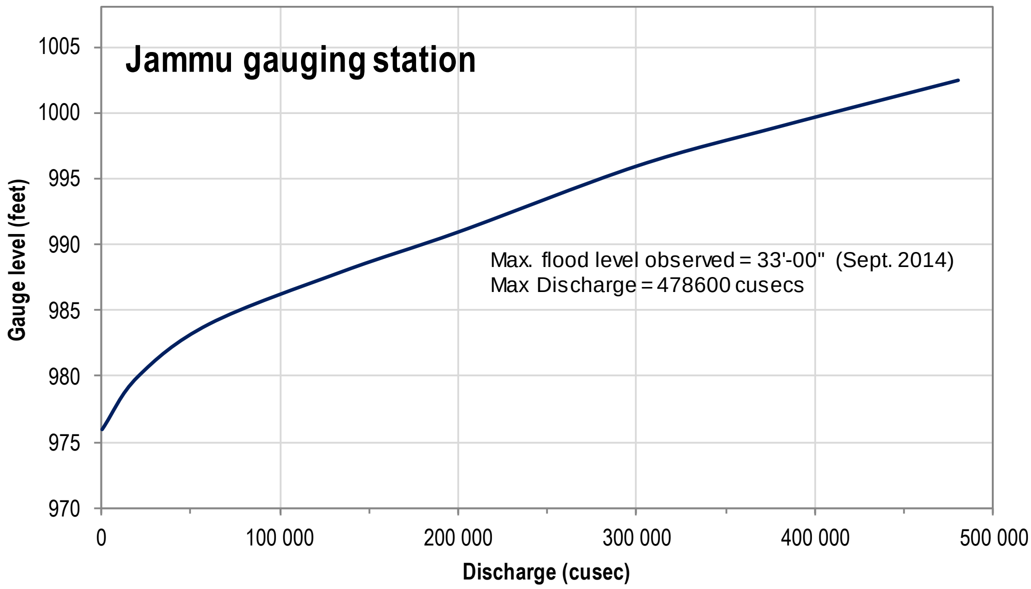


Figure 8.2: Rating curve of the Jammu gauging station.

The team also visited hydrological station at Salmay Bridge near Udhampur City. Photo 8.2 below shows the hydrological station at Udhampur. The water levels are measured by vertical gauges painted at the pier of the bridge. This station is very important for flood warning to the Jammu City and downstream.

Photo 8.2: Hydrological station on Tawi River at Udhampur

The rating curve of the Udhampur gauging stations is presented in the Figure 8.3.

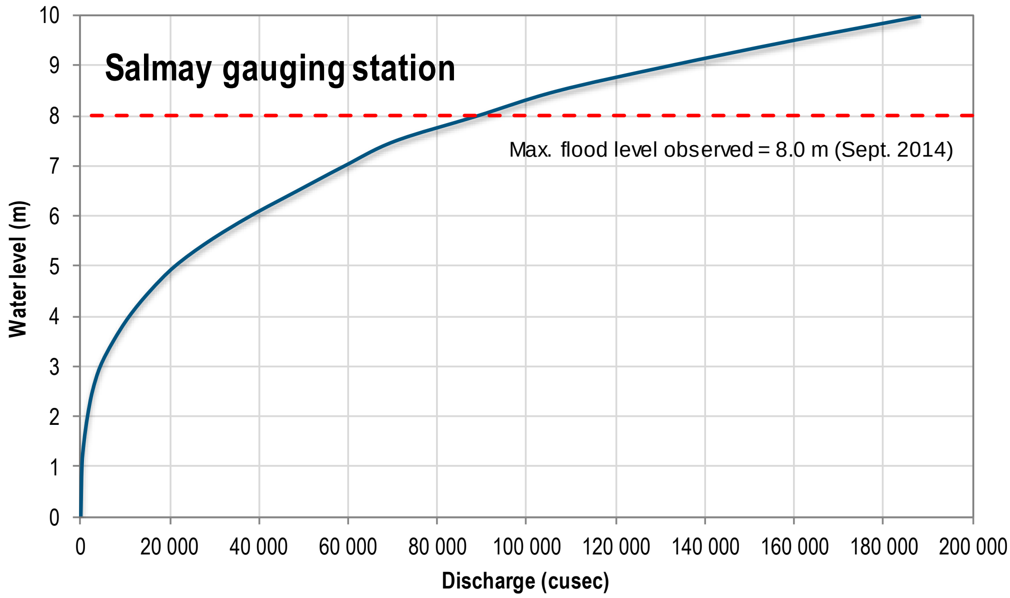


Figure 8.3: Rating curve of the Udhampur gauging station.

The length of the main channel from Udhampur to Jammu City Bridge is about 80 km which can provide approximately 6-7 hour lead time. The hydrological stations at Jammu City Bridge and Udhampur will be assessed for upgrading with real-time telemetry system.

According to local staff at Salmay gauging station, the highest flood level of around 8 m was recorded on September 2014 floods, which corresponds to around 88,652 cusec.

Within the scope of the Assignment, the Consultant will assess the current hydrologic monitoring network and scrutinize the existing data time series, detecting possible malfunctions and damages/problems in the monitoring stations. In fact, with the passage of time, stream gauges may be displaced or destroyed or they may be changed in elevation as the result of natural (e.g. river scour or deposition, vegetation growth) and/or anthropic (e.g. vandalism) causes.

Nonetheless, a preliminary quality analysis was included in the **Preliminary Hydrology Report**.

8.3 METEOROLOGICAL DATA

It was identified the availability of a document with the location of existing and proposed rainfall gauge stations in the Tawi River Basin (including other meteorological data as rainfall, temperature, evaporation and relative humidity).

One of the stations is located and operated by the National Institute of Hydrology (NIH), Jammu's office. The respectively available data (hourly records of rainfall, temperature, evaporation and relative humidity) can be provided free of charge after the issuing of a request letter by the Director Technical of PMU/JTFRP.

After provision and analysis of the above referred document with the location of other existing and proposed rainfall gauge stations in the Tawi river basin, the Consultant shall contact the Indian Meteorological Department, based in Pune, Maharashtra, requesting quotation for the available data for meteorological stations, namely: daily and hourly records of rainfall, temperature, evaporation and relative humidity. This contact will be done after the issuing of a recommendation letter by the Director Technical of PMU/JTFRP.

8.4 TOPOGRAPHIC DATA

The available topographic sheets of the Tawi River Basin are restricted and cannot be shared electronically. The Consultant analysed the existing topo-sheets after approval from the Chief Engineer of I&FC Department for the propose of document access and share.

Other available topographic surveys can be available after permission from the Chief Engineer of I&FC Department: namely:

- existing surveys from the prefeasibility study performed by WAPCOS;
- DPRs of the Jammu Barrage and river training works;
- other topo-sheets of existing schemes/works (bridges, etc).

However, it is considered that the available topographic data is neither adequate nor sufficient to prepare the feasibility and detailed project report for flood mitigation and comprehensive river management measures for Tawi Basin. Accordingly, fresh topographic and bathymetric surveys of the Tawi River and major nallahs are essential for the development of the project and will be carried out in the scope of the subsequent Task of the Assignment: *Task 2 – Conduct Data Collection Campaign.* The acquisition strategy and planning for the topographic survey.

Moreover, there is no digital elevation model for Tawi Basin available with the I&FC Department.

The Consultant has already proceeded with the acquisition/collection of the available SRTM data with horizontal resolution of 1º arc second (approximately 30 m) for the Tawi River Basin – **Figure 8.4** during the Inception Phase. The NASA Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation models on a near-global scale. SRTM consisted of a specially modified 2 antenna radar system known as "Interferometric Synthetic Aperture Radar" that enables the acquisition of elevation (topographic) data. The SRTM has one arc-second resolution (approximately 30 m at the equator) for the globe.

This DEM will be further complemented and integrated with high resolution DEM's derived from fresh high resolution satellite imagery of 1 to 2m resolution.

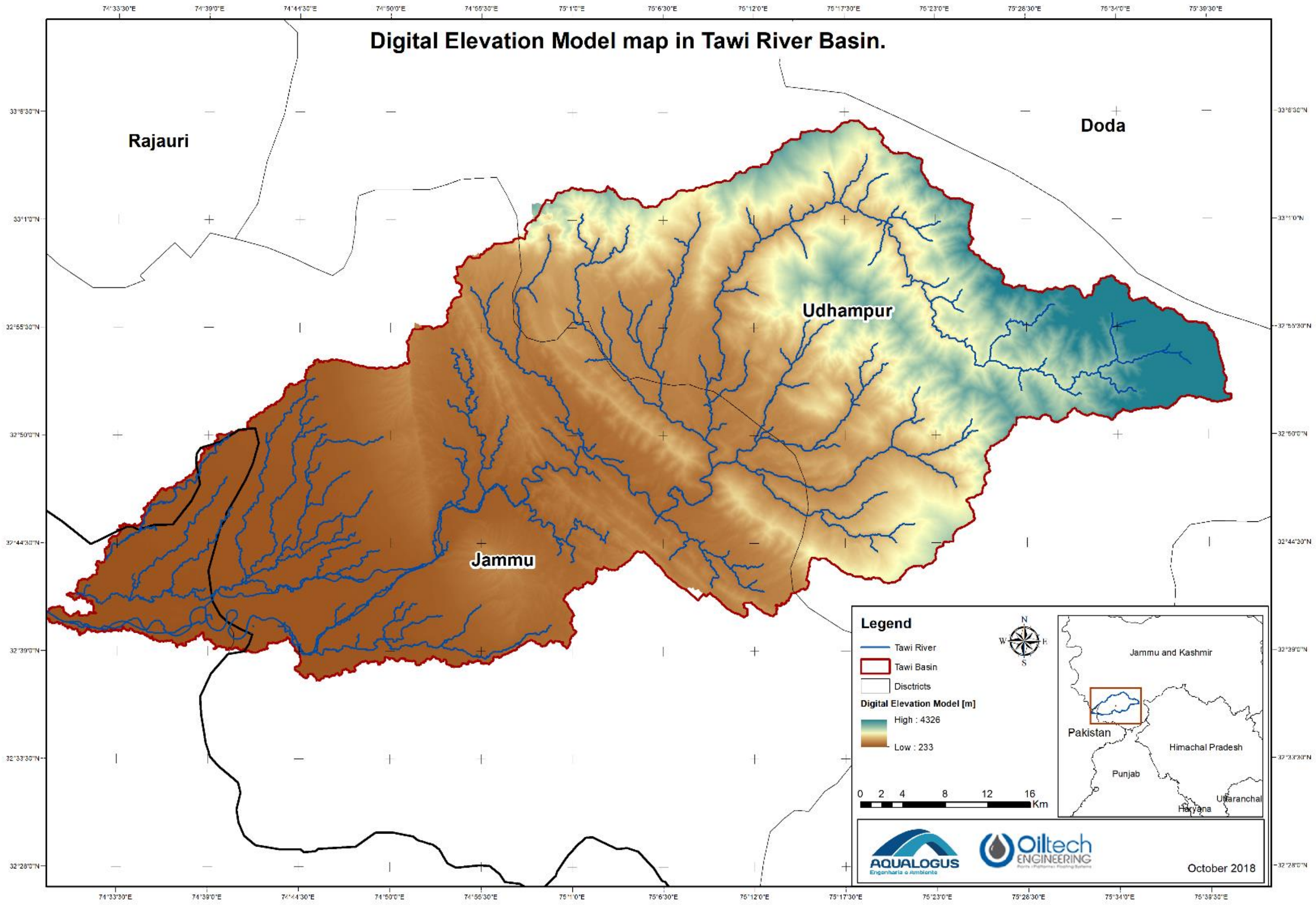


Figure 8.4: Digital Elevation Map including the Tawi River Basin. Source: *SRTM NASA*.

8.5 GEOLOGICAL AND GEOMORPHOLOGICAL DATA

As can be seen in Figure 8.5, between Udhampur and nearly 5 km upstream Jammy, the river Tawi intersects mostly the Siwalik Group of Miocene-Pliocene age.

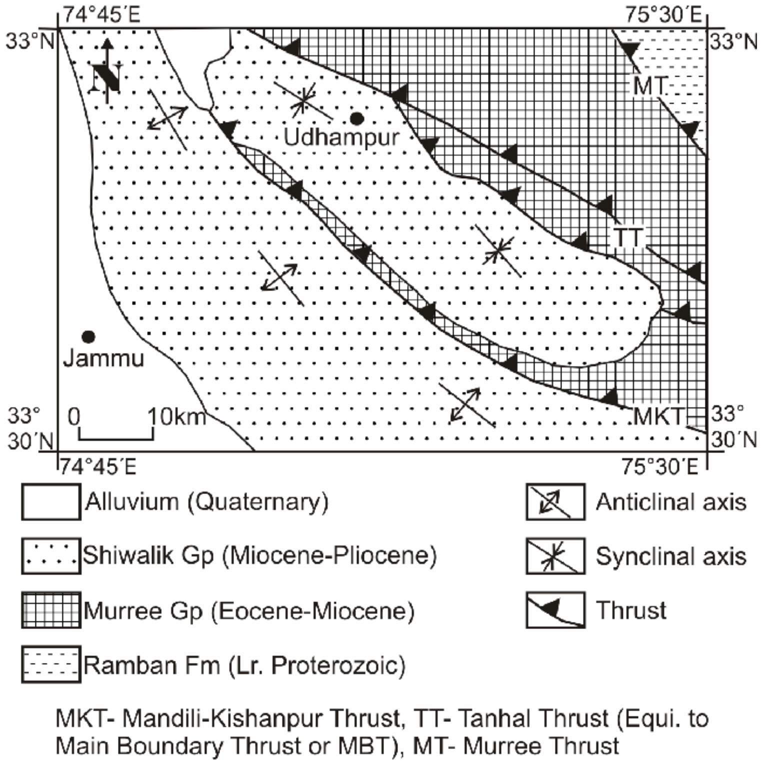


Figure 8.5: Geological map of the Udhampur region, Jammu & Kashmir (Dhang, 2016).

In Figure 8.6 the Siwalik group is presented in more detail in the area between Jammu and Nagrota. In this area ,river Tawi intersects the Boulder Conglomerate formation and Nagrota formation.

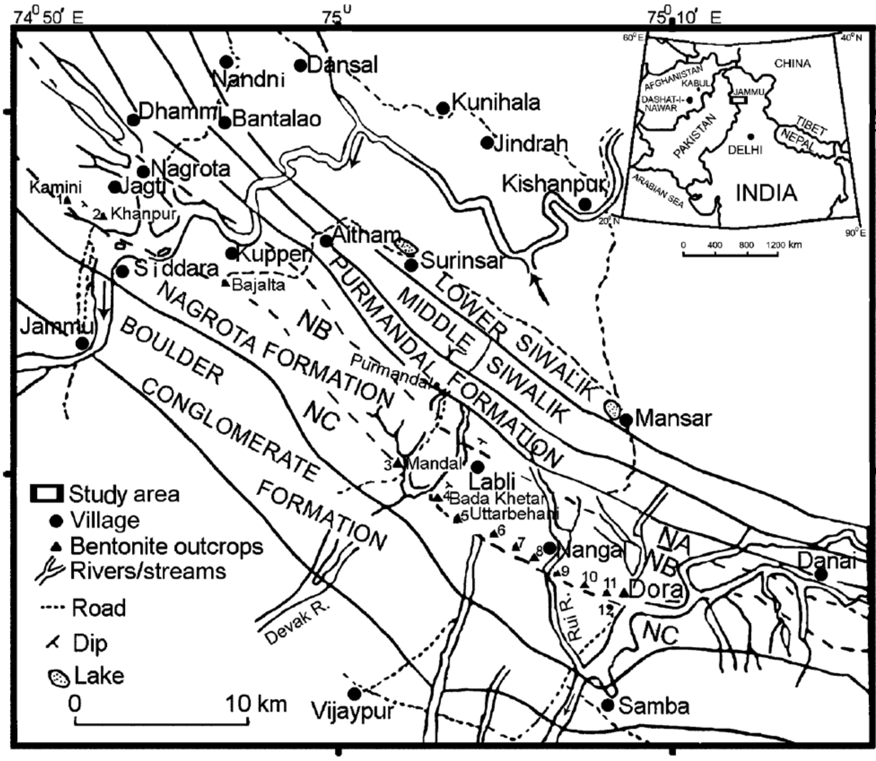


Figure 8.6: Geological map of the Siwalik Group at Jammu (G. M. Bhat et al. , 2008)

Photo 8.3: Boulder Conglomerate formation upstream Jammu.

Further downstream, the river Tawi enters the Quaternary alluvial deposits of the Indogangetic Alluvial Plain (**Figure 8.7**).

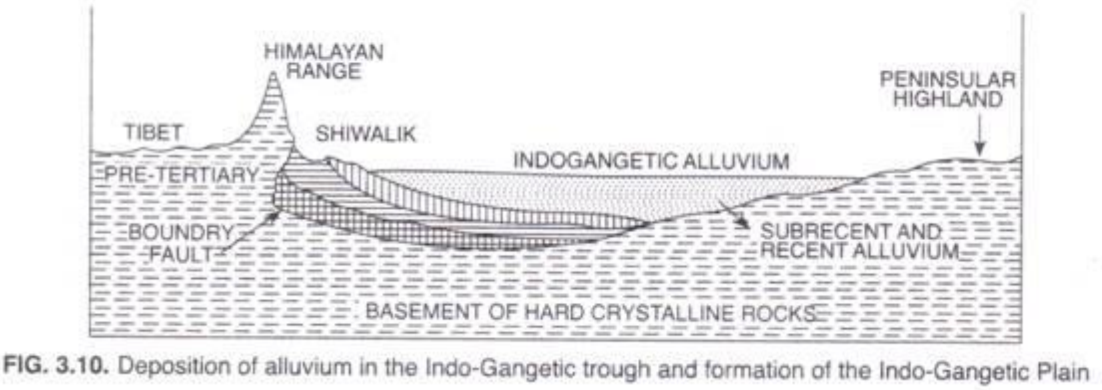


Figure 8.7: Indogangetic alluvial plain (G. M. Bhat et al. , 2008)

Photo 8.4: Alluvial deposits in Jammu.

Regarding geological data, the following documents from the Geological Survey of India (GSI) will be analysed:

- Geological Map of Jammu and Kashmir
- Jammu Quadrangle

The information from the hazard maps produced by the Building Materials & Technology Promotion Council may be incorporated in the studies, namely:

- Earthquake Vulnerability Map of Jammu and Kashmir;
- Landslide Vulnerability Map of Jammu and Kashmir;

These documents will be requested to the Department of Mining and Geology of Jammu and Kashmir.

The geological data included in the projects of Jammu Barrage and the new Nikki Tawi Bridge, namely the estimated alluvial depth will be solicited to the relevant state agencies.

Additionally, it was identified the possible availability of relevant Geological and Geomorphological data in the following organizations:

- Geological and Geophysical data:
  - ✓ J&K Geology and Mining Department (http://geominjk.nic.in/maps.htm)
- Soil maps and soil data:
  - ✓ J&K Department of Soil & Water Conservation (http://www.jkdosc.com)
  - ✓ J&K Forest Department (http://jkforest.gov.in)
  - ✓ J&K Forest, Environment and Ecology Department (http://jkforestadm.nic.in)

The Consultant shall contact these departments, checking for the available data. These contacts will be done after the issuing of a recommendation letter by the Director Technical of PMU/JTFRP.

Additionally, the Consultant has also obtained the soil map for Tawi Basin from the Harmonized World Soil Database as presented in the Figure 8.8.

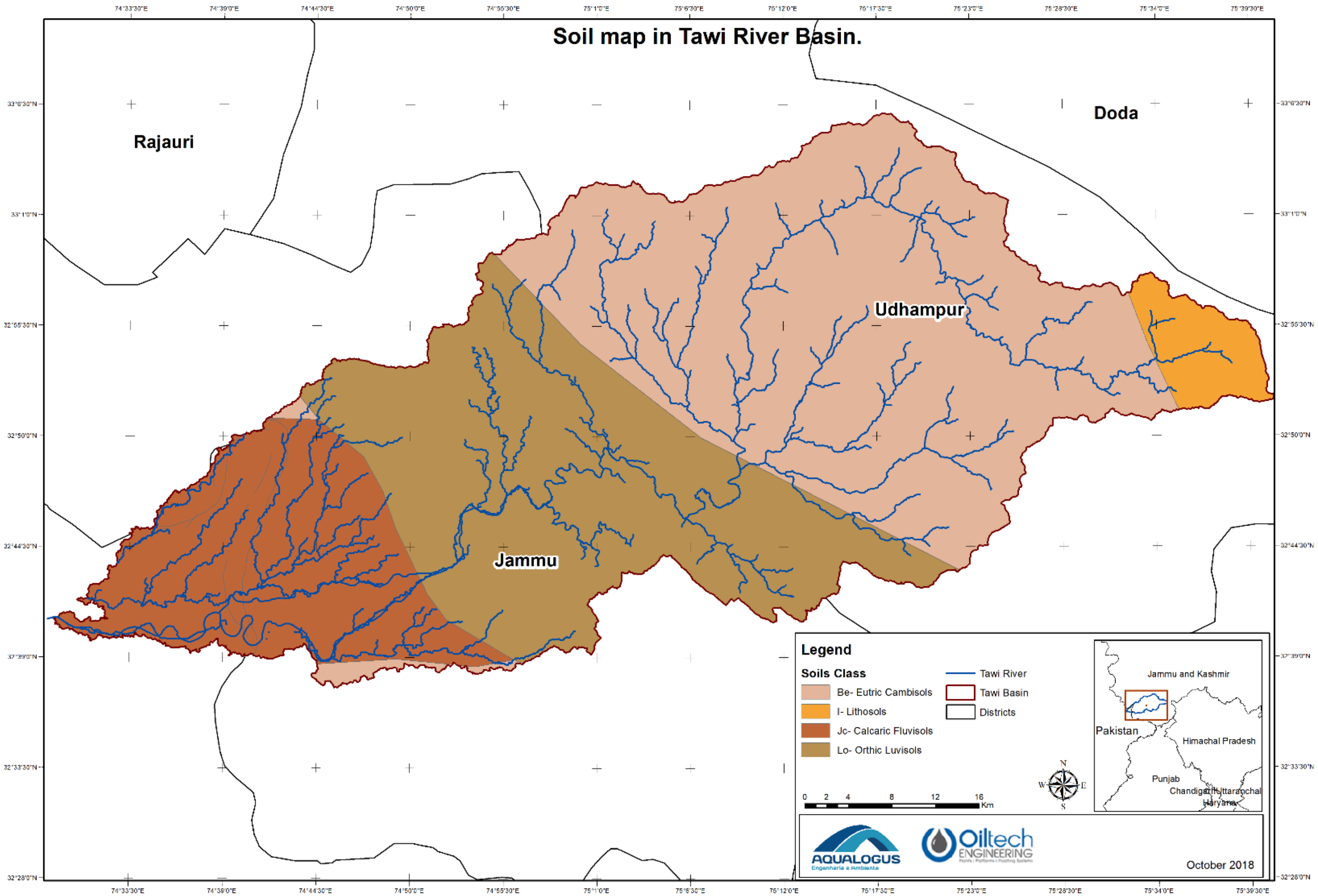


Figure 8.8: Soil Map in the Tawi River Basin. Source: Harmonized World Soil Database

8.6 EXISTING STRUCTURES AND PROPOSED SCHEMES

The I&FC Department – Jammu Division shared the following site plans of existing and proposed structures in the Tawi River Basin:

- Site Plan of existing and proposed training river works in Tawi River from Manwal to exit of Indo-Pak Border at Spots (Figure 8.9)
- Site Plan of existing and proposed protection works in the Nikki Tawi between 4th Bridge and Surya Chak Bridge (Figure 8.10)
- Site Plan of existing and proposed works in Balole Nallah (Figure 8.11)

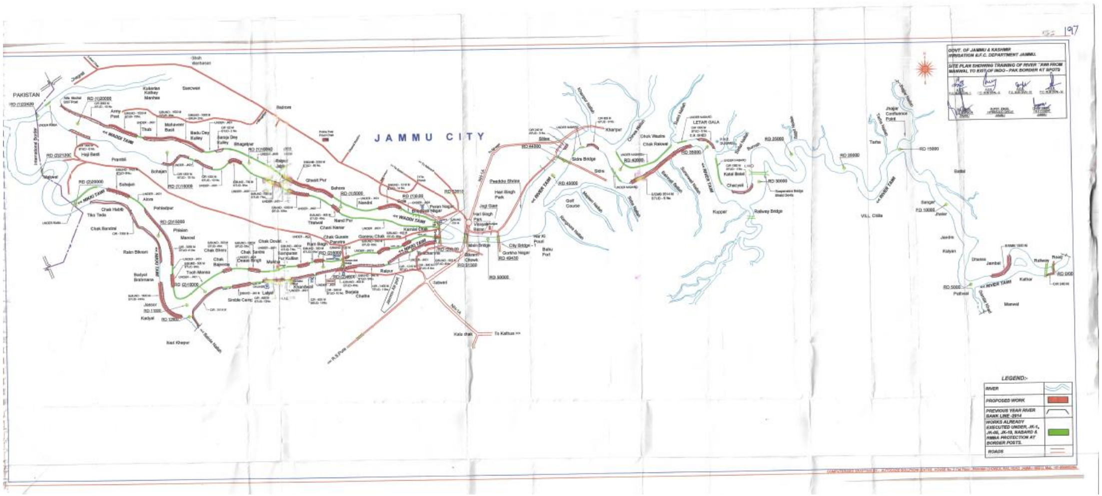


Figure 8.9: Site Plan of existing and proposed training river works in Tawi River from Manwal to exit of Indo-Pak Border at Spots.

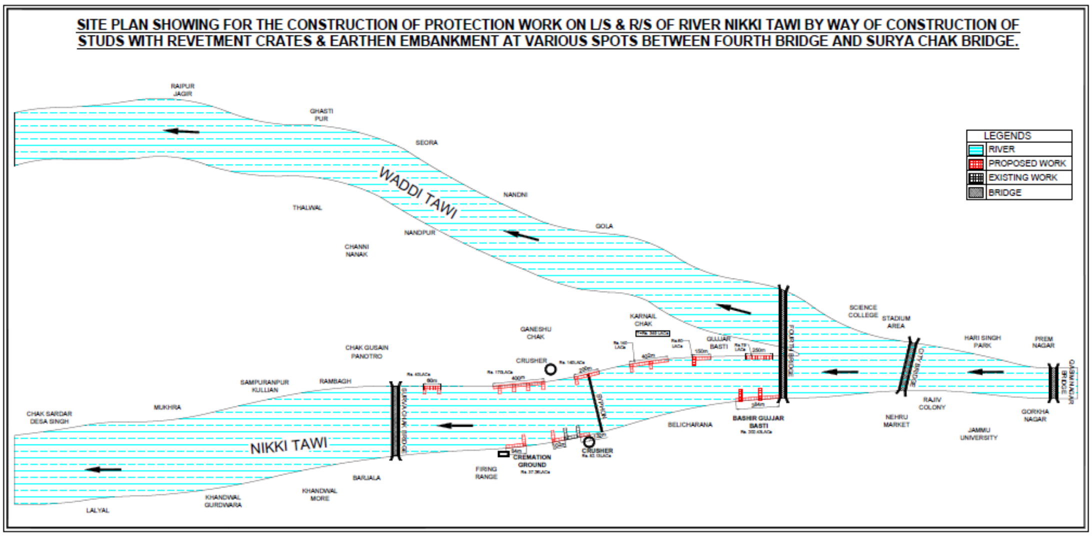


Figure 8.10: Site Plan of existing and proposed protection works in the Nikki Tawi between 4th Bridge and Surya Chak Bridge.

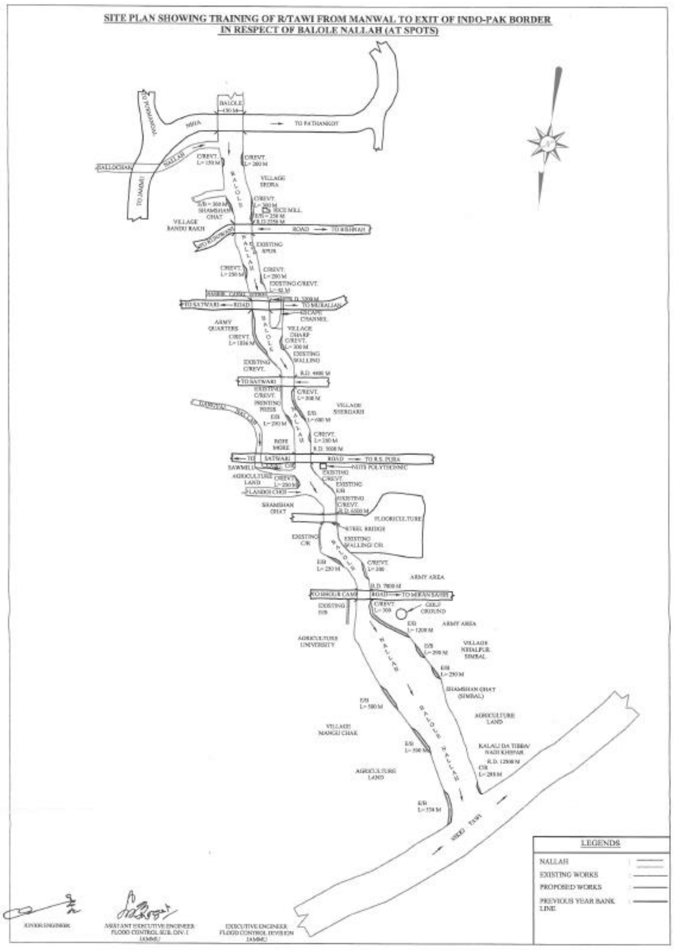


Figure 8.11: Site Plan of existing and proposed works in Balole Nallah.

Additionally, the Consultant has also requested access to the DPR of Jammu Barrage and DPR of existing and proposed river training works in Tawi River. The access to these documents is restricted and therefore the Consultant has prepared and submitted letters of authorization requesting for document sharing to the Chief Engineer of I&FC Department.

The interest of DPRs information will be analysed after receiving the authorization by the Chief Engineer of I&FC Department.

8.7 LAND USE AND LAND COVER

It was identified the possible availability of relevant land use and land cover data in the J&K Department of Ecology Environment & Remote Sensing (http://www.jkdears.com/eers/files/index.asp).

The Consultant shall contact this department, checking for the available data. These contacts will be done after the issuing of a recommendation letter by the Director Technical of PMU/JTFRP.

Additionally, the data developed by the ESA Climate Change Initiative (CCI) can be also considered since it provides accurate information with 350 m resolution, which generally is adequate for catchment wide studies. The Land Cover map of the Tawi River Basin in 2015 is presented in the Figure 8.12.

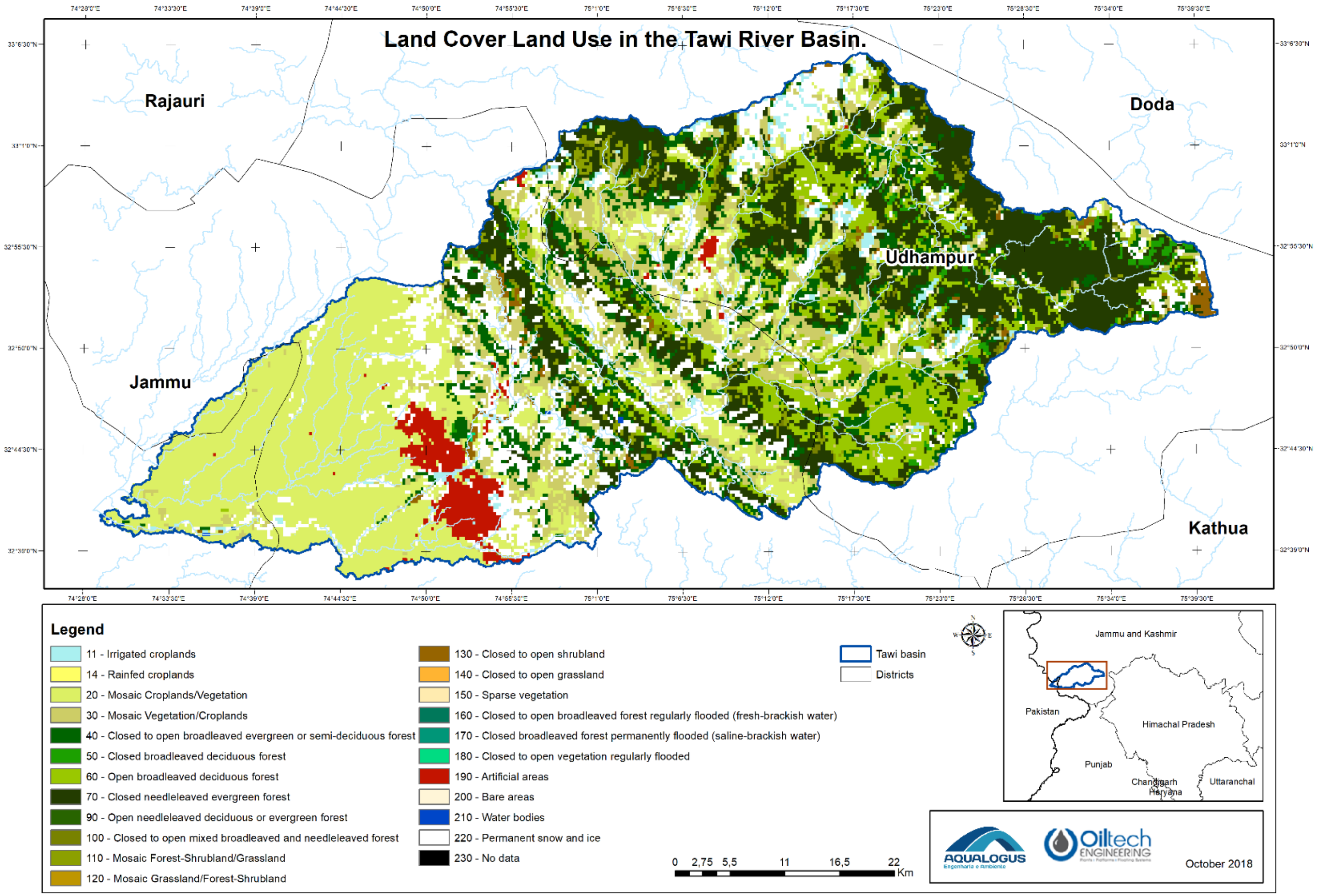


Figure 8.12: Land cover map for 2015 year of Tawi Basin (source: ESA Land Cover CCI)

8.8 SOCIO ECONOMIC DATA

Regarding the socio-economy, the following secondary data will be collected:

- Publication on vital statistics by Directorate of Economics and Statistics
- Census 2011 Data and records
- Latest District Economics and Statistics Handbook
- National Sample Survey Organization Survey Data
- Historical Data on Disasters from Disaster Management Dept, State Govt. of J&K
- Applicable Circle Rate document by the Revenue Department
- Latest Available District / State Disaster Management Action Plan Document
- Data from line department as per check lists

In this context, the record of damages / loss & relief assessments from 2014 flood event was already shared by the I&FC Department – Udhampur Division. Additionally, the record of damages / loss & relief assessments, namely the data from 1997, 2005 and 2008 flood events will also be provided under approval of Chief Engineer of the I&FC Department.

8.9 OTHERS

Other additional data that can be important are the *Vulnerability maps of Wind & Cyclone, Flood, Earthquake, Landslide & Guidelines for Improving Flood Resistance of Housing*. These will be bought @ Building Materials and Technology Promotion Council (http://www.bmtpc.org).

9 ADDITIONAL SURVEYS AND INVESTIGATIONS REQUIRED

The following sections specify the additional surveys and investigations required to support preparation of final hydrology and morphology reports as well as conduct the feasibility studies and DPRs of flood mitigation and comprehensive river management measures for Tawi Basin.

9.1 HIGH RESOLUTION DIGITAL ELEVATION MODELS

According to the ToR of the present Assignment, the Consultant shall "*prepare satellite based DEM, at two different resolutions, about 5 m for hilly areas and 1 to 2 m for plane areas- explore SRTM data at 30m grid for the former and high resolution satellite imagery for 1 to 2m resolution and evaluate potential error".*

Therefore, the Consultant will prepare digital elevation models for the entire Tawi River Basin which has an area of approximately 2200 km^2 up to the India-Pakistan border. Thus, the elevation data obtained from the two different data sources will be processed and integrated: i) SRTM data and ii) 1 to 2m resolution digital elevation models.

The digital elevation models (DEMs) will be used for the modelling tasks (as well as topographic and bathymetric surveys) and other complementary studies such as morphology analysis, identification of low lying areas, planning of flood mitigation and comprehensive river management measures, etc.

Since limited time is available to procure the necessary satellite imagery and prepare the DEMs, and since they are crucial for the planning of flood mitigation and comprehensive river management measures for Tawi Basin, the Consultant shall ensure that high resolution satellite images are obtained as soon as possible in order to avoid significant delays in the work plan. The proposed process to handle this critical task is presented in the **Appendix A – Methodology and Technical Approach** and was also presented in the **1st Kickoff Meetings and Field Visit Report**.

Following the comments of the I&FC Department – Jammu Division on the **1st Kickoff Meetings and Field Visit Report**, the Consultant hereby clarifies and confirms that the area of interest (AoI) of the Project is the entire catchment of the Tawi River up to India-Pakistan Border. However, the extension/area to acquire high resolution satellite imagery (1 to 2m resolution) shall be limited to the plane areas and flood plains according to the ToR.

Therefore, the Consultant has preliminary identified the plane areas for which high resolution satellite imagery of 1 to 2m resolution will be acquired and processed. A polygon comprising all these areas was delineated and is presented in the **Figure 9.1**. This polygon has an area of around 500 km^2, comprising the flood plains and plane areas downstream of Udhampur and up to India-Pakistan border. This polygon was submitted on 3rd September, 2018 to PMU and I&FC Depart. for appraisal and approval in the **1st Kickoff Meetings and Field Visit Report**.

Complementary, SRTM data (as suggested in the ToR) was already collected as presented in the **Subchapter 8.4**.

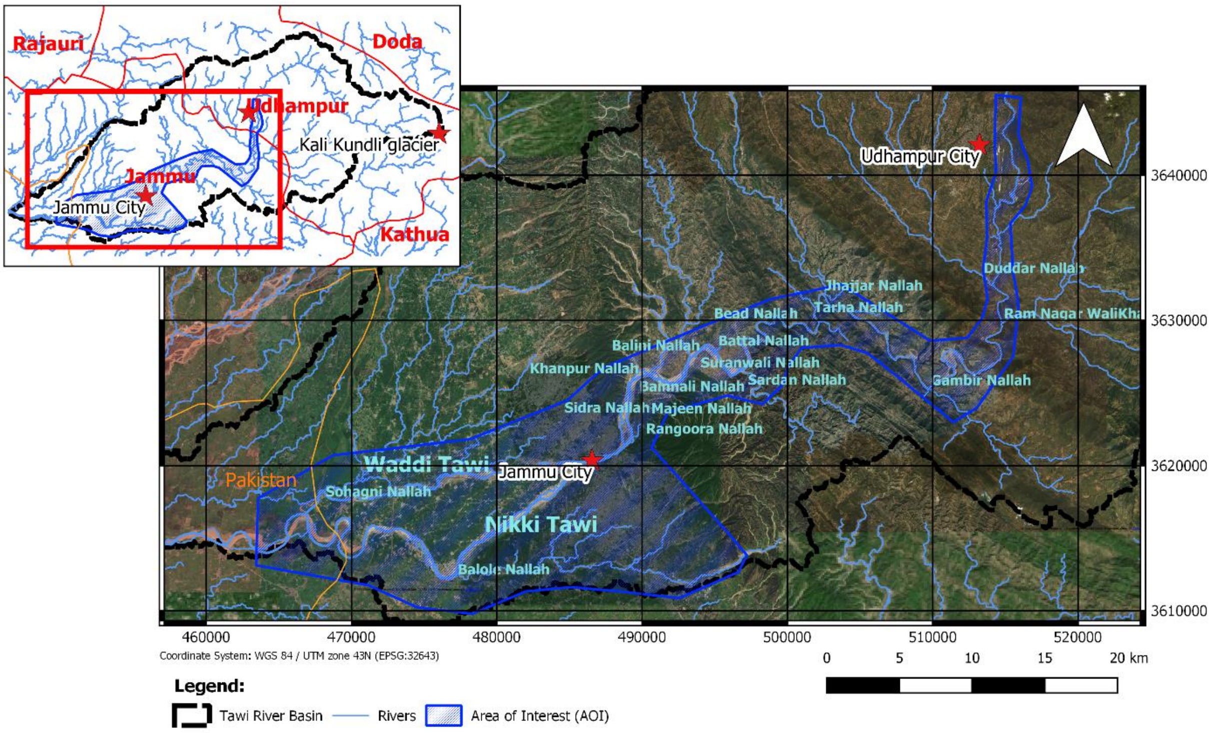


Figure 9.1: Area to acquire high-resolution satellite imagery.

9.2 TOPOGRAPHIC AND BATHYMETRIC SURVEYS

The hydrodynamic modelling of Tawi River as well as the feasibility study and detailed design of flood mitigation and river management solutions should be carried out over adequate topographical and bathymetrical data. Consequently, fresh topographic and bathymetric surveys shall be conducted along the Tawi River and major tributaries, limiting the areas for survey to that most relevant to the project outcomes according to the ToR of the present Assignment.

Therefore, in order to avoid significant delays in the project schedule, the Consultant will prioritize and procure the topographic and bathymetric surveys in 2 (two) phases as follows:

- **Phase 1.A**: Ground control points and benchmarks (during October, 2018)
- **Phase 1.B**: Tawi river and lower reaches of the major Nallahs (from October to December, 2018)

- **Phase 2**: Remaining nallahs and areas found necessary (during 2019)

During the **Phase 1.A**, the ground control points (GCPs) to support the preparation of satellite based Digital Elevation Models (DEMs) will be collected. Additionally, the benchmarks will be also implemented in order to support all the topography and bathymetry surveys along the Tawi River Basin.

After successful completion of **Phase 1.A**, the topographic and bathymetric survey of the Tawi River and the lower reaches of the major Nallahs shall be initiated – **Phase 1.B**. The major Nallahs to be survey during the **Phase 1.B** are identified as follows:

- Duddar Nallah
- Ram Nagar WaliKhad Nallah
- Gambir Nallah
- Jhajjar Nallah
- Sardhan Nallah
- Ballini Nallah
- Chirwa Nallah
- Balole Nallah
- Sohagni Nallah

The **Figure 9.2** presents the Tawi River sub basins and the Tawi River and major Nallahs extensions to be surveyed during **Phase 1.B**.

The river extensions to be surveyed in the Phase 1.B are summarized in the Table 9.1.

Table 9.1 – Tawi river and Nallahs extensions to be surveyed during Phase 1.B.

No.	River / Nallah	Extension (km)	Comments
1	**Tawi**	**135**	– Survey from India-Pakistan border up to 5 km of Salmay Bridge – Include Waddi and Nikki Tawi – Detail survey of existing structures, namely bridges, Jammu barrage, spurs, embankments, stabilization works, etc
2	**Balole**	**28**	– Complete extension from Tawi confluence up to Kat Walta Bridge
3	**Sohagni**	**5**	– Lower reach
4	**Chirwa**	**5**	– Lower reach

No.	River / Nallah	Extension (km)	Comments
5	**Ballini**	**5**	– Lower reach
6	**Sardan**	**5**	– Lower reach
7	**Jhajjar**	**5**	– Lower reach
8	**Gambir**	**5**	– Lower reach
9	**Ram Nagar WaliKhad**	**5**	– Lower reach
10	**Duddar**	**5**	– Lower reach

Accordingly, the total extent to be surveyed during the **Phase 1.B** is estimated as around 203 km (135 km along the Tawi River and 68 km along major Nallahs).

Following the comments of the I&FC Department – Jammu Division on the **1st Kickoff Meetings and Field Visit Report**, the Consultant hereby clarifies and confirm that the remaining Tawi River extension and nallahs not included in the **Phase 1.B** shall be surveyed during **Phase 2**, complying with the extensions envisaged in the ToR.

The river cross section surveys are to be carried out at every 100 m, and closer at curved reaches and where there is rapid change in cross-section or gradient.

The topographic and bathymetric surveys of the shall preferably be carried out during the lean flow period. Therefore, the Consultant intends to initiate the **Phase 1.B** of the surveys on early December.

Accordingly, the Consultants has already prepared the Request for Proposals (RFP) for the Topographic and Bathymetric surveys to inquire survey firms for quotations and methodology / technical approach. The draft version was included in the **1st Kickoff Meetings and Field Visit Report**.

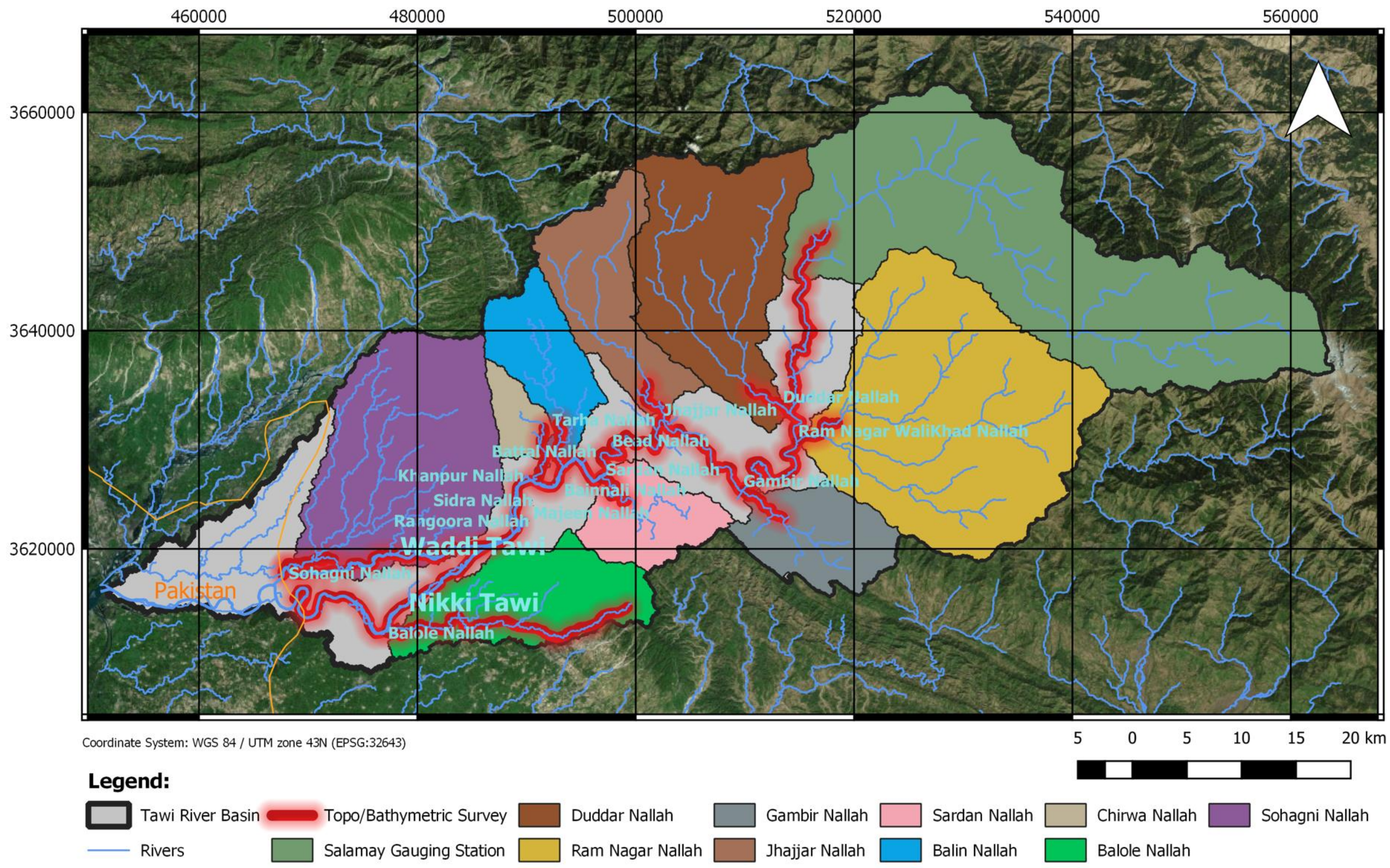


Figure 9.2: Tawi River and major Nallahs extensions to be surveyed during Phase 1.B.

9.3 GEOTECHNICAL, GEOMORPHOLOGICAL AND GEOLOGICAL INVESTIGATIONS

Under the scope of the Geological and Geotechnical studies, the most relevant issues concerning both geological, geotechnical and geomorphological context in the Tawi River Basin will be carefully analysed.

The first stage to be performed is the **geological mapping** of the area of the studies. This activity aims to the identification of the zones more prone to riverbank erosion/instability and to access preliminary foundation conditions along the riverbanks for the flood mitigation structures.

Geological mapping will comprise the following most relevant geological aspects:

- Identification of main rock types and boundaries;
- Identification of soil and alluvial covered areas;
- Identification of the main geological structures.

Based on the gathered information it will be possible to identify at the earliest planning phase any potential situations and constrains regarding geological, geotechnical and geomorphological contexts that may hinder any flood mitigation solution from being technical and/or economically feasible.

Taking into account all the available information after the desk studies, **geological, geotechnical and geomorphological studies** will aim at obtaining a preliminary characterization of relevant sites in Tawi River Basin.

Moreover, and besides any existent and available data, **additional geological and geotechnical investigations** should be performed to support the feasibility study and the detailed design of flood mitigation structures.

Therefore, after the preliminary definition of the mitigation structures and respective location a geological and geotechnical investigation campaign will be proposed. According to the existing data, the field investigations types that are considered necessary are the following:

- Test pits;
- Rotary core drilling.

Geophysical investigations, seismic and resistivity surveys, might be also needed, depending on the geological setting of the flood mitigation structures.

9.4 SOCIO ECONOMIC SURVEY

Within the scope of the project, fresh socio economic surveys shall be conducted. The purpose of the primary data collection is to validate and cross check the secondary data sets and to capture qualitative data and understanding the community perceptions, societal values and traditional and indigenous disaster coping mechanism. Three distinct or focused field investigations will be carried out to capture

(1) Historical and current flood and flash flood disaster events – intensity recurrence and exposure

(2) Damage Data and economic values

(3) Relief, Rescue, Recovery, Rehabilitation

These surveys will be carried out at three levels

- Infrastructure loss and damages including public / private buildings and infrastructure – on the spot survey of at least 10% of such sites where during Sep 2014 loss and damage was reported and replacement or restoration costs were arranged.
- Gram Panchayat or Urban Local Body level - Selected sample GPs where household level interviews held group interviews with GP Official and members of GP are being held.
- Household Level: It is one to one interview with sample households across all spatial typologies. The household level demography, their social and economic status, housing conditions, contents – furniture – equipment, their economic assets, an assessment of loss due to damage during latest disaster experienced, and disaster coping capacity.
- In addition, the study team is to capture and document field conditions on building / infrastructure vulnerable zones, etc for triangulation and further studies.

Primary data collection will be done using methods of (1) one to one interviews (2) Focus Groups Discussions with groups of men and women (3) Key Informant Interviews with key stakeholders and (4) Rapid Vulnerability and Capacity Assessment (5) PRA method, transect walk – walk through in most vulnerable areas will be used to facilitate the community to map risk zones, exposure and most vulnerable spatial pockets in the study area.

The sample locations and no of households will be done based on population proportionate to size (PPS) method and cover at least 10% of the human settlements in urban and rural areas. The number of households will be done based on stratified random sampling method having representation of each category of socio – economic r strata.

The qualified, experienced Enumerators from J&K state are selected, trained and deployed for the surveys. Before beginning of survey the Enumerators have field tested the tools and technique, sampling etc as part of their training and orientation.

The team will design the data tables for data entry. The data is to be used as main source for loss and damage estimation in both feasibility and DPR phase of the project.

10 SHORT-LIST OF LICENSE-FREE AND PUBLIC DOMAIN MATHEMATICAL MODELS

10.1 GENERAL REMARKS

Frequently historic flood data are insufficient for an appropriate assessment of the hazard and risk associated with flooding. Therefore, numerical models can be extremely useful to estimate the characteristics of the flood events (*e.g.* water depth, inundation extends, duration and flow velocity). These models guarantee an appropriate and accurate flood hazard and risk analysis, assessing the exposed and vulnerable areas.

In fact, processes involved in the formation of floods are complex and consequently numerical models have been used historically to simulate these processes in order to: (i) calculate the extend of floods for given meteorological conditions, (ii) evaluate the impact of land use changes / construction of infrastructures in terms of flood risk and vulnerability, (iii) emit early warnings.

Since the formation of floods depends on the hydrological response of the river basin and on the hydraulic capacity of the rivers, historically models have been divided into hydrological models and hydraulic/hydrodynamic models. More recently integrated models have been developed, as the fully distributed, process based, which have a wide range of possible application areas, covering oceans, coastal areas, rivers, groundwater and watersheds.

This chapter presents the short-list of available and relevant hydrology, hydraulic / hydrodynamic and morphological models. Subsequently, during the *Task-3 - Develop, calibrate, validate and operationalize hydrology, hydraulics, hydrodynamics and morphological model/s*, a selection of public domain and license free software will be made, taking into consideration the specific Client needs and the experience of the Consultant. This selection will address the most relevant concerned aspects, particularly, but not limited to, the following:

- Specific hydrology and hydraulics of the complex Tawi River basin;
- No commercial license required (*i.e.* preferably free license-free and public domain);
- Data availability;
- User friendliness;
- Existing tools for model operationalization;
- Knowledge of the numerical models;
- Possibility of integrating new features (*e.g.* outputs alerts generation, link with Client database) and boundary conditions (*e.g.* automatic satellite rainfall data acquisition, RTDAS), namely for operationalization;

– Scalability to other river basins.

Accordingly, the selection of the numerical models will be supported by a qualitative and quantitative evaluation of each previously short-listed model as well as an assessment of the pros and cons of each model.

In the following sections, the short-list of available and relevant hydrology, hydraulic / hydrodynamic and morphological models is presented.

10.2 HYDROLOGICAL MODELS

First models for watershed appeared in the 50's - 60´s making the focus on water - the called rainfall-runoff modeling (Donigian and Imhoff, 2002). Since then a wide range of hydrological models have been developed. These models can be distinguished in 2 major types: (i) stochastic models and (ii) process based models.

With the objective of making daily forecasts of flood levels, using as baseline information from satellite assembly rainfall and GIS data, the process based models are more suitable, since they solve all individual processes (*e.g.* precipitation, infiltration, surface runoff, subsurface flow, evapotranspiration) based on physical equations rather than using a "black box" approach, commonly used by stochastic models.

Processed based models can be distinguished in terms of spatial resolution into: (i) lumped models, (ii) semi distributed models and (iii) fully distributed models.

Lumped models usually are empirical based and describe the watershed and processes in a very simplified fashion usually considering the watershed as a single entity (*e.g.* peak flow rational equation, USLE erosion equation, etc.). There are many examples of open source models of this kind, but they have very limited usage since processes are very simplified. For example, precipitation can be highly variable in large watersheds, and therefore these type of models would not be able to represent correctly the complex spatial and temporal rainfall patterns.

Semi distributed models generally divide the watersheds into sub-basins in which hydrological behaviour is to consider to be equal (hydrological response units). The processes solved in the response units tend to be empirical so this type of models are similar to lumped models but with higher spatial discretization. There are many open source models of this kind, being the HEC-HMS and SWAT (Neitsch et al., 2005) models the most well-known. Other semi distributed models are for example the HSPF and BASINS.

Fully distributed models are grid-cell based and take into account the spatial variability of meteorological input and other inputs like terrain, soils, vegetation and land use. In distributed hydrological models, the runoff generated in a grid cell is transported downstream to the neighbour cells using the local drain direction, representing the “real world” water routing in high detail. The fully distributed models have the advantage of not averaging the hydrological behaviour into sub-basins, making their response similar to the “real world” behaviour, however they require much more computational power. Examples of fully distributed hydrological models are MOHID (license free and source code available), Mike SHE (commercial, from DHI), ANSWER (Areal Nonpoint Source Watershed Environmental Simulation) or WMS (commercial, from Aquaveo).

The short list of hydrological numerical models is presented in the Table 10.1.

Table 10.1 – Short list of hydrological numerical models

Name	License	Source Code	Spatial Resolution	Possibility to integrate with Hydraulic Model
License-free and public domain numerical models				
MOHID Land	**Free**	**Available**	**Full Distributed**	Integrated
HEC-HMS	**Free**	Restricted	Semi Distributed	Link with HEC-RAS through files
SWAT	**Free**	**Available**	Semi Distributed	Lumped Integrated
TOPMODEL	**Free**	**Available**	**Full Distributed**	Not available
Bilan	**Free**	Not available	Semi Distributed	Not available
GSFlow	**Free**	**Available**	Semi Distributed	Not available
DR3M	**Free**	**Available**	Semi Distributed	Not available
RRI	**Free**	Not available	**Full Distributed**	Integrated
IFAS	**Free**	Not available	**Full Distributed**	Not available
TUWmodel	**Free**	**Available**	Lumped	Not available
SAC-SMA	**Free**	**Available**	Lumped	Not available

Name	License	Source Code	Spatial Resolution	Possibility to integrate with Hydraulic Model
Commercial numerical models				
MikeSHE	**Commercial**	Not available	**Full Distributed**	Link with Mike SHE through files
SOBEK	**Commercial**	Not available	**Full Distributed**	Integrated
TOPKAPI	**Commercial**	Not available	**Full Distributed**	Lumped Integrated
RRL	**Commercial**	Not available	Lumped	Not available
WMS	**Commercial**	Not available	**Full Distributed**	Link with SMS

10.3 HYDRAULIC MODELS

In terms of flood modelling, the hydrological models previously described are generally used to simulate the hydrological behaviour of a catchment and consequently produce boundary conditions (inflow) for more detailed hydraulic models, which simulate the movement of water inside rivers or over flood plains. Hydraulic models can be distinguished in terms of spatial resolution, being generally either 1D or 2D models.

Most of the hydraulic models simulate the flow based on the Saint-Venant equation, using different levels of simplifications: (i) dynamic wave which describes the full equations, (ii) diffusion wave which does not consider momentum and (iii) kinematic wave which does not consider momentum and considers that the surface water level is parallel to the bottom.

Hydraulic models can also be distinguished based on the method for solving the above mentioned equations: some models are capable of only calculating one solution for a given boundary conditions (stationary or steady flow models) while other are able to simulate time varying boundary conditions (non-stationary or unsteady flow models).

Unidimensional (1D) models generally simulate the hydraulics - using either the dynamic, diffusion or kinematic wave approach - along a river (or along a river and its tributaries) defining the geometry through vertical cross sections (with or without floodplains) and between cross sections, the section shape is maintained or interpolated.

The results of these models include the flow, velocities and water levels/depth in each section. However, this type of models is rather inaccurate in rivers like the Tawi River Basin, which has a huge extent of floodplains and comprises highly variable along river streams, being difficult to describe only with cross sections, especially during flood events. The need for a huge number of cross sections to describe the flood plain makes it more suitable to use a 2D model that explicitly describes all surface topography and morphology.

Bidimensional (2D) models generally simulate hydraulics over a bi-dimensional grid, solving the same equations as 1D models, but in two directions, similar to the fully distributed hydrological models. 2D models are more suitable to be used in areas like the Tawi River, since a detailed digital terrain model can be used to feed the model to describe correctly the complex flood plain shape changes, complemented and integrated with river cross-sections.

The short list of hydraulic numerical models is presented in the Table 10.2.

Table 10.2 – Short list of hydraulic numerical models

Name	License	Source Code	1D/2D
License-free and public domain numerical models			
MOHID Land	**Free**	**Available**	**1D & 2D**
HEC-RAS 5	**Free**	Restricted	**1D & 2D**
ANUGA	**Free**	**Available**	**2D**
SWMM	**Free**	**Available**	**1D**
ANN Models	Non applicable	**Free**	-
Delft3D Flexible Mesh	**Free**	Restricted	**1D-2D-3D**
Commercial numerical models			
TUFLOW	**Commercial**	Not available	**1D & 2D**
SOBEK	**Commercial**	Not available	**1D & 2D**
MIKE Hydro River	**Commercial**	Not available	**1D**
MIKE 21 and MIKE21 C (morphology model)	**Commercial**	Not available	**2D**
MIKE FLOOD	**Commercial**	Not available	**1D & 2D**
SMS	**Commercial**	Not available	**2D**
River Flow 2D	**Commercial**	Not available	**2D**

10.4 MORPHOLOGICAL MODELS

Morphological models are used to simulate the changes of river planform and cross-section shape due to sedimentation and erosion processes. Due to sediment transport processes, the cross-section and planform of alluvial rivers may change continuously. Morphological models provide valuable information for design and maintenance of rivers, and the constructions within a river. River morphology may change due to natural processes or human interferences. Construction of river training structures (levees, groynes etc) can change river morphology. Morphological modelling is useful to know the complex interaction between flow and alluvial bed and sediment transport at river bifurcations in Tawi River.

A short list of morphological numerical models is presented in the Table 10.3.

Table 10.3 – Short list of morphologic numerical models

Name	License	Source Code	1D/2D
License-free and public domain numerical models			
TELEMAC 2D	**Free**	**Available**	**2D**
Morpho2D	**Free**	Restricted	**2D**
HEC-RAS 5	**Free**	Restricted	**1D & 2D**
Delft3D Flexible Mesh	**Free**	Restricted	**1D-2D-3D**
CCHE2D_SEDIMENT	**Free**	Restricted	**1D-2D**
Commercial numerical models			
TUFLOW	**Commercial**	Not available	**1D & 2D**
MIKE 21 and MIKE21 C (morphology model)	**Commercial**	Not available	**2D**
Flow 3D	**Commercial**	Not available	**2D**

11 FINAL REMARKS

The **Inception Report** was prepared after successful completion of *Task-1: Review flood and river management options and list potential options* of the Part A of the present Assignment. Accordingly, it includes comprehensive analysis for the planning of flood mitigation and river management measures for Tawi Basin, covering the tasks and activities performed as envisaged in the ToR, namely, but not limited to, the following:

- Review flood management issues and opportunities, previous studies, reports and guidelines
- Review of river basin hydrology, morphology and diagnosis of current situation
- Review flood mitigation solutions proposed by I&FC Department
- Preliminary assessment of applicable innovative flood management solutions
- Data availability and quality analysis
- List of fresh and or additional data required for the completion of the work.
- Specification of survey and investigation required
- Short-list license-free and public domain mathematical models

Additionally, the **Inception Report** also includes the Consultants' methodology for carrying out the Assignment. The consultancy services require necessarily a careful and thorough planning of the tasks and activities involved, in order to achieve the objectives/outputs with accuracy and within the established deadlines. Therefore, the Consultant prepared an appended document: **Appendix A: Methodology and Technical Approach** which details the project objectives as well as the technical and methodological approach for carrying out the Assignment. These follow, in general, the Consultant's proposal, though some adjustments are already provided based on the information collected and analysed so far. Furthermore, the strategy for the upcoming tasks and activities is also presented.

Flood Mitigation and Comprehensive River Management Measures for Tawi Basin need to be guided by policy frameworks for disaster risk management and integrated water resources management. Therefore, the review of national and state level policies and plans on disaster management, flood control and integrated water resources management were conducted.

Particular attention was dedicated to scrutinize and detailed assessment of the Indus Waters Treaty, 1960, since flood mitigation and river management measures for Tawi Basin must be planned and specified taking into consideration the provisions, constrains and obligations as per this Treaty. In this context, it is worth noting that construction of works for temporary water storage, even only during the flood period (flood storage dams, weirs, artificial reservoir) is not permitted. However, the river training works and natural water retention measures are both permitted, although some technical aspects and obligations must be ensured (*e.g.* avoid any obstruction to the flow in the rivers, maintain the natural channels of the Rivers).

All the reviewed policies and plans highlights the importance of ensuring a flood resilient society that should be able to prepare for, respond to and recover from flood risks. This will be ensured by considering an Integrated Flood Management (IFM) approach as proposed by the Consultant.

Following, a detailed review of the relevant studies and reports was performed, including national and global studies in similar river systems. These views aimed to assess the major findings, existing data, proposed solutions, main risks and constrains, etc. This activity was very effective, supporting the assessment of potential solutions for flood and erosion mitigation in the Tawi River Basin. In this context, the REFORM project is particularly relevant, since it includes a complete investigation of natural, degradation and restoration processes in large rivers and consequently provides tools for cost-effective restoration of river ecosystems. Moreover, some interesting findings are included regarding the effectiveness of natural-based river restoration solutions for the flood control and mitigation, such as: floodplain restoration and management, re-meandering and wetland restoration and management.

In addition, the Seminar “Retrospective and Prospective of 2014 Floods for Building Flood Resilient Kashmir” also specified some urgent short and long-term recommendations for flood mitigation, being however in agreement with the solutions proposed by I&FC Department for the Tawi River Basin.

The Consultant also reviewed the feasibility study for Bangladesh: “Main River Flood and Bank Erosion Risk Management Program”. The proposed program is based on an integrated approach combining flood and riverbank erosion risk management. The program includes structural measures, extensive non-structural activities, and institutional strengthening.

Additionally, the Consultant also reviewed the relevant national guidelines and handbooks in order to ensure the effective feasibility and detailed design of flood mitigation and river management solutions for Tawi River Basin. Moreover, the identification of the pertinent national design codes was also carried out.

Within the scope of the Task 1 as envisaged in the ToR, the Consultant has prepared the **Preliminary Hydrology and Morphology Reports**. The summary of the major findings of the conducted analysis were also included in the **Inception Report**, namely the review of current morphology (covering river channel, banks, and flood plan) of Tawi River and tributaries, identifying recent and past changes, trends and a preliminary assessment of important factors that enhance the flood risk in Tawi River.

The Consultant also reviewed the various flood mitigation and river management options proposed by the I&FC Department, including major findings from site visits, analysis of the proposed site plans and assessment of compliance within the ambit of Indus Waters Treaty-1960. In general, all the proposed solutions are in compliance within the provisions and obligations of *Indus Water Treaty-1960,* excepting the construction of flood storage works. In fact, the Indus Water Treaty (particularly in Article III and Annexure E) anticipates that India must not store any water or construct any storage works on Tawi River. The same Annexure provides some exceptions addressed to flood control and mitigation for Western Rivers. However, most of the exceptions related with storage water are specifically addressed to the flood control in Jhelum River. Additionally, there are some exceptions related with water storage resulting from natural processes. These types of natural solutions for water detention (*e.g.* wetlands, natural depressions, ponds) might be applicable in tawi River Basin and therefore will be further analyzed by the Consultant.

After the review of the various options proposed by the I&FC Department, the Consultant conducted a preliminary assessment of applicable innovative flood management solutions. The Consultant considers essential to consider an Integrated Flood Management (IFM) approach for the Tawi River Basin, in order to achieve a flood resilient society and ensure the effective disaster risk reduction. Therefore, the potential flood and river management scheme for Tawi River Basin shall include both structural and non-structural measures within the following five components:

- Component 1: Comprehensive Flood Risk Assessment
- Component 2: Flood Risk Governance and Capacity Development
- Component 3: Structural Measures for Flood Risk Reduction:
    a. Green infrastructure and nature based solutions
    b. Grey infrastructure for flood risk reduction
- Component 4: Flood Risk Resilience through Risk Transfer and Insurance
- Component 5: Flood Preparedness and Emergency Response
    a. Community based flood risk management
    b. Flood forecasting and warning systems
    c. Flood emergency measures

The flood and river management measures shall be designed using latest and upgraded technology, having the desired resilient features to meet all future contingencies of bigger magnitude well in time and space variables.

Regarding the data collection, the Consultant assessed the availability of base data to support the preparation of final hydrology and morphology reports, and conduct feasibility plans and DPRs. Moreover, a preliminary identification of the main gaps and inconsistencies was also conducted. The data availability analysis indicates that relevant data is currently available with I&FC Department (*e.g.* hydrological data, toposheets, existing DPRs). Most of these base data were already shared with the Consultant. Additionally, the Consultant has also prepared and submitted letters of authorization requesting for access to the restricted data.

Besides relevant base data being available, some additional data must be arranged and procured to support preparation of final hydrology and morphology reports, and conduct feasibility plans and DPRs, worth noting the following:

- High resolution satellite imagery to derive digital elevation models
- Meteorological data from the India Meteorological Department (IMD)
- Fresh topographic and bathymetric surveys
- Geological and geotechnical investigations
- Socio economic surveys

Finally, the Consultant has also carried out a short-list of available and relevant hydrology, hydraulic / hydrodynamic and morphological models. Several numerical models have been shortlisted, highlighting some important characteristics such as license requirements, source code access, spatial resolution and possibility to integrate with other models. This activity will constitute the basis for the Consultant's selection of public domain and license free numerical models as requested in the ToR, to be conducted within the scope of the *Task-3 - Develop, calibrate, validate and operationalize hydrology, hydraulics, hydrodynamics and morphological model/s*.

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